EDWARD HITCHCOCK'S TEACHING NOTES

1825 – 1863

Transcriptions of the original hand-written

manuscripts in the collections of the

Amherst College Archives and Special Collections,

Amherst, Massachusetts

Transcribed by

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INTRODUCTION

Edward Hitchcock (1793-1864) is best known as a geologist and paleontologist who taught at Amherst College from 1826 to 1863 and served as the third president of the college from 1845 to 1854. He was also a minister who preached in churches throughout southern New England for over thirty-five years.

Hitchcock received his first appointment as Professor of Natural History and Chemistry at Amherst College in August, 1825. At the time he was pastor of the Congregational church in Conway, Massachusetts, a post that he resigned in October. He and his wife, Orra White Hitchcock, then moved to New Haven where Edward worked for two months in the chemistry laboratory of Professor Benjamin Silliman. In the course of that apprenticeship, he carried out hundreds of chemistry and experiments in order to prepare for his teaching.

The couple moved to Amherst in January, 1826. Hitchcock began teaching chemistry in April. That fall he repeated his course in chemistry while adding mineralogy and geology. In 1827 he added courses in botany and natural history. Hundreds of pages of Professor Hitchcock's hand-written notes for those courses have been preserved in the Amherst College Archives and Special Collections.

In 2017 I began studying the life and works of Edward Hitchcock with the goal of writing a biography. His teaching notes were important to my research and I began transcribing them in late 2018. I used voice-to-text software to dictate the notes from the images available at acdc.amherst.edu into a document file, then reread them, comparing the transcription to the images of the originals.

This document contains the transcriptions that I made of his teaching notes arranged in five categories, Chemistry, Geology, Mineralogy, Botany, and Natural History. It does not include transcriptions of all of Hitchcock's teaching notes, only those that seemed of the most value to my research.

Many variations in spelling have been preserved in the transcription. Some of these may have been Hitchcock's own, others were customary for his time. Examples include *eccentrick*, *independant*, *volcanoe*, *risque*, and *favour*. Hitchcock was frugal in all things, including the use of punctuation. In some instances I have added commas or replaced colons with semicolons or periods to make the meaning clearer. My comments are shown in brackets.

I am indebted to Amherst College and particularly to Margaret Dakin and Michael Kelly of the Archives for preserving the unpublished writings of Edward Hitchcock and making them accessible to all. If you make use of this transcription, please be sure to cite your source including, of course, the Amherst College Archives and Special Collections.

Readers wanting to learn more about Edward Hitchcock may wish to read my biography, *All the Light Here Comes from Above: the Life and Legacy of Edward Hitchcock.* It is my hope that the book and this transcription will inspire others to get to know the man behind that quill pen.

Sincerely,

Robert T. McMaster
September 24, 2020

CHEMISTRY: HEAT OR CALORIC

[Edward Hitchcock classroom lecture notes, "Heat or Caloric," EOH, Box 10, Folder 4]

[Some of these appear to be copied from Silliman's notes for a text he published in 1830, *Elements of Chemistry, In the Order of the Lectures Given in Yale College* 2 vols. New Haven, CT: H. Howe, 1830.]

[Most images show two facing pages. "Page number" is the number of the image. It is followed by the number written by Hitchcock in the upper left corner of the even pages.]

Page 1

Chemistry heat or caloric

1. <u>Heat</u> - A sensation excited by a body hotter than the hand or other part of the human frame applied to it. <u>Caloric</u> (a term proposed by Lavoisier) is the cause of that sensation. The nature of this cause is unknown. Does not consist in any general quality of bodies nor reside in a peculiar kind of matter.

Caloric probably an extremely subtle fluid.

2. <u>Caloric</u> is opposed to the attraction of cohesion and it conspires with and increases elasticity.

3. All bodies in nature are subject to the action of these two opposite forces – the mutual attraction of the particles-2 the repulsive force of caloric.

Instance of ice – water – vapour

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4. Caloric exists in two states - first uncombined - or caloric of temperature - a state of combination - or lateral caloric latent caloric.

It may conveniently be heated of according to divisions

Temperature refers to the power of a body of exciting the sensation of heat and producing expansion. The extremes of temperature unknown - only a few of middle links.

5. One of the most important effects of caloric its power of expanding bodies.

6. An important property of fire caloric its tendency to an equilibrium.

This is effected in two ways:

1. By radiation

2. By the conducting power of the medium. Radiant caloric moves in parallel lines of in measurable velocity.

About one half of the caloric of a heated body[????] is caused by radiation and the other half is caused by the atmosphere .

The rate of a bodies cooling bears a proportion to its temperature. Hence it loses an equal quantity of caloric in equal times - very nearly in a geometrical ratio.

Caloric radiates only in vacuum or through transparent media.

It radiates at all temperatures - hence all bodies however unequal their temperatures mutually radiate.

Radiation from the earth one reason why the heat of it is not continually accumulating.

Bodies conduct caloric very slowly.

7. Bodies in passing from a denser to a rarer state generally absorbed caloric - which thus becomes insensible or latent.

Page 3 (numbered 4)

8. Bodies passing from a rare to a denser state give out caloric - passing from a latent to a free state.

Is latent heat chemically combined?

<u>Effects of free free caloric illustrated.</u>

Caloric expands all bodies

Experiment 1. Exhibit a thermometer (Cutbush Exp. 16 f)
[James Cutbush, The Philosophy of Experimental Chemistry, 2 vols., 1813)

Experiment 2. Immerse three glass tubes containing one water and the third spirit of wine. Expansion of gases

Experiment 3. Show a bladder half filled with air near the expansion of solids. (See also Cutbush's Chemistry p. 59, Vol. 1, Exp. 17)

Experiment 4. Heat a bar of iron and apply to it a pyrometer (Cutbush Exp 18 p. 60)
Show what a pyrometer is. (Wedgewood pyrometer)
Different solids have different degrees of exposure
Effects of expansion on the pendulum of clock
How remedied
Winds, theory of - trade winds - monsoons etc.
Balloons - by expansion of air

Construction of thermometer

1. Sanctorio’s air thermometer (Henry Vol. 1, p. 91)
2. Leslie's differential thermometer (Ditto p. 93)
3. Fahrenheits, Beaumais, Celsius and Delisle’s
(See Henry vol. 1 p. 91 - 98 ninth edition.)

Water an exception to expansion.
See Exp. 11 and 12 Parkes Catechism, p. 525

Passage of caloric through solids and fluids

Bodies possess different degrees of conducting power

Experiment 1. Cutbush p. 64 experiment 27. Two copper plates with cylinders of different metals and phosphorus on top place over a sand bath - the bath upon a white clay furnace. Some bodies conduct more rapidly than others. This explains why some bodies feel colder than others. Fluids scarcely conduct except by [????].

Experiment 2. Burn sulphuric ether on water (Cutbush p. 66). Have a window glass ready to slip over the vessel to stop the flame .

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Experiment 3. Introduce into a glass vessel of water at the top a stratum of litmus – cabbage - or nitrate of copper tinged with ammonia and place a hot cannonball on the top of the water - which will cause the water to boil – Use the dropping tube (Cutbush p. 66)

Experiment 4. Reverse the experiment - put in alkaline - the lower stratum and alcohol above and apply the heat beneath. The alkanet will be immediately diffused. Vessel for this experiment should be 12 or 14 inches and of this shape. [Illustration] Alkanet. In this experiment take care not to fill the vessels very far. *[Alkanet is is borage type plant with red dye]*

Experiment 5. Put a stratum of alkanet on water - hold it to a spirit lamp and no disturbance of the upper part take place will the water begins violently to boil.

See also experiments b, c, d, e, f, g of Henry Vol. 1 p. 104

Cabbage liquor prepared from red cabbage. Pour boiling water upon it and let it stand some hours. It will remain good only three or four days.

Radiation of caloric

Reflection of heat
It follows the same law as light.

Experiment 1. The metallic plates or reflectors - placed them 6, 8 or 10 or more feet apart. Reflectors should be parallel place in one focus either a candle or heated ball - or coals in a mouse trap or a cage on a lamp support - in the other focus a different thermometer (with the ball blackened with ink) or phosphorus placed on a bit of wool upon a candlestick. Upon candlestick. Fulminating mercury or silver or common gunpowder will explode but with some difficulty and they are apt to soil the mirrors. Plate or sheet should be placed on the table beneath the fire. Cannonball may be placed on the lamp support. Hold a common window glass between the fire and the screen.

A [????] flask of hot water strongly affected the different thermometers 8 feet distant and a cannonball 2 ½ inches diameter ignited phosphorus 15 feet distant one red-hot. The handful of focus 4 1/2 distant move the diff therm sensibly. To [????] [????] forms place a candle in one of them and see where…

Page 5 (numbered 8)

…image falls before the other mirror.

Radiated caloric is refracted according to the same laws as light.

Experiment 2. Hershel's experiment with prism

The nature of the surface of bodies influences radiation.

Experiment 3. Canister of planished tin of cubrial form Henry vol. 1 p. 103

Caloric is absorbed within different facility by different substances.

Experiment 4.Henry vol. 1 p. 104 a, b, and c

Use a window glass to keep off the heat in close to examine a very hot furnace.

Rays of heat from the sun pass through glass – but from a fire or candle they do not.

Experiment 5. Fill two vessels with hot water - one polished tin the other blackened - the black one will cool much faster.

Black vessels heat quickest – hence rub off soap from flasks. Negroes radiate more heat than whites - hence they indoor heat better and cold not so well for their temperature is higher than the atmosphere. To diffuse heat black surfaces should be chosen - to contain it bright surfaces should be chosen - How to construct fireplaces and stoves for warm rooms.

<u>Caloric produces liquidity</u>

A body is fused when melted by heat.

Experiment 1. The sensible heat of ice is not changed by melting until the whole mass be melted.

Experiment 2. A pound of water at 32° and a pound of ice at 32° exposed in a room warmer than this -

the water will reach temperature of the room much before ice melts though the ice must have been imbibing caloric all the time.

Experiment 3. Pound of water of 172° with pound of ice at 32° the result will be water at 32°. Hence 140° of heat has disappeared or become late and this is called latent heat.

Lavoisier's calorimeter.

Different degrees of heat become latent in the fusion of different bodies

Henry, p. 112

Experiment 4. Mixture of dilated nitric acid diluted much gases with fresh fallen snow experiment
Experiment 5. Fresh snow and common solvent 32°
Experiment 6. Crystallizing muriate of wine mixed with snow
Experiment 7. Number three of Henry p. 113

Table of frigorific fixtures Brande p. 28

Experiment 8. A delicate air thermometer suspended beneath a cake of melting ice to discover the stream of cold air

Page 6 (numbered 10)

Liquids when becoming solids evolve heat.

Experiment 9. Suspend over water frivings by frigorific mixture on air thermometer.

Experiment 10. Cutbush p. 69 experiment 36

* Experiment. On freezing mixture. Equal weights of glauber's salt and muriatic acid (the books say eight of salt and five of acid) the salt pounded. Introduce a small phial filled with water and corked - one globe of a Cryophorus may also be introduced at the same time - likewise a thermometer of this construction. The water in the cryophorus did not freeze until its removal when spiculae appeared. [Illustration]

October 27th, 1826 Used one pound of each in the above experiment.

Experiment 1. To show that aerial fluids are real palpable substances. Fill a large inverted receiver partly with cabbage liquor - place on its surface a lighted taper or cover it with a smaller receiver and press down the inner one and the taper will descend and continue to burn.

Experiment 2. Water hammer – One may readily be made from a common retort by driving out the air by heat then corking it partly full of water. [Illustration]

<u>Phenomena of vapourization</u>

Vapour is invariably produced by caloric and every liquid has a particular point of temperature at which it boils. A few exceptions to this position are stated by Gay-Lussac arising chiefly from the material of which the containing vessel is made.

Experiment 1. Boil water in a Florence flask to see the bubbles forming at the bottom.

Steam and boiling water have the same temperature.

Experiment 2. Shown by putting a thermometer in a tin vessel partly filled by water boiling water and partly by steam. Hence heat goes into a latent state to form steam.

Perfectly formed steam is invisible .

Fluids boil more readily and at a lower temperature the less is the pressure of the atmosphere.

Experiment 3. Put water that has just ceased to boil under the exhaust receiver of an air pump and the boiling will recommence.

Experiment 4. Boil water in a Florence flask partly full – cork it - the boiling ceases - plunge it in cold water it recommences – A retort may be employed in the liquor cabbage liquor. The effect continues more than half an hour. Prepare two or three retorts lest one should break.

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Experiment 5. Put ether under an air pump and exhaust - it will become converted into vapour.

This principle applies successfully to the measurement of the height of mountains - by using Doctor Wollaston's thermometer (Henry vol. 1 p. 119).

By increasing the pressure water may be heated to above 400° without boiling.

Apparatus for proving this described in Henry vol. 1 p. 122.

The density of steam is nearly proportioned to its elasticity. That is steam of double and triple elasticity require twice and thrice as much water to produce it.

The latent heat of different vapours is different though constant for vapour of the same kind of a given elasticity (Table see Henry vol. 1 p. 125).

The same weight of steam contains the same quantity of caloric.

Experiment 6. Moisten a thermometer bulb with alcohol or ether and expose it to the air - repeat the process.

Water converted into steam is enlarged according to Watt 1800 times - according to Gay-Lussac 1698 times.

Latent heat in great quantities is involved in the condensation of steam - the quantity of ice melted by steam of ordinary density is always 7 1/2 times the weight of the steam.

Steam escaping rapidly from an aperture does not scald and even the water in such case does not scald - and both by the thermometer are shown to be of temperature below 212°. May be owing to the sudden expansion of the rising steam, but the solution is difficult. Henry vol. 1 p. 132.

To ascertain the whole quantity of heat in bodies is a problem not just yet solved. But the heat added to or taken from different bodies in certain cases may be accurately determined.

Experiment 7. Eolipile employed in blowing the fire: half filled with water being first heated to expel the air and then dipped in the water and cold water poured upon the sphere will blow the pipe half an hour.

Experiment 8. Candle bomb. Put into a candle - the candle lighted by the explosion takes place in half a minute.

Experiment 9. Place a heated iron on a plate of mercury - put on the iron a piece of gum camphor - cover both with a receiver - the camphor will be evaporated - and on admitting the air will be again condensed to show that solids may be converted into aerial fluids. If an earthen plate is used to contain the mercury take care to put a crucible or a brick for the hot iron to rest upon lest the plate be broken.

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Experiment 10. Take a manometer tube and and fill it with mercury nearly to the top. Pour on some ether in the upper part of the tube - place your fingers on the top and invert the tube in a vessel of mercury - the ether will rise to the top and on removing the finger the pressure of the atmosphere being taken off it boils and forces out most of the mercury - but is condensed on again inverting the tube.

<u>Remark:</u> Probably all bodies solid and liquid might be converted into vapour could we command a heat sufficiently high - and with little doubt all permanent gases owe their gaseous state to lateral heat and could be reduced to solids could they be exposed to cold sufficiently intense. Thompson's Chemistry vol. 1 p. 97.

Experiment 11. Nearly fill a flask or retort with water - put a little ether on the top - invert then pour hot water on the bulb - the ether will boil – or applying cold by again condensed.

Experiment 12. Put a little ether in the top of a bolt head inverted under a receiver - exhaust the air and ether will be vaporized. *[Illustration]*

Experiment 13. <u>To pure water with ether</u>: Provide a glass tube 6 inches long and not more than 1/4 inch bore open at one end into which insert a small coiled wire - provide a glass of this form *[Illustration].* Take some washed ether (see note next page) and cause it to enter the globe of the glass by inserting that globe in boiling water to expand and drive out the air - and if enough does not enter the first time – pour on hot water and evaporate a part of the ether and make a more perfect vacuum - repeat the operation. None up the straight glass tube filled with water and let the ether run upon it for some minutes and ice will be formed which may be drawn out by the coiled wire the globe filling with ether as above pointed out bursts with a loud explosion into a thousand pieces but did not much injury.

Experiment 14. Set on fire the ether as it proceeds from the glass globe exhibited above and a more beautiful flame will be produced (see next page for No. 15)

Experiment with <u>Papin's Digester</u> (to be conducted carefully)

It should not be more than half full of water. Place it upon a French furnace. Do not let the mercury rise in the gauge more than an atmosphere and a half additional.

Experiment 1. Let the steam be thrown into a tumbler of water - it will very soon set it boiling rapidly.

Experiment 2. Attach a glass jar containing a coil of lead tube filled with cold water and the process of distillation will be handsomely shown.

Experiment 3. The hand may be applied to the current of steam that rushes out of the instrument either three or four inches without burning - also a thermometer.

Experiment 4. Show how the latent heat of steam may be ascertained by seeing how many degrees the water rises in the distilling glass by the conversion of a pound of more water into steam and thus condensing it.

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Experiment 15. In a narrow glass filled partly with washed ether put a tube half an inch bore partly filled with water and ether on top and place the whole under an air pump - ice will be formed on exhaustion.

Experiment 16. Exhibit pulse glass – the heat of the hand will drive the alcohol from one ball into the other – pour on ether upon one ball it will drive the fluid to the other by the cold it produces.

Experiment 17. Show the tube and piston for setting fire to tinder by sudden condensation.

Experiment 18. Freeze water in Dr. Wollaston's Cryophorus.

Experiment 19. Evaporate water in a balance by applying heat.

<u>Note</u>: <u>To wash or purify ether</u> rinse with an equal quantity of cold water – shake them together holding the finger on the aperture – the ether will now rise to the top - decant the water by a glass funnel - repeat the process once or twice. Necessary to be done in experiments upon freezing water under an air pump.

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Show the principle on which the steamboat is constructed - steam engine used on.

Water for a warm bath may be heated by steam conducted into it by means of a coiled tube as in case of distillation or thrown into it directly without condensation.

Experiment 1. <u>Natural evaporation</u> Hold hand in a receiver and notice the vapour that collects from insensible perspiration.

Experiment 2. Balance a quantity of water by sand and leave it till the next day.

Evaporation from the human body has the effect of guarding the body from the effects of heat. Case of Sir Joseph Banks and Sir Charles Blodgen see on page ___

<ins>To seal glass tubes hermetically</ins> - fuse the tube within two or 3 inches of the end by a blow pipe gradually and draw the parts slowly asunder then melt the projecting point at the end. Large flexures may be made in tubes by heating them gradually over a charcoal fire in a French furnace. They must be annealed or gradually cooled before a fire to prevent their breaking.

An excellent cement for uniting bandages to make any joint airtight may be made of finely sifted quick lime in the white of eggs. Rye paste one of the best.

<ins>Specific caloric</ins>. The quantity of caloric one body contains compared with that of another is termed specific caloric.

Equal weights of the same body at the same temperature contain the same quantity of caloric. Equal weights of different bodies contain unequal quantities. Equal weights of different mixed at unequal temperatures will not give the authentic mean. Thus a pound of mercury and 40° next with a pound of water at hundred degrees will get the temperature of 97 and half degrees that is the caloric that raised a pound of water 1° will raise a pound of quicksilver 23°. But a pound of water at 40° mixed with another pound of 100° will give 70° of temperature or the arithmetical means. If equal measures of mercury and water be taken instead of equal weights it will be found that the latter has double the capacity of the former for caloric. By experiments of this kind which cannot be shown in a public lecture the specific calories of different substances is ascertained.

The power of different bodies to retain unequal quantities of caloric is called their capacity for caloric.

Bodies heat and cool in different times according to their capacities for caloric - those heating cooling most slowly having in general the greatest capacity for heat. Example - water and quicksilver.

The calorimeter employed by Lavoisier and La Place is used to measure the specific heat of bodies by surrounding them when heated by ice and estimating the quantity of ice melted by them when cooling (not an accurate instrument).

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The specific heat of bodies are greater at high than at low temperatures. That is it requires a greater quantity of caloric to raise bodies to a given number of degrees at a higher than at a lower temperature.

It is probable from the researchers of Pettit and Dulong that the atoms of all simple bodies have precisely the same specific heat.

Difficult to determine the specific heat of gases - yet it has been done in some measure (Henry vol. 1 p. 151).

Specific heat is not a different kind of heat from latent and sensible heat but it embraces them both and is merely a term for expressing their comparative quantity.

*<u>Ignition</u> Bodies are ignited when at a certain temperature they become luminous. Iron is just visible in the dark at 650°F it shines strongly in the dark at 952° at red heat in daylight at 1270°. Gases not capable of ignition as appears from experiments that while they remain gases. White heat still higher than the red (The highest measured he is 125° Wedgewood or 25,127°F).

Whence does the light proceed in the ignition? From the body? Are are heat and light essentially the same?

<u>Extract from Parkes Chemical Essays</u>

*"Sir Joseph Banks and Sir Charles Blagden for some time breathed an atmosphere in Rome prepared by Doctor Goodyear which was 52° higher than that of boiling water viz. 276°F. The temperature of their bodies was not at all raised both their watch chains and everything else metallic all about it then persons were so heated that they could not bear to touch them. [Asterisk] *The thermometer which hung in the room always sunk several degrees when either of the experimentalist touched them or breathed upon them. Some eggs and beef steak were placed on a tin frame; the eggs were hard roasted in 20 minutes and the beef steak was over done in 33 minutes. Water placed in the same room did not however acquire a boiling heat until a small quantity of oil was brought into it when it soon began to boil briskly. The evaporation from the surface of the water had prevented it from acquiring the heat of 212°: but when the surface became covered with a film of oil evaporation could not go on and ebullition commenced."* (2 Loud. Edit. Vol. 1 p. 271)

"The other girls in Germany often sustained a heat from 250 to 280° and one of these girls once breathed in and air heated 325°F for five minutes." (Same work)

A more full account of these experiments is given in Rees Cyc. Art. Heat.

[Asterisk] *"The heat of metals at 120°F is scarcely supportable. Water scalds at 150° but air may be heated to 240° without being painful to our organs of sensation." Davy

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<u>Sources of heat</u>

1. The rays of the sun
2. Combustion (give some general notions of it, mention Phlogiston)
3. Chemical action without combustion exhibited by mixture
4. Electricity and galvanism
5. Condensation of aeriform bodies by pressure and cold
6. Condensation of solids by mechanical action including percussion and friction

<u>Attraction or affinity</u>

That force by which bodies tend to approach each other is called attraction or affinity. It is of the following kinds

1. Attraction of gravitation
2. Attraction of magnetism
3. Electrical and galvanic attraction
4. Attraction of cohesion or aggregation
5. Chemical affinity or attraction

May be reduced to three: 1. Gravitation 2. Magnetism 3. Elasticity

1. Attraction of gravitation. That which retains the planets in their orbits and by which substances on the earth's surface are drawn toward its center. Mention some of its laws and effects

2. Magnetic attraction and repulsion
Illustrate by some simple experiments:

Experiment 1. Natural magnet
Experiment 2. Artificial magnet - needle - horseshoe magnet - etc.
Experiment 3. A small boat loaded with iron drawn by a magnet

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3. Electrical and galvanic attraction and repulsion

Sealing wax and dry raw flannel rubbed together become capable of attracting and repelling each other. They are in such case said to be electrically excited. If the pith balls be electrified by touching them with the same electric they repel but if one be touched with the with wax and the other with the flannel they attract.

Hence bodies similarly electrified repel each other but dissimilarly electrified they attract each other.

Terms vitreous and resinous electricity were applied to these two kinds of states of electricity but Franklin supposed only one fluid - and the body containing this in excess is said to be positively electrified and the body deficient of its natural thus is negatively electrified. Hence this law as in magnetism – poles of the same name repel - bowls of different names attract.

Experiment 1. Rule a dry glass and hold it to suspended corks or pith balls.

Experiment 2. Rub white paper with India rubber and it will adhere for some time to an upright wall.

<u>Affinity</u>

Galvanism is but another mode of exciting electric fluid.

When an insulated plate of zinc is brought into contact with one of copper or silver the former is found to be positively and the latter negatively electrified. The most oxidizable metal is always positive in relation to the least oxidizable metal which is negative.

Explain a galvanic circle.

Also a galvanic pile.

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Cohesion or attraction of aggregation

This takes place between particles of the same kind only.
Example: Drops of water mercury or any fluid

Cohesion however may operate upon masses of different natures "provided that they may be again separated by mechanical means and that their contact be not followed by change of properties." (Gorham's Chemistry vol. 1 p. 5)

Example: Capillary Attraction

When cohesion is confined to the surface of bodies it is called adhesion.

*Experiment 1. Scrape two bullets and press them closely together and suspend weights by means of wires.

Cohesion may be lessened or destroyed by heat mechanical violence or more powerful attraction. (Gorham Vol. 1, p. 6)

As the result of cohesion the particles of matter may unite and form a confused irregular mass or regular geometric figures. The latter is called crystallization.

Explain solution and evaporation. Saturation - water may be saturated with more than one salt. Ex. seawater - mineral springs. Slow evaporation essential to regular crystallization.

Water of crystallization –Effervescence - deliquescence.

Crystallization assisted by immersing in the solution a crystal of a substance or a stick or any foreign body.

Agitation sometimes assist crystallization.

Among an almost infinite variety of crystalline forms there are only six primitive forms viz. 1. the regular tetrahedron, 2. the parallelepiped, 3. all solids which have six faces parallel two and two, 4. the hexahedral prism, 5. the dodecahedron with rhombal faces, 6. the dodecahedron with triangular faces.

The integrant molecule is a primitive crystal reduced by sections parallel to its face as long as division be possible. If reduced by sections not parallel to the faces the integrant molecule will have a form different from the primitive. Only these forms for the molecule has yet been discovered - viz. the tetrahedron - the triangular prism and the parallelepiped.

The secondary crystals are produced by the addition to the primitive forms of lamina of integrant molecules decreasing gradually by the subtraction of one or more rows.

The internal structure of crystals may be determined by mechanical division. But a different and more successful mode has recently been adopted by Mr. Daniel. He expose a crystal of a molecular soluble salt to the action of a solvent. In the course of days or weeks it will be partly dissolved and some crystals of various dimensions will be found in high relief developing the internal structure. From his experiment and other considerations it is rendered probable that the ultimate particles of bodies are of a spheroidal form. See Brande p. 13.

*Ex. Take large crystals of glauber's salts and expose them 24 hours and they will effloresce.

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Chemical affinity

The ultimate particles of bodies consist probably of solids that are incapable of mechanical division and possessed of the dimensions of length breadth and thickness. These particles are denominated simple atoms.

In compound bodies the particles consist of the smallest parts into which bodies can be resolved without decomposition. These are denominated compound atoms. Two atoms uniting to form a third or compound atom are called component atoms and if they have not been decomposed they may be called elementary or primary atoms.

Chemical affinity is that power by which particles or atoms of different kinds are united.

1. By chemical affinity bodies undergo a chart change of properties. E.g. potassium and sulphuric acid.

When opposing properties disappear the bodies combined are said to saturate each other. This term however should be limited to weaker combinations - and that of neutralization applied when more energetic affinities are brought into action.

Synthesis consists in effecting the chemical union of two or more bodies.

Analysis consists in separating those bodies.

Proximate analysis is the separation of two or more ingredients of a body which are themselves compounded.

Ultimate analysis consists in the separation of a compound into its most simple principles.

By an element or simple body is not to be understood a body incapable of further decomposition but one that has not been as yet decomposed.

2. In almost any instance the result of chemical affinity is an increase of the specific gravity of the compound above the mean of its ingredients. Some bodies - especially aeriform ones an exception.

3. Chemical combinations generally produce a change of temperature.

E.g. sulphuric acid and water.

4. Chemical combinations often change the form of bodies. Two solids may become fluids or fluids solids. E.g. quicksilver slowly then intensely heated.

5. Chemical action frequently changes the form of bodies. For example chlorine acting on a solution of indigo, liquid potash added to a dilute syrup of violets.

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Doctrine of definite proportions in a chemical combinations.

"The great fundamental truth is now established beyond all controversy that every body enters into chemical combinations always with the same weight or with a weight bearing an accurate arithmetic ratio to the smallest weight of the given body which is capable of entering into combinations hence some body being agreed upon as a unit the weight of all others can also be expressed by numbers which will always represent a one proportion or two or more of the combining body." Silliman *American Journal of Science* vol. 10 p. 163.

Some bodies united in one proportion only, e.g. oxygen and hydrogen to form water.

Other bodies unite in several proportions. But the numbers indicating the greater proportions are always exact simple multiples of that denoting the least proportion. For example 100 parts of manganese combined with 14 or 28 or 42 or 5066 of oxygen but with no intermediate numbers.

How is the principle to be reconciled with certain mixtures for (e.g. alcohol and water) which seem to unite in all proportions? In such cases the agency of the affinities is always weak. Do not such instances belong to a kind of union that is intermediate between mere mixture and perfect chemical union (See Davy's Chemical Philosophy).

Atomic Theory. This attempts to account for the facts concerning different proportions.

It is probable that chemical combinations take place only between the atoms or smallest particles of bodies and not between masses. It is probable that though incapable of demonstrative proof that the atoms of bodies are different sizes and spherical. These atoms do not touch and cannot be made to touch one another as is proved by compression. Now the atomic theory of Mr. Dalton is that when only one combination of two elementary bodies exist there are united atom to atom singly. These combinations he calls binary - but when several compounds can be produced in the same elements they combine he supposes in proportion as expressed by some simple multiple of the number of atoms and these are termed ternary, quaternary, etc. From these principles it follows that the relative weight of atoms is in the same proportion as their binary combinations.

Berzelius classification of atoms

1. Elementary atoms
2. Compound atoms these are thus divided:
   1. Atoms found of two elementary substances or compound atoms of the first order.

2. More than two elements or organic atoms because found only in organic bodies.
3. Of two or more compounds or compound atoms of the second order.

Mr. Dalton fixes on hydrogen as unity in the calculation but Drs. Wollaston, Thompson, and Berzilius take oxygen.

Gay-Lussac's modification of this theory by assuming volumes instead of weights for the union of bodies.

Objections to the atomic theory (Henry vol. 1 pages 50-51)

Doctor Wollaston's Scale of Chemical Equivalents (Henry Vol. 1, p. 53)

Electric affinity. Bodies have not the same affinity for all others hence they will unite with some rather than others. This disposition or power is called electric affinity.
Affinity is modified by the following circumstances.

1. The quantity of the bodies brought into contact 2. Cohesion 3. Insolubility 4. Specific gravity 5. Elasticity 6. Efflorescence 7. Temperature 8. Electricity 9. Mechanical pressure.

Doubtful whether there is any such thing as disposing or predisposing affinity according to M. Berthollet (Gorham Vol. 1 p. 38.) Doubtful whether quantity modifies affinity. (See forward two leaves.)

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Experiments upon affinity

Experiment 1. Place four fluids of different specific gravities upon each other viz. the lowest mercury, cabbage liquor oil, alcohol tinged with alkanet or turmine. Drop different solids into the tube of such gravity that they will rest upon the several strata, viz. shot or fossil coal upon the mercury, oak wood upon the oil, pine wood on the alcohol - on the water and or take mercury cabbage water and ether or alcohol and lead or iron, oak wood and pine wood or cork. Agitate the whole together they will return to the original position. This experiment shows that different substances may be brought into contact without union if they have no affinity.

October 26, 1826 used mercury water and oil and succeeded well; put a piece of lead into wood to make it just swim on water and a brass weight on the mercury.

Experiment 2. Mix sulphuric acid and alcohol - use alkanet. They will at first separate but on shaking united. Alkanet dissolved in alcohol is better.

Experiment 3. Mix any of the carbonates e(.g. carbonate of soda with muriatic acid) with any of the acids - commotion ensues - muriatic acid unites with the soda and carbonic acid is liberated.

Experiment 4. Mix alcohol and water a union results without commotion. No physical nor moral commotion.

Experiment 5. Into a glass of water put a drop of muriate of lime (or any other muriate). Pour into the water nitrate of silver and a white cloud will appear showing the extreme diffusion of matter. Muriate of silver is precipitated; nitrate of lime remains in solution

Experiment 6. Sulphate of iron dissolved in water - a drop or two in a glass of water – pour its tincture or infusion of galls - a dark cloud will be produced. Gallate of iron or inks forced - the sulphuric acid remaining in the water.

Experiment 7. Nitrate of copper a drop or two in water - pour in the ammonia – a blue cloud will be produced to hydrated peroxide. (Manual page 321)

Experiment 8. Drop of sulphate of soda in the water – Muriate of barytes poured in will produce an abundant white cloud. Sulphate of barytes precipitated – muriate of soda remains in solution

Experiment 9. <u>To show the difference between mere diffusion and solution</u>. Mix clay and water and put it into a filter. The water will pass through clean. Dissolve salt water and it will pass through still salt.

Experiment 10. Mix nitrate of potash and alcohol - the salt will be precipitated. Add a sufficient quantity of water - the salt will be again dissolved - <u>instance of electric affinity</u> (Does not succeed) Does succeed April 12,1826. The alcohol combines with water and liberates the salt

Experiment 11. Lumps of chocolate or marble dissolve slowly in muriatic acid but in powder rapidly. Sugar or salt and lineups and powder thrown into water and lumps and powder thrown into water. Instance of the power of cohesion in resisting chemical action.

Lite for preparing oxygen gas may be made of white potters Clay (now found at New Haven) mixed with an equal quantity of sand and some rye paste.

Experiment 12. <u>Conversion of two fluids into a solid by chemical union.</u> Take very strong Muriate of lime and pour upon it sulphuric acid - stir them together and the vessel may be inverted. Sulphate of lime is formed and the muriatic acid escapes.

Experiment 13. <u>To show that the bodies act chemically upon one another much more powerfully when in a state of solution</u> - Take common soda powders mix them dry no unions dissolve one – effervescence ensues one a carbonate of soda the other tartaric acid a tartrate is formed and carbonic acid escapes.

Experiment 14. <u>Elective affinity</u>. Put an iron rod into nitrate of copper. The copper will adhere to the iron. Nitric acid has stronger affinity for iron and copper and unites with it depositing the copper.

Experiment 15. Pour an alcoholic solution of camphor into common water - a dense white precipitate will be produced camphor precipitated - alcohol unites with the water.

In order to be sure of success in such experiments as the foregoing make use of distilled water.

Experiment 15. Into sub carbonate potash pour some sulphuric acid - effervescence occurs liberating carbonic acid and crystals of sulphate of potash are precipitated.

Experiment 16. Put a bright piece of copper into nitrate of mercury - it will be covered with mercury. Nitric acid has a stronger affinity for copper than mercury and mixes with it.

Experiment 17. Do the same with nitrate of silver. Same explanation as the last.

Experiment 18. Into oil and water in a tumbler put caustic alkali and soap will be produced from two fluids. Add an acid and decomposition will ensue.

Experiment 19. Explode fulminating mercury on an anvil.

Experiment 20. Explode gunpowder.

Experiment 21. <u>Double elective affinity exemplified</u>. Mix a solution of sulphate of zinc acetate of lead. Sulphate of lead will be precipitated and acetate of zinc remain in solution.

<u>Simple elective attraction</u>. When a simple substance is presented to compound one and unites with one of the ingredients of the compound one excluding the other. Doubtful whether we know of any such cases in the present state of our knowledge.

<u>Double Elective Attraction</u> or <u>complex affinity</u> is expected when an attraction is exerted between two primary compounds and both are decomposed and two new compounds produced. E.g. sulphate of barytes and carbonate of potash the latter being boiled will enter and the result will be sulphate of potash and carbonate of barytes.

<u>Oxygen</u>

Derivation of the term
An aeriform gas or permanent elastic fluid.
Discovered by Priestley and Scheele 1774.

Make some remarks upon the four simple bodies oxygen chlorine iodine and fluorine.

1. They are supporters of combustion
2. They produce acids
3. They are electronegative

<u>To prepare oxygen</u>. Put a pound or two of oxide of manganese powdered in an iron bottle - place it in the furnace – use charcoal to heat it – do not attach the leaded tubes to convey it to the gasometer until satisfied gas comes out purer which may be known by applying a candle. Sometimes if the tube gets stopped an explosion takes place.

<u>Properties of oxygen</u>

1. It is not absorbed by water
2. Heavier than common air
3. Refracts the rays of light less than any other gas
4. Luminous by compression

5. Eminent supporter of combustion
   1. During the combustion of bodies in oxygen gas a large quantity of caloric is liberated
   2. Bodies burnt in oxygen acquire an additional weight - 100 parts of iron gain about 30
   3. The products of combination with oxygen and are

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1st An acid   2. An alkali or earth   3. An oxide

6. Oxygen is an eminent supporter of animal life
7. It has an effect on the colour of the blood – oxygen units with all the simplest bodies except nine.

Experiments upon Oxygen gas

Experiment 1. Lower a candle into a jar of the gas.

Experiment 2. Blow out the candle having some fire upon the wick and relight it. Use a glass of this form: *[Illustration]*

Experiment 3. Coil a small wire put it through a cork and to its lower end attach the end of a sulphur match. Tie the match to the wire with binding wire or it is apt to fall November 1826. Prepare a glass of this form *[Illustration]* with a cork in it. Fill it with oxygen gas - put it on a plate and set it on a stand. Light the match and draw out the cork and introduce wire just as the match begins to burn with a white light. If a bottle be employed the bottom must be covered with sand to prevent its breaking. Prepare two or three glasses less one be broken.

Experiment 4. Repeat the same experiment with a watch spring inserted into a cork and not bent.

Experiment 5. Put a candle under a receiver filled with common air and another under one filled oxygen - light them at the same time.

Experiment 6. Attach the compound blow pipe (one arm of it) to gasometer. Light the stream of oxygen issuing from the candle holding a piece of charcoal beneath and on this hold a watch spring or iron wire- A most brilliant combustion will take place.

Experiment 7. Do the same with copper wire.

As soon as more than one kind of gas is collected in the laboratory let the jars be labeled to prevent mistakes.

Experiment 8. Put two animals under receivers one containing common air the other oxygen. In the latter life will be longest preserved.

Nitrogen   *[See Silliman V. 1. P. 193]*

It was first called azote - from *zoe* and *a* privative on account of its unfitness for supporting animal life. Nitrogen from its combination with oxygen to produce nitric acid.

Properties

1. No absorbed by water
2. Specific gravity less than atmosphere viz. 0.9760
3. It extinguishes flame
4. It is fatal to animal life
5. Mixed with oxygen in the proportion of four parts of four parts.

Experiment 1. To obtain nitrogen. Put a piece of phosphorus in a dish on water on the shelf of the pneumatic cistern and set it on fire and place over the dish a large receiver holding it up a little at first to prevent too violent agitation. Nitrogen will remain in the receiver. By transferring it two or three times to another receiver it will be free from the phosphoric acid or by standing 24 hours it will be absorbed.

Experiment 2. Or mix equal parts of iron filings in sulphur and moisten them with drops of water - place it in saucer under receiver and in three or four days the oxygen will be absorbed and the nitrogen will be left.

Experiment 4. Put a candle into a jar of nitrogen. It is immediately extinguished.

Experiment 5. Put four parts of nitrogen and one of oxygen into a receiver and transfer them to be sure they are well mixed. Factitious atmospheric air will be the result. Fill a jar with this air - another with oxygen and another with nitrogen. Put a lighted taper into the nitrogen - it is extinguished – into the oxygen it is relighted and then it burns as in common atmospheric air. These jars should be conveyed with window glass to be sure to be shoved aside on inserting the tapers.

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Berzelius has attended the decomposition of nitrogen partly by experiment and partly by hypothesis declaring a base 44,32 called nitricum combined with oxygen 55,68. Not known whether nitrogen be compound.

Atmospheric air - a compound of 21% of oxygen with 79% percent of nitrogen.

General properties of the atmosphere. Doctor Wollaston's remark concerning its extent. (Henry vol. 1 p. 284 Supplement p. 19)

Give an account of the endiometer - same work p. 288.

Atmospheric air always contains a small proportion of carbonic acid gas and aqueous vapours.

Whether oxygen nitrogen are chemically united in the atmosphere or whether it is a mixture are questions not easily decided.

Nitrogen unites with oxygen in four proportions viz. 1. Nitrous oxide 2. Nitric oxide 3. Nitrous acid and 4. Nitric acid these and the other compounds will be treated of in some other places.

Hydrogen

*[Asterisk] Water may be decomposed by putting into a phial a mixture of iron and zinc and water with sulphuric acid – cork it and introduce a small glass tube and the hydrogen will rise through the tube and may be set on fire and then put under a receiver over water filled with oxygen and water will appear on the inside – or convey hydrogen from the gasometer by leaden tube to the cistern and setting it on fire first over a receiver filled with oxygen (See 2 of subsequent experiments)

<u>Experiments on Hydrogen</u>

Experiment 1. <u>Decomposition of water.</u> Take a clean gun barrel 2 feet long open at both ends. Introduce into it iron turnings tied together mixed with a few iron filings. Into one end insert a glass retort about one third full of water. Pass the gun barrel through a furnace. Apply heat to the flask as well as to the furnace and the water will pass through the barrel in the form of steam and will be decomposed by the iron which will enter into combination with the oxygen. The hydrogen will pass over and may be collected in the small cistern by a glass tube passing from the barrel to the receiver. The gun barrel should be covered with butter?

To introduce oxygen into a glass globe or jar for recomposing water. Keeping the vessel dry. Introduce one of the tubes of the compound blow pipe into the globe nearly to the bottom turn the cock to let the oxygen escape and by its specific gravity it will displace the common air and by letting down a taper into the vessel it may be known when it is full of oxygen - then let it be corked.

Vessel for recomposing water of this form: *[Illustration]* Caption: 14" diam.

Experiment 2. Recomposition of water. Fix a cork near the end of the compound blow pipe so that it will set rather loosely. Set on fire the oxygen and hydrogen at the mouth and introduce the tubes into the globe figured above pushing in the cork rather loosely and taking care that there be no leakage near the end of the blow pipe. (*[Asterisk] See top of the page)

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Experiment 3. One part of zinc or iron fragments or filings two parts of sulphuric acid diluted with five or six parts of water put together into the lead pot will produce an abundance of hydrogen - which may be conveyed by a leaden tank to the gasometer (half pint sulphuric to a quarter of water 2/3 tumbler of iron filings). Do not stop the vessel immediately.

Experiment 4. Show how gases may be weighed with a Florence flask.

Experiment 5. Explode hydrogen by touching a candle to proof glasses.

Experiment 6. Mix two parts of atmospheric air and three parts of hydrogen and fill with this mixture an air pistol *[Illustration]* (copper tube) holding the finger up on the vent. Cork the orifice before it is withdrawn from the water then apply a sulphur match to the touch hole and a violent explosion will take place and the cork be driven across the laboratory.

Experiment 7. Do the same with two parts hydrogen and one part oxygen. The explosion will be more violent.

Experiment 8. Mix bar soap and warm water until it has become nearly as thick as paste - let it stand several hours - then take a bladder with a stopcock and fill it with _____ parts hydrogen and ____ parts oxygen – attach to the end of the stop cork a brass or copper pipe like a tobacco pipe *[Illustration]* and press upon the bladder after dipping the bowl of the pipe in the thick soap suds and a large bubble will be blown which will usually ascend several feet in the air. Touch them with a candle and they will explode (Balloons).

[Illustration] Method of introducing air into a receiver full of water or mercury in a gradual manner. Put the finger on one end and of the bent glass tubing. Introduce the other into the receiver then withdraw the finger and the air will move in.

<u>Sketch of the furnaces in the laboratory at Yale College</u>

[Illustration] A detailed illustration of Yale furnaces]

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<u>Canons of the laboratory at Yale</u>

1. Hot water
2. Dust the stove tables etc.
3. A place for everything and everything in its place
4. Clean towel on or near table
5. Candles and lamps always ready
6. Bottle or pitcher of water on lecturing table
7. Every bottle and vessel clean
8. Nothing put up without a label
9. In cold weather fire in the office - office dusted and clean
10. Saturday - lecture room swept and dusted throughout
11. No dirty hands on walls
12. After each lecture clean and put up everything.

Experiment 9. Attach a bent iron tube to arm of the compound blow pipe through which hydrogen may issue. Turn the stopcocks and set fire to the stream of gas that issues. Hold over the flame glass tubes of various diameters and lengths (also tin or iron or earthen tubes) open at both ends introducing the flame several inches and various musical sounds will be produced.

Experiment 10. Suspend a jar in the air mouth downward full of hydrogen – the gas will remain some time as may be shown by applying a candle. Do not let it hang too long lest it become explosive.

Experiment 11. Turn the mouth of the jar thus suspended upwards and let a person hold a candle several feet above it and it will ascend and take fire.

Experiment 12. Take two volumes hydrogen one of oxygen mixed together and let it rise in bubbles through the shelf of the pneumatic cistern and as it rises apply a burning paper dipped in spirits of turpentine. Loud and successive explosions will take place.

Experiment 13. Fill a beef bladder with the same mixture as in the last and take a pole 10 feet long with a sharp bent wire fastened at one end on which is tied a rag dipped in spirit of turpentine. Set this rag on fire and perforate the bladder with the wire and a very loud explosion will result.

Experiment 14. Fuse a piece of pipe of silver platinum copper etc. by the compound blow pipe. Take care to regulate the instrument before the operation.

Explain the construction and give the history of the compound blow pipe.

Experiment 15. Blow a quantity of bubbles in a dish of suds within explosive mixture and throw into the dish a coal afire.

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Properties of hydrogen [See Silliman V. 1 p. 205]

1. Origin of the word (two words in Greek letters)
2. Weight 14.4 times lighter than common air just 6×10 times lighter than oxygen. Hence applied to filling balloons.
3. Fatal to animals
4. Not absorbable by water except very slightly
5. Destitute odour in a pure state
6. Highly inflammable
7. Yet it extinguishes flame
8. It enters largely into the composition of vegetable and animal and in considerable proportions in that of minerals
9. Its most important combinations are

    1. To form water with oxygen 88.3 grains of the latter to 11.7 grains of the former or 250 and 500 cu. in.
    2. Deutoxide or peroxide of hydrogen discovered in 1816 by Thenan (*vide* Henry p. 262 vol. 1)
    3. Hydro chlorine or muriatic acid - hydrogen and chlorine
    4. Hydriodic Acid – hydrogen and iodine
    5. Hydrofluoric acid - hydrogen and fluorine

These will be considered in their proper place.

Experiment 16. On hydrogen - attach a tube of this form *[Illustration]* to the compound blow pipe. Let out the hydrogen and at the same time pour iron filings into the bowl setting fire to the gas and a beautiful jet of flame will ensue.

Alkalis

Origin of the term from *kali* a Latin name name of a plant.

“Alkalis may be defined as those bodies which combine with acids so as to neutralize or impair their activity and produce salts.” (Use. Ch. Dict. Art. Alkalis).

There are three classes of alkalis:

1. Those consisting of a metallic basic compound with oxygen viz. potash soda and lithia
2. That containing no oxygen or ammonium
3. Those containing oxygen hydrogen and carbon viz. Aconite, Atropia, Brusia, Cicuta, Datura, Delphia, Hyosciame, Morphia, Strychnia, and perhaps some truly vegetable alkalis as besetra, cinchonia, ruinia, and picrotonia.

Potash, soda, lithia and ammonia have the following common properties:

“1. They change the principal colour of many vegetables to green - the reds to a purple and the yellows to a brown. If the purple have been redden by an acid alkalis restore the purple.
2. They possess this power on vegetable colors after being saturated with carbonic acid, by which criterion they are distinguished from the alkaline earth
3. They have an acrid and ruinous taste
4. They are powerful solvents on corrosives of animal matter with which as well as with oils in general they combine so as to produce neutrality.
5. They are decomposed or volatilized at a strong red heat.

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6. They combine with water in every proportion and also largely with alcohol
7. They continue to be soluble in water when neutralized with carbonic acid; while the alkaline earths thus become insoluble.”

(Ure’s Dictionary of Art, Alkalis)

<u>Ammonia</u>

Ammonia is a compound of hydrogen and nitrogen, three parts by measure of hydrogen and one of nitrogen.

Called by Priestley alkaline air

<u>Properties</u>

1. A very strong and pungent smell (smelling bottles)
2. It extinguishes flame
3. Lighter than atmospheric air - its specific gravity is six air being 10
4. It is fatal to animals
5. Ammoniacal gas may be burned in oxygen with a pale yellow flame. So it may in atmospheric air according to Professor Silliman when collected in large jars.
6. Ammonia is rapidly absorbed by water a cubic inch of water takes up 475 cu. in. of the gas

Solution of ammonium or carbonate or ammonium or indeed any of the alkalis will take the red spots from woolen cloth produced by acids.

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Experiment 1. To procure ammoniacal gas. Introduce two parts of quicklime and one of muriate of ammonia into a glass retort. Apply a gentle heat and the gas will escape and may be collected over mercury. *[See Silliman V. 1 p. 231]*

Experiment 2. To decompose ammonia. Fasten a retort containing two parts quicklime in one of muriate of ammonia to one end of an iron tube and a bent glass tube to the other end. Let the tube pass through a universal furnace. Apply heat to the retort and also to the iron tube. Ammoniacal gas will first be produced by the mixture in the retort and in passing into through the iron tube which should contain iron filings or wire or turnings; and hydrogen and nitrogen may be collected in a cistern placed at the end of the iron tube.

Experiment 3. Effects of alkalis upon vegetable infusions. Cabbage liquor becomes green, alkanet bluish purple, turmeric brown, infusions of Brazil wood (diluted) deep brown. All these liquids may be restored to their natural colors by the addition of an acid.

Experiment 4. Perform the same thing with the alkanet and turmeric papers.

Experiment 5. After the ammonia gas is collected over mercury pour up into them a quantity of water colored by some vegetable test. A rapid absorption of the gas takes place and the test is changed in colour.

Experiment 6. To collect this gas without mercury. Put quicklime in and muriate of ammonia into a long necked flask into which a smaller tube is inserted and under it apply the heat of a lamp. Over the neck of the flask invert another and apply a feather dipped in muriatic acid to its mouth. After a few minutes and if a white fume appears the vessel is filled. This same method may be adopted to ascertain in any case when ammonia gas comes over pure.

Experiment 7. Apply the thumb to the orifice of the upper flask in the last experiment and dipping it into cabbage liquor let in a very small quantity and let it run over the whole of the inside shaking it a little and it will absorb the gas. Apply now again in the mouth of this flask to the cabbage liquor and on the removing the thumb the liquor will rush violently into the glass assuming a beautiful green colour.

N. B. The lime and all the experiments on ammonia should be dry slaked previously to mixing it with the sal ammoniac.

Experiment 8. To make liquid ammonia or to saturate water with ammoniacal gas. Into an iron ball (such as contain quicksilver at the shops) put equal parts of quicklime and muriate of ammonia and set in the furnace. Let a communication be made between the iron bottle and the glass ones of Woulfe's apparatus. In the first bottle put cold water an inch deep into the second distilled water the third full and so on in others if you wish to saturate more than one. Let the second glass jar be placed in a vessel so that cold water may be made to surround either glass. Towards the conclusion this experiment requires to be narrowly watched lest regurgitation take place. It is better to pull out the corks and waste some other gas than to endanger the vessels. Be careful in turning water into the iron bottle after the cork is detached. Reserve that contents of the iron vessel filter it and it will be muriate of lime which may be kept in a for various experiments and sulphuric acid and a solid will be formed.

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Potash or Potassa

Experiment 1. To produce hydrated protonide or caustic potash. Into a pot of hot water put equal parts of quicklime and carbonate of potash (or pearl ash), e.g. 2 pounds of each. Boil them till there will be no effervescence on adding muriatic acid to a quantity taken out in a wine glass nor any precipitate on adding limewater. Then filter it through a clean linen towel. Put the lye? into black bottles and let it stand overnight and decant the liquor or draw it off by a siphon. This will be a solution of caustic potash free from carbonic acid but not from all impurities. It may be kept in a state of solution or evaporated and contains dry and obtained dry according to the use that is to be made of it. Sometimes limewater will throw down a precipitate if the solution be very strong even when there is no carbonic acid. In this case add water to the solution and this effect will be prevented.

To purify the potash still further dissolve it as purified above in alcohol and leave it to stand till the impurities subside at the bottom and then filter it and evaporate it.

Soda may be purified in the same way.

Experiment 2. Show the manner of obtaining lye from wood ashes as practiced in making soap. Pour hot water upon ashes and after a little time filter the water – pour an acid upon it and it will effervesce showing the presence of carbonic acid. It is the presence of this that prevents lye from making good soap. Hence the use of mixing quicklime with ashes which absorbs soap.

Experiment 3. Mix oil and potash together so as to make…

Experiment 4. Apply the various tests to caustic alkaline in solution.

Soda

This differs but little from potash.

Obtained from plants growing in the vicinity of salt water.

Soda is distinguish from potash by the different salts they form with the acids and potash is more deliquescent than soda. Pour a solution of potash into a solution of the ore of platina in nitro-muriatic acid and a yellow precipitate will appear but if soda be used no precipitate will be formed.

Potash and soda so nearly resemble each other that in their general properties they may be heated treated of together.

Notice the use of the fixed alkalis in the making of glass – in dying colouring etc.

Potassium

Give the history of the decomposition of Potassia and the methods of effecting it first by galvanic apparatus, second by a bent gun barrel. (Brande p. 175.)

Experiment 5. Throw potassium on water - it immediately takes fire and runs rapidly over the surface. It is well to guard the sides of the vessel if it be glass by tin.

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Experiment 6. Take a small flask and tightly fill it with cabbage liquor. Drop in a piece of potassium and it will burn - apply the thumb to the orifice pf the flask and shake the fluid and it will be turned to green showing conclusively the recomposition of the potash.

Experiment 7. Put potassium upon alcohol in a wine glass. It does not usually inflame.

Experiment 8. Do the same with ether - sometimes they both take fire.

Experiment 9. Potassium upon sulphuric or muriatic or nitric acid.

Combinations of potassium. See Brande and Henry.

Why should the two fixed alkalis have a metal for their bases while ammonia has a gas? Perhaps hydrogen and nitrogen have metallic bases also. Pass an electric spark through quicksilver placed upon a piece of muriate of ammonia and its bulb will be greatly increased and an amalgam formed. Perhaps the mercury in this case unites with the metallic base of the hydrogen.

Sodium

Discovered in 1800 by Davy.

Resembles potassium but less inflammable. May be welded by mere pressure at common temperatures.
Lighter than water - specific gravity 0.972
Melts at 180 or 190°F.
Recombining with oxygen at common temperatures it does not so readily burn as potassium. In hot water a few scintillations are observed.
Its action on alcohol ether volatile oils and acids is similar to that of potassium.

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Lithium

Obtain from petalite and spodumene. Exhibit these minerals.

Earths

General remarks upon them. All now considered the oxides of metals.

Lime

To obtain lime in purity - put the common quicklime into a reverberatory furnace mixing it with charcoal and after letting it burn for a time it will be freed from its evaporable impurities.

Experiment 1. Fuse quicklime before the compound blow pipe file the piece to be tied into a pyramidal form and place on charcoal.

Experiment 2. Try the test liquors and papers upon a solution of lime and water viz. limewater.

Experiment 3. Slake lime in the common way.

Experiment 4. Slake it in a glass tumbler with a large receiver inverted over it to catch the vapours - at first a cloud afterwards invisible.

Experiment 5. Put a bit of phosphorus on slakeing lime.

Experiment 6. Slake it in the dark and show the extrication of light.

Experiment 7. Two parts ice to one of lime and heat will be evolved. Calcium the metallic base of lime.
Uses of lime - mortar - cement - hydraulic lime

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<u>Barytes</u>

Obtained from the sulphate or carbonate. See Henry.
It slakes with water much more violently then lime.

Experiment 1. Before the compound blow pipe this earth burns with a peculiar yellow flame. To prevent the earths in powder from being blown away mix them with tallow.

Experiment 2. Solution of barytes in water acts upon the test like liquors and papers like alkalis.

It is poisonous. It unites with oils to form soap.

Barium the metallic base of barytes - how obtained - Henry etc.

<u>Strontites</u>

Obtained from the carbonate - heat of 140° Wedgewood expels the carbonic acid or it may be dissolved in nitric acid and this driven off by heat.

Its properties similar to barytes. It differs in being less fusible and less soluble weakens in its affinities and not poisonous.

Experiment 1. Before the compound blow pipe it fuses with a red flame.

Experiment 2. A solution of it in water acts on the chemical tests like alkalis.

Strontium is the metallic base of strontites. Obtained in the same way as barium.

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Magnesia

Native magnesia found at Hoboken, New Jersey. May be obtained from bittern (a fluid that remains after the separation of soda from seawater) by adding an alkali by which it will be precipitated. Carbonate of magnesia also parts with its acid at a red heat.

Magnesium metallic base of magnesia can hardly be said to have been obtained in a separate state: but the amalgam formed with mercury leaves no doubt concerning its existence.

Experiment 1. Fuse this earth under the compound blow pipe.

Experiment 2. Put the calcine magnesia of the shops and put it into the cabbage liquor and this will turn green. This is only one alkaline property magnesia presents.

Calcined magnesia is the pure magnesia. That sold in the shops in cubical pieces is carbonate of magnesia.

Silex

Exhibit rock crystal and flint.

Heat colorless quartz crystals to redness – quench it in water - reduce it to a fine powder. Fuse one part of the powder with that of potash in silver crucible. Dissolve the mass in water add slight excess of uric acid and evaporate to dryness and work the dry mass in boiling distilled water upon a filter and the white substance remaining is silex.

Silicium has not been obtained in a separate state - Brande p. 309.

Glass is composed chiefly of silex and one of the fixed alkalis. Sometimes litharge (oxide of lead) nitric lime brick clay manganese and cobalt [????] are added.

Give an account of the process of making glass.

Experiment 1. Subject silex to the flame of a compound blow pipe. It fuses.

Experiment 2. Attach a common blow pipe to a gasometer filled with common air (or make use of the compound blow pipe uniting a stream of oxygen and hydrogen) and put a glass tube about 1/3 inch diameter – sides rather thick - into the flame - let the assistant take hold of one end of it and draw it out gradually and it melts and with care a glass wire tube 20 or 30 feet away may be drawn not larger than a knitting needle. Two tubes 28 feet long were drawn in this manner. December 6th 1825 in Yale laboratory and hung up for exhibition the next day.

Experiment 3. Blow globes at the end of tubes from four thermometers.

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Experiment 4. Break some of Prince Rupert's drops. Put on the goggles to perform this experiment and gloves.

Experiment 5. Break Bologna bottle.

Glass tubes are drawn by first blowing a bottle and then one of the workmen takes hold of one end and draws out the glass while the other continues gradually to blow.

Window glass is first blown in the shape of a large globe and then the iron is applied to the bottom of this globe - the other end having an orifice the whole is now put into a furnace and a rotary motion given to it. The orifice continues to enlarge and at length the lid suddenly expands by the centrifugal force into a plane having a thick knob in the center called the <u>bull's eye</u>.

Experiment 6. Show how cracked glass vessels may be broken into any convenient shape by applying a hot iron. They may also be broken by tying round the place where you would crack the glass a string wet with spirits of turpentine.

Looking glasses are cast upon iron tables and rolled with the cylinder. Only two establishments of this kind viz. in England and France. (See Parke's Chemical Essays.)

Experiment 7. Lay a pine stick an inch square and 2 ½ feet long upon the edges of two wine glasses and strike a very heavy blow on the stick. It will be broken and the glass is uninjured.

Experiment 8. Exhibit an harmonicon.

Experiment 9. Exhibit glass plumes.

<u>Alumine or Alumina</u>

Found in the hardest gems as sapphire, ruby, topaz, etc., also in all varieties of clay.

To obtain pure alumina - to a solution of alum add carbonate of ammonia and wash to ignite the precipitate.

Experiment 1. Before the blow pipe it fuses being previously made plastic by a little water.

Experiment 2. Exhibit specimens illustrative of the manufactory of common earthenware and also of porcelain.

Alumina is important in most [????].

Also in many mortars.

Aluminium can hardly be said to have been obtained.

Alumina in silex constitutes the principal ingredients in potteries and porcelain manufactures.

Explain the modus operandi from the graphic granite to the finished china.

Glaze of porcelain is made of a fusible kind of feldspar. muriate of soda is an excellent glaze.

Oxide of lead is an ingredient in common glass and is very poisonous - acids and preserves ought not to be kept in articles of this kind. (Parke's Chemical Essays vol. 2 p. 90)

Lustre ware is covered - the dark yellow articles with the oxide of gold - the silver coloured with platina.

Most delicate figures on porcelain are put on with a brush – in other cases they are put on with a stamp - with a bibulous paper which has been impressed on a copper plate.

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Zircon

Exhibit the zircon in the mineral of that name. Zirconium - or base of the earth

Glucine

Found in the beryl and emerald etc.

Glucine on the oxide of gluconium consists of 8 oxygen and 21.3 zirconium

Yttrium

Found in the gadolinite and some other rare minerals. It is composed of 8 oxygen and 32 yttrium.

Thorinia

Obtain from gadolinite and certain ores of Cirsium but in very minute quantities.

Acids

The doctrine of Lavoisier was that oxygen was the universally acidifying principle that all acids consisted of a peculiar base uniting with oxygen cannot be maintained - since the muriatic, flaconic, boracic, hydriodic and hydrocyanic acids become such by the addition of hydrogen. No single acidifying principle therefore exist so far as our knowledge extends.

In Dr. Murray's opinion water is the acidifying principle (Ure’s Art Acids).

"It seems to me says Dr. Hare that the galvanic fluid is the acidifying principle and that the acid state is the consequence of galvanic arrangements or polarities." (Ure’s Art Acids).

An acid is a substance containing the following properties *[See Silliman V. 1. P. 307]*

1. Their taste is sour - sometimes acrid and [????]
2. They generally combine with water in every proportion with a condensation of volume and evolution of heat.
3. With few exceptions they are volatilized or decompose at a moderate heat.
4. They usually change the principal colour of vegetable to a bright red.
5. They unite in definite proportions with the alkaline earths and metallic oxides and form salts.

The acids derived from inorganic nature as enumerated by Ure are 37 of which 25 are formed…

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…formed by the union of oxygen with some base nine a metallic ore and 16 nonmetallic and eight a form by the union of hydrogen to a base – and four are destitute of either oxygen or hydrogen.

The remaining 38 acids are of organic origin.

Oxygenized acids acids are such as have a surcharge of oxygen imparted to them. Discovery of Thenard (Ure Art Acids).

<u>Sulphur</u>

Experiment 1. Show its electricity by friction - use a magnetic needle.

Experiment 2. Heat a crucible to almost 600°F and put it under an inverted glass jar after putting into it a quantity of sulphur - sublimation will take place in a short time.

Experiment 3. Throw some of the powder of the Lycopodium upon the flame of the candle and it will flame instantly. Do this to correct an impression that this powder which sometimes floats like a cloud in the atmosphere is sulphur.

Experiment 4. Heat sulphur in a crucible a considerable time then pour it into a dish containing water and it may be impressed by a coin or medallion.

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<u>Sulphurous and sulphuric acids</u>

Experiment 1. Into a flask put three parts by measure of sulphuric acid to one and two thirds water and shake them together. Introduce into the flask a tube half an inch calibre partly filled with cabbage liquor - and the liquor will boil in a few minutes. Be careful when such mixtures are employed for the vessel sometimes breaks and a boiling gas would be extremely dangerous.

Experiment 2. To purify sulphuric acid that has become coloured – Put quantity into a flask and leaving the mouth open apply heat and it will become transparent provided the impurities were of a carbonaceous kind.

Experiment 3. To obtain pure sulphuric acid by distillation. Take a glass retort from 2 to 4 quarts and put it into a plate of sulphuric acid. Connect it to a large globular receiver by an adapter 3 or 4 feet long which fits loosely at both ends. Put the retort into a sand bath and gently increase the heat placing a screen before it to avoid explosions. We continued the fire under this retort as much as six hours and less than one half of the acid was carried over. Slight explosions not dangerous occasionally took place. Put into the retort some broken pieces of glass or platina.

Experiment 4. Fill a jar with oxygen pouring into it a little cabbage liquor - put sulphur into it on fire and after a little time agitate the water and it will become red. Sulphuric acid or rather a mixture of sulphuric and sulphurous acid will be formed.

Experiment 5. Burn sulphur in similar manner in a jar of common air and sulphuric acid will be produced.

Experiment 6. Pour sulphuric acid upon mercury in a flask; from the neck of the flask let a glass tube proceed and bend over into a phial filled with water. On applying heat to the flask sulphuric acid will pass over and saturate the water - the mercury abstracting one proportional of the oxygen.

Experiment 7. Put the same materials as in the last experiment into a flask and apply heat and sulphurous acid may be collected over mercury.

Experiment 8. Turn up the jar containing gas thus collected and let into it a candle which will be immediately extinguished.

Experiment 9. Pour this gas from one jar to another.

Experiment 10. Pour it in upon a candle.

Experiment 11. Into a large matrass or flask put a quantity of glauber's salts and pour in enough boiling water to take it all up in solution no more. Then take hold of the neck of the retort with the hands covered and hold it over the furnace until the solution boils and no more salt remains at bottom. When sufficient vapour has escaped to drive out the common air cork it tight (some twine being previously wound around the mouth to prevent its breaking by the cork) and set it carefully away resting it upon cloth by putting some paste around the cork. It will continue to boil nearly an hour if all be right and remain a liquid an indefinite time but if the air be let in crystallization immediately takes place of sulphate of soda. Take care not to move the vessel after it is set away nor hold it over the fire after it is corked.

Carbonate of magnesia a good thing to be taken into the stomach if sulphuric acid be swallowed through mistake or use any alkali that may be at hand and getting it down with as little water as possible because water and sulphuric acid produce a great heat.

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Experiment 13. Show the effect of these acids in reddening the vegetable colors.

Experiment 13. Freeze sulphuric acid one pint acid to 28 oz. water put outdoors at night.

Experiment 14. Pounded ice one part and sulphuric acid four parts produce a boiling heat.

Experiment 15. Four of ice and one of acid produce intense cold.

Give an account of the manufacture of sulphuric acid and its used in the arts. See Parkes Chemical Essays volume 1.

The sulphates brought forward by Professor Silliman are sulphate potash - of soda - of ammonia - of barytes – of strontites - of lime – of magnesia – of argil and potash or ammonia in both viz. alum.

[Asterisk] * Experiment: Put 2 ounces sulphuric acid into a tea dish and into a balance - Balance by sand or weights and and leave the scales in the open air - the acid will absorb moisture from the air (In 4 days 21 hours this gained 630 grains at Yale lab.)

(*See over the next leaf explosion of Pyrophorus)

<u>To prepare Pyrophorus</u> - Mix three parts of lamp black four of calcined alum and eight of pearl ashes and heat the mixture in an iron tube (gun barrel) to a bright cherry red for one hour. (Some danger of applying too much heat.) Continue the heat an hour – then cork the tube and set it away and probably Pyrophorus is formed. Dr. Hare's method which he says usually succeeds - well to have two or three tubes prepared as one may succeed when others do not even in the same furnace. (See Brande p. 316 also Ure). The alum may be calcified by simply heating it in a ladle. Material should be pounded sifted and thoroughly mixed then set the tubes aslant in the Black's furnace and fill with coal and close the orifices nearly and let it burn partly down – then renew the fire once and leave it to burn down.

<u>General properties of the sulphates</u>

1. Generally crystallizable perhaps all are
2. Not decomposed by heat except sulphate of ammonia
3. Ignited with charcoal decomposed into sulphurets (same exceptions)
4. The alkaline sulphates have a bitter taste
5. Decomposed by the barite salts and the precipitate is insoluble in acetic acid
6. Precipitated crystallized by alcohol (Silliman's notebook)

Experiment 16. Pulverize the alum of the shops and dissolve in boiling water pouring through a filter as soon as possible into a long glass vessel in which are suspended several threads arranged as fancy dictates. Set the vessel away to cool and beautiful octahedra will attach themselves to the threads in abundance.

Experiment 17. Into strong solution of muriate of lime (the residuum of a preparation of ammonia) pour sulphuric acid and violent effervescence ensues and a solid substance is produced viz. sulphate of lime.

Experiment 18. Take cabbage liquor and pour into it a carbonate of soda and no changes produced because this is a neutral salt - pour into it sel carbo-ammonia or soda potash and it will be changed to green because alkali in excess - pour into it a solution of super carbonate of potash and it will be changed to red because the acid is in excess.

Experiment 19. Exhibit specimens of sulphate of lime, strontium, barytes and crystals of alum.

Experiment 20. Pour alcohol into any of the sulphates that is does not dissolve and they will be precipitated – add water and they will be redissolved.

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Experiment 21. Pour sulphuric acid upon carbonate of magnesia of the shops and sulphate of magnesia will be formed with effervescence and remain in solution.

Experiment 22. Show the same with recently calcined magnesia on which the action will be more violent.

Experiment 23. Show the same with carbonate of lime.

Experiment 24. The same with quicklime on which the action is very violent - the glass is liable to be broken.

Experiment 25. Put a spoonful of sulphate of ammonia upon a red hot shovel - it will evaporate in a dense white fume. Put on sulphate of soda and sulphate of magnesia and they will undergo aqueous fusion or lose their water of crystallization - put in sulphate of potash and it will decrepitate.

Experiment 26. Into a solution of alum put the carbonate of an alkali and it will be decomposed or precipitated by adding an acid. In general potash soda, ammonia barytes strontites and lime decompose alum.

Experiment 27. Pour out pyrophorus into common air and if it does not kindle breathe upon it.

Experiment 28. Pour it into oxygen and it will inflame fiercely.

Experiment 29. Soak paper or a piece of shingle in a solution of alum water and they become incombustible.

[Asterisk] *<u>Explosion of Pyrophorus</u>. A preparation of this substance in an iron tube having stood 10 days was opened for transferring to another vessel and a ramrod was run into it producing considerable friction when an explosion took place as loud as a common gun blowing the contents in a jet of fire scorching hair and eyebrows of the person who held it and giving a violent jerk to the hand that held the ramrod. The glove with which this hand was fortunately covered was burned in several places to crisp. The eyes were considerably inflamed and the sensation precisely like that which results from having common gunpowder fired in the face. In putting the ramrod into a second tube containing pyrophoric

and very gently pressing it down upon the substance another equally violent explosion took place aloud and accompanied by as much flame as a common musket. The tubes had been standing in the laboratory tightly corked. This preparation of pyrophorus had been observed 20th December 1825 to be unusually good and when breathed upon in the air had burnt with a slight explosion. The friction of the ramrod doubtless produced the explosion.

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<u>Sulphuretted hydrogen</u>

Gases uniting with other bodies makes the name in –etted instead of [????].

Experiment 1. Put proto-sulphuret of iron with a little water into a retort or flask - connect this by a tube passing over into a phial of water - pour into the flask muriatic acid - and sulphuretted hydrogen will rapidly come out and the water be saturated. The phial which should be put into a large tumbler and surrounded by ice and water.

Experiment 2. Perform the same process with liquid ammonia and a hydro-sulphuret of ammonia will be formed - put a little fire under the flask if necessary.

Experiment 3. Into acetate of lead mixed with distilled water pour either liquid sulphuretted hydrogen or hydrosulphuret of ammonia and a dense precipitate will be produced. These sulphurets are an extremely delicate test of lead. Indeed sulphureted hydrogen precipitates all the metals except iron nickel cobalt Macanese titanium and molybdenum .

Experiment 4. Into a tribulated retort pass proto-sulphuret of iron – water and muriatic acid and sulphureted hydrogen will be evolved which may be collected over water a little warmer then blood heat. Over cold water it will be rapidly absorbed.

Experiment 5. To prepare proto-sulphuret of iron for making sulphuretted hydrogen. Mix intimately together in a mortar three parts of flowers of sulphur and one of iron filings - put the mixture over a common fire in a crucible (an iron one is the best) and continue the heat till the whole mass becomes red-hot and the excess of sulphur is driven off. If not continued to this heat it will not answer well. It is now prepared for use.

Experiment 6. To convert a sulphate into a sulphuret. Take sulphate of barytes - pond and sift it - put it into a common heavier crucible and with about one sixth part of charcoal or lampblack. Place the crucible in the furnace - heat to redness - the charcoal will seize upon the oxygen of the substrate of barytes and go off in the form of carbonic acid and sulphuret will remain. Danger of too much heat.

Experiment 7. Write with a solution of lead or silver on cards and it will be invisible - but dip the ends into a liquid sulphuretted hydrogen and it will appear legible.

Experiment 8. Smear over the whole card with the same solution and expose it to this gas and it will become black.

Experiment 9. Liquid sulphur and hydrogen reddens infusions of violets and litmus.

Experiment 10. Nitric or oxymuriatic acid precipitates the silver poured into liquid sulp. hydrog.

Experiment 11. Electricity throws down sulphur.

Experiment 12. Potassium heated in this gas burns brilliantly. Use a small retort for this experiment and introduce the potassium in a foil of platina and apply heat.

Experiment 13. Mix equal bulbs of sulphurette hydrogen and oxygen and they will explode. A strong glass jar may be used for this purpose.

Experiment 14. Into water charged with sulphuretted hydrogen pour a few drops of nitric or nitrous acid and sulphurette will be precipitated.

Experiment 15. Take the sulphurette of barytes prepared for Experiment 6 and dissolve in hot water. Into the solution pour some one of the carbonated alkalis and the carbonate of barytes will be thrown down in a dense white precipitate which may be passed through a filter.

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<u>Sulphuretted hydrogen</u>

<u>Properties of this gas</u>

1. Smell extremely offensive
2. Exceeding irrespirable (Henry p. 431)
3. Inflammable - silently in common air with detonation in oxygen
4. Tarnishes silver mercury and other polished metals and blackens white paint and acetate of lead.
5. Absorbent by cold water
6. Water saturated with this gas reddens the most delicate vegetable infusions. Hence some have called it an acid.
7. Nitric or nitrous acid precipitates sulphur from water charged with sulphuretted hydrogen.
8. This gas is decomposed by chlorine.
9. Also decomposed by long mixture the atmospheric air.
10. Also buy electricity
11. Also when passed over ignited charcoal
12. It precipitates all metallic solutions except certain ones (see Henry p. 433)
13. Copiously absorbed by alkalis and all the earths except alumina and zircon
14. Specific gravity about 1.1912.

<u>Bi-sulphuretted or super-sulphuretted Hydrogen</u>

This consists of two atoms sulphur and one hydrogen. Obtained by pouring hydrosulphuret of potash by little and little into muriatic acid (Henry p. 435 where the properties of this compound are described.)

Sulphurets

Sulphur and a base

1. When dry without odor
2. Giving with heat sublimed sulphur and leaving the base behind
3. Of a liver colour if formed with caustic alkalis with carbonates – if with carbonates greenish.

Mr. Silliman treats of sulphuret of potash of soda of ammoniac of lime and of barytes.

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Hydro-sulphurets

These embrace compounds of sulphuretted hydrogen with salifiable bases as alkalis and oxides.

They are mostly soluble in water and have the odor of rotten eggs - are decomposed by fire - by long keeping or exposure to the air they pass to sulphite and ultimately to sulphate - they precipitate all metallic solutions and alumina and iron - generally crystallizable - absorb oxygen and used in endiometry.

Experiment 1. To form hydrosulphurets pass sulphuretted hydrogen gas through base (alkalis or oxides) dissolved or suspended in water as described in the first experiment under sulphuretted hydrogen.

Experiment 2. Precipitate metallic solutions by pouring a bisulphurette into them.

Experiment 3. Put an acid into the hydrosulphurettes and sulphuretted hydrogen will be evolved and the base combined with the acid.

See Ure's Dictionary on this subject .

Hydrogenized – Hydroguretted – Hydrogenated – or sulphuretted – hydro-sulphuretted

These are compounds of bi- sulphuretted hydrogen gas and a base: hence they contain twice as much sulphur as the hydrosulphurettes.

They are greenish or brownish – have an acid very bitter taste and excessively offensive smell – deposit sulphuric when kept in close vessels - become more transparent and brightly colored. Absorb oxygen from the atmosphere and are decomposed by dilute sulphuric or muriatic acid (See Henry p. 437, Ure Article sulphur).

Experiment 1. To form these substances - Into a solution of pure potash (pearl ash will answer Silliman) pure soda or of barytes or strontian put some pieces of flour or sulphur and boil them over a gentle heat in a matrass. Lime may be powdered with sulphur and boiled in the same manner with water and hydrosulphurets will be formed.

Experiment 2. Decompose these compounds thus formed by adding dilute sulphuric or muriatic acid.

Hydrogenized sulphurets useful to detect lead in cider and wine.

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Carbon *[compare to Silliman V. 1 p 355]*

1. Diamond
2. Plumbago
3. Anthracite
4. Charcoal

Experiment 1. To purify charcoal for clarifying liquors put it pulverized into a crucible and subject to strong heat - then bottle it tight.

Experiment 2. See exercise three under carbonic acid.

Experiment 3. Mix alkanet and water with purified charcoal in a teacup and let the whole simmer at the fire for 15 minutes - throw it on a filter and the colour will be found discharged.

Experiment 4. Take a large coal on fire and put it on mercury and place over it a tall jar and the charcoal will absorb so much of the air that in the short time the jar will be a third filled with mercury.

Experiment 5. Take the coal thus filled with air and plunge it in hot water and the air will be driven out.

Experiment 6. Show how lampblack is collected from a candle or lamp.

Stakes driven into the Thames (Eng.) in the time of the invasion of Julius Caesar were pulled up 50 years since in a state of of preservation. (Notes to Blackes Lectures Vol. 2 p. 285.) The fact related by Tacitus - knife handles made of them and sold as antiques. The piles on which the Temple of Diana at Ephesus was built were charred and lately when taken up 2000 years after they had put them.

Fusibility of carbon. First attained by Professor Silliman with Hare's Deflagrator – Note the controversy on the subject. Also specimens from the vessels of the gaslights in England.

Explain how charcoal is prepared in the usual way in cold pits. It is also prepared for making gunpowder in large iron cylinders open only at one end. (Parkes Essays vol. 1 p. 396).

In the process pyroligneous acid is distilled over - every kind of wood will produce it even peat.

The tar from pyroligneous acid good for coating over timber exposed to air – (Parke's Essays vol. 1 p. 399.)

Charcoal absorbs all the gases and some liquids *[compare to Silliman V. 1 pp. 356-7]*
Powerful antiseptic
Unalterable and indestructible by age
Bad conductor of heat
Nonconductor of electricity
Fusible by galvanic deflagrator
The powder very hard and sharp nearing end of file.

1 gallon wood tar and half pint rectified spirits intimately mixed jet generate heat furnishes a beautiful varnish for rolled or cast iron to be laid on hot. (Parke's Essays vol. 1 p. 401.)

Boletus Ignarius boiled in an alkaline lye - dried and boiled again in solution of saltpeter makes excellent tinder (Parkes p. 405)

Wheat charred in in Herculaneum A.D. 79 could be distinguished from rye - an arrow has been charred without cutting even the form of the feather. (Parkes p. 407)

Charcoal used to prep molasses spirits honey (Parkes p. 419)

Water in ships purified by charcoal.

Trees sometimes preserved from final decay by charring the decaying part (Parkes p. 427).

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<u>Carbonic acid</u>

Experiment 1. Put lime water in a bottle or jar joined by a stopper at top. Shake it and no effect will be produced but put into the bottle a stick on fire then close it and shake it the lime will be precipitated.

Experiment 2. Take another jar prepared in the same manner and blow into it and agitate and precipitation will ensue.

Experiment 3. Heat lead in a ladle very hot and press into it a small stick which will soon be carbonize showing how charcoal is prepared.

Experiment 4. Take a small piece of bark charcoal well burnt and fasten it to wires and let it into oxygen gas and set it on fire. Carbonic acid will be produced as may be shown by pouring in lime water and agitating it.

If the oxygen contained carbonic acid as may be learned by agitating it with lime water pour into the jar some caustic alkali agitate and pour it out then try the lime water again it is necessary to repeat the process. The Vermont magazine produces oxygen that needs not purifying.

Glass vessels coloured with a deposition of iron may be cleaned by muriatic acid.

Experiment 5. Burn a candle in a jar of common air and show that carbonic acid is produced.

Experiment 6. Put marble powder (or chalk) into a retort and add diluted sulphuric acid and carbonic acid will be evolved.

Experiment 7. Put marble powder (or chalk) into a into a gun barrel and apply a strong heat and carbonic acid may be collected.

Experiment 8. Fill a large globular tribulated receiver with carbonic acid gas and let down into it some gunpowder and let an assistant touch it with a red-hot iron. It will explode and fill the receiver with a smoke rendering the carbonic acid visible which may then be poured out upon flame.

Experiment 9. To saturate water with carbonic acid gas. Employ Nooth's apparatus in the manner described in the books - taking care that there be no stoppage in the passages and the stopper and top is not fixed tightly as an explosion is to be feared. Put marble powder in the lower part and how it is diluted sulphuric acid still not very particular in regard to proportion.

Experiment 10. Show by an inverted jar containing carbonic acid and a pendant candle the phenomenon of choked damp in wells.

Experiment 11. Hold the hand and arm for sometime in a large receiver then remove the air it contains to another receiver that has a narrow opening and pour in limewater and agitate it and the lime will be precipitated showing the boric acid is evolved by respiration.

Experiment 12. Heat subcarbonate of soda in strong solution with phosphorus and this will seize upon the oxygen and carbon will be precipitated.

Experiment 13. Collect a jar of air in the upper part of the lecture room after lecture and agitate in it lime water and precipitation will take place – showing…

Experiment 14. Take the water saturated by Nooth's apparatus and put it under the receiver of an air pump and by exhaustion the gas will be involved in abundance.

Experiment 15. Try the same water upon a delicate test for acids and some effect will be produced viz. it will be reddened.

Experiment 16. Take the liquor thus reddened and put it upon the fire and the original colour will be restored by the evolution of the gas. No other acid can be expelled in a similar manner.

Experiment 17. Take a small matrass and fill it with carbonic acid over mercury. Take platina foil making a small…

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…tray of it and put into it a bit of potassium which slip into the matrass. Put a cork into the matrass through which passes a small vent to the other end dipping into mercury. Apply a mousetrap of coals to the matrass and the vapour will fill the matrass after which it will become clear and after a time the potassium will take fire in carbonic acid gas –and caustic potash and charcoal will remain upon the tray.

It is well to dilute sulphuric acid before the experiment upon carbonic acid and to make a trial of it before hand.

Charcoal cannot be burnt in a room unless a fireplace more than 20 to 30 minutes without imminent…

<u>Carbonic oxide</u>

A gaseous compound of one prime equivalent of carbon and one of oxygen.

Discovered by Priestley.

Smell offensive – fatal to animal life. Sir H. Davy once inspired it three times the effects were a partial loss of sensation giddiness sickness acute pain and extreme debility. Mr. Witter of Dublin was struck down in an apoplectic condition by breathing the gas – but was speedily restored by inhaling oxygen.

It is 13. 2 times heavier than hydrogen.

Chlorine mixed with this gas and exposed to the sunshine produces a curious gaseous compound called chlorocaloric or more properly chlorocarbonaceous acid. It is nearly four times heavier than atmospheric air and the heaviest of the gases.

Experiment 1. To prepare the gas mix carbonate of lime or barytes with about 1/5 of its weight of rounded charcoal both having been heated to expel impurities and put them into a gril[?] barrel in Black's furnace supplying a strong heat and carbonic oxide will be involved. (Cutbush vol. 2 p. 91) (Rationale)

Experiment 2. Or mix white oxide of zinc with 1/8 charcoal or iron filings with an equal weight of chalk previously heated moderately red - and put the mixture into Black’s furnace and apply strong heat and carbonic or carbonous oxide will come over. As there is some change danger of this process failing through a mixture of carboretted hydrogen it is well to have both preceding processes going on at once. It may be known when the gas is good by its burning with a dark blue flame languidly. Frequently used to be work with lime water.

Experiment 3. Set fire to the gas and it burns with a dark blue flame.

Experiment 4. Mix with common air and burn. Does not explode though it burns more rapidly.

Experiment 5. Two parts with one oxygen explodes by electricity. This mixture makes a whistling noise but hardly explodes.

Experiment 6. Fill the water jar with this gas and hence a jet by pressing it into the water.

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Carbonates

Experiment 1. To convert caustic alkali into a carbonate – Fill a long tube with carbonic acid and pour into it a caustic alkali (potash soda or ammonia) agitate it - the carbonic acid will be absorbed – and on pouring into it an acid effervescence will ensue - show first that this will not take place for the alkali alone.

Experiment 2. To form carbonate of ammonia. Fix two retorts in this matter into a a glass cylinder (not quite tight) Into one muriate of ammonia and quicklime for forming ammonia. Into the other marble powder and dilute sulphuric acid. No fire under the flask but aspirate lamp under the other. The ammonia and carbonic acid will meet in the cylinder and crystallize on its sides. One of Woulfe's bottles may be used when no cylinder is at hand and two tubes be made to pass into the same orifice or by laying it on the side of the retorts may enter by different orifices.

Experiment 3. To make smelling bottles. Take a matrass with a rather long neck. Introduce a quantity of carbonated ammonia (with which smelling bottles are filled and the only oderant salt known). Put in a cork in which is a small straight glass tube a foot long. On the top of this invert a phial and put a fire under the matrass or flask turning the phial a little aside from the direct course of the heat and carbonate of ammonia will be volatilized and condensed again in the phial.

Experiment 4. Form soap by mingling oil and caustic alkali.

Carbonates

General properties

1. All the strong acids cause them to give out carbonic acid with effervescence.
2. Decompose more or less perfectly by heat - carbonic acid being expelled - decomposition complete if charcoal be mixed - base left behind.
3. Alkaline carbonate still turns vegetable blue to green, browns yellow etc.
4. Alkaline carbonate soluble in water
5. Earthy carbonates washable except there be in excess of carbonic acid
6. Most of the carbonate found in nature and all may be found by passing the carbonic acid through the base suspended or dissolved in water.

Mr. Silliman treats subcarbonate as potash or pearl ash. Carbonate potash. Subcarbonate soda - carbonate soda – subcarb. ammonia - carbonated of soda carb. barytes - of strontites - of lime – of magnesia - carbonates of magnesia - of alumina - of yttrium and zircon.

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[This is a continuation from the bottom of the following page numbered 85]
The heads of the barrel will be <u>hollowed</u> inwards. Open now the passage from the gasometer and the gas rush in for a time and then it ceases less be forced in by working the piston. Turn over the barrel again and let more water run out - so that the whole 6 or 8 gallons have going out. Right again the barrel and let in the gases as before. Now is the time for putting in the soda as before - let this dissolve a force in a quantity of gas – agitate until it is obsorbed by the water – pour in again and agitate. So on until the water is supersaturated. This aeration requires several days for its completion and in this way real good soda water is produced. Method communicated by Prof. Silliman.

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<u>Carbonates</u>

Solutions better kept in globular vessels than others because less liable to break by frost. A sudden cold turn in December at New Haven made great havoc with the glasses and experiments at Yale.

Experiment 5. Pour boiling water in carbonate of ammonia and a violent effervescence will ensue resulting from the volatilization of the salt.

<u>To form a soda water</u>. This is water in which carbonated soda is dissolved which is also charged with carbonic acid gas. Most soda fountains contain nothing but the latter. 2 1/2 ounces of carbonate of soda or 2 1/2 pounds to a barrel are first put into water and dissolved. Then carbonic acid is prepared and put into a barrel. Next a condenser of this form *[Illustration]* is attached by the side pieces and the barrel of carbonic acid and this is forced into the water - or rather the whole process may be thus described.

[Illustration]   [See Silliman V 1 p. 370)

A is a band in a molasses hogshead B partly filled with water A series as a gasometer and is to be filled with carbonic acid by mixing.

C is a very strong barrel full of water. D is a piston screwed into the barrel and E a lead tube proceeding from the gasometer to the piston. Work this piston and force in the quantity of gas into the water in C. Take it out and turn the barrel half round by means of the crank F and a small quantity of water will be forced out by the pressure of the gas. Right the barrel again stop it and agitate the water by means of dashers placed within it and the gas will be absorbed. (see previous page)

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Respiration

1. Take a bent tube and put one end of it in a bell glass and breathe through it inhaling the air in the glass not more than three times. Take the air thus breathed and put into it a candle which will speedily be extinguished. Put into it limewater and agitate in a deposition will result.

This shows that air in breeding requires carbonic acid. It loses none of its oxygen in any other way.

Explain how the air has access to the blood in the lungs.

The venous blood is charged with carbon and hence has a dark purple colour and every expiration of air sends out from 4 to 8%.

The arteries carry the blood from the heart to the extremities for the nutrition of the body. The veins bring it back to the heart. Arterial blood is of a florid red colour. Venous blood darker because charged with carbon. The grand object of breathing appears to be to discharge this carbon by the formation of carbonic acid.

Carbonetted Hydrogen or Olefiant Gas

Experiment 1. To prepare this gas: Take fat pine knots or the meats of walnuts or maple wood or charcoal or buckskin - or pit coal - and put them into an iron tube which place in the furnace (Black's) cooks them and connect with the pneumatic cistern by a leaden tube. Heat the iron tubes and the gas will come over and may be collected over water and the different jars should be labeled. Or attach a retort containing ether to one end of the tube that passes through Black's furnace connecting the other end with the cistern.

Experiment 2. To prepare all olefiant gas. Take two parts by measure of sulphuric acid (undiluted) and one of alcohol – pour the latter first into a large retort and having carefully shaken the materials together place the retort over a mousetrap of coals leaving the mouth open until the gas begins to come over in a pure state put in a cork which is attached to a lead tube to carry it to the gasometer. You may know when the gas is good by the liquor becoming extremely black and swelling in large bubbles. Great care should be taken in conducting this experiment as the retorts are liable to break in that case a violent burst of flame would ensue and the hot air be settled around. No explosion would occur unless the retort should break when it is partly full of atmospheric air. It is well to have a metallic plate at hand to put between the fire and the retort when the action becomes too violent. The gasometer need not be more than half filled with olefiant gas and the other half may be supplied with hydrogen and still the flame will be good. Let the hydrogen be put in last. Let it make the retort in collecting with gas point upwards.

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Experiment 3. Mix three parts of oxygen with one of olefiant gas and put the mixture in the tin air pistol and apply a candle and a tremendous explosion will take place.

Experiment 4. Exhibit and explain the safety lamp.

Experiment 5. Fix a tube 14 inches long into the top of the water jar - then put over a wide mouth bell glass under which also put the safety lamp on fire - then let out the olefiant gas from the water jar and it will pour around the lamp causing it to burn feebly - the by base glass being a little raised it burns again better. If the mixture of atmospheric air and olefiant gas in the tall glass is touched by fire it would explode tremendously. But the larger lamp secures the whole from danger or rather the risk of the lamp.

Experiment 6. Blows soup bubbles in the explosive mixture above-mentioned and set fire to them.

Experiment 7. Put the tube designed to exhibit jets of fire upon the gasometer darken the room and set the gas on fire. Various tubes for exhibiting the gas lights may be provided as fancy dictates.

Experiment 8. To detonate gases by electricity take the detonating tube and fill it with the explosive mixture either of hydrogen and oxygen or hydrogen and common air or of olefiant gas and common air or the same of oxygen and introduce into the tube fastening into to the side of the pneumatic system which embraces the tube around the middle. Introduced the coil wire beneath fastening to its bottom a chain fill the electrical receiver take it into the hand with the chain pressing the chain against the lower part of the receiver and touch the knob to that of the tri-tube and explosion will take place. There is danger of explosion if the tube be held in the hand. Carbureted hydrogen and atmospheric air are at their maximum of explosive power when 1/6 th of the former is mixed with 5/6 ths of the latter. They are explosive even when only $1/12^{th}$ carbureted hydrogen be present.

If the retort becomes soiled in preparing olefiant gas pour in a little nitric acid and warm it and it will clean off the impurities.

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<u>Combustion</u>

In general this consists of the union of some substances with oxygen.

Exceptions - chlorine and fluorine.

No that was chlorine and iodine

Gaseous product of a common fire are - vapour of water - carbonic oxide - carbonic acid - nitrogen - hydrogen – carbureted hydrogen - and when coal is burned sulphurous acid. Carbon is also carried up chimney in finely divided state in the carbonate and sometimes a sulphate of ammonia is formed and is found chiefly in the soot which consists chiefly of carbon. It contains also as does smoke - pyroligneous acid which is nothing more than acetic acid mixed with gaseous products of the fire. Not only hams and other fresh meat may be preserved with the acid but it may also be rubbed over the bodies of the dead when it is necessary to preserve them unburned for some time and if this be done seasonably it is a powerful antiseptic.

The fixed products of common combustion can be sometimes soda, silex, alumina, manganese, fixed oils, the latter of which constitute the paste of soot.

The effect of smoke on the eyes is imputable to the mechanical and chemical effect of the fixed alkali that is volatilized and the action of the pyroligneous acid.

The colour of smoke proceeds partly from the fixed oils that are caught up with the carbon.

The light and heat from gunpowder and other explosive mixtures cannot be accounted for on the common preambles of combustion. Difficult to be explained as we should expect the contrary result.

<u>Phosphorus</u>

Experiment 1. Burn a piece of phosphorus by touching it with a coal of fire .

Experiment 2. Set a piece on fire by friction rubbing it with a piece of leather.

Experiment 3. To make phosphorized ether - Put a stick of phosphorus into a phial of ether and let it stand and the ether will dissolve it and become phosphorized.

Experiment 4. To make phosphorized oil - Take olive oil and perform the same process with the ether.

Experiment 5. To make phosphorous acid - Take a tall open mouthed glass vessel - put into the bottom a little water into the top place a glass funnel and put into it a piece of phosphorus 3 or 4 inches long. In a few minutes the acid descend in the form of a dense smoke to saturate the water.

Experiment 6. To make phosphoric acid - Take an open porcelain dish and put into it a piece of phosphorus placing it on mercury and setting it on fire with a hot iron. Put over it a tall receiver and the acid will be seen to condense on the glass like snow and the mercury will rise.

Experiment 7. Take a glass globe open at the two axes (the larger the better). Let the lower end be stopped by a metallic plate and let a small piece of copper plate be raised an inch or two from the bottom to receive the phosphorus. Hold the globe to the tube of the compound blow pipe and let the tube go down to the bottom. Then let in the oxygen and it will expel the common air – it may be known when the vessel is full by holding a candle to the mouth. Put the globe on the table and put into it one or two pieces of phosphorus an inch long and set them on fire. Darken the room and the illumination will be most brilliant and phosphoric acid will be condensed in the flakes on the inside (The globe used…

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…at Yale 1825 broke in the midst of the experiment) No danger in these cases from explosion.

Experiment 8. Put boiling water into a large matrass 4 or 5 inches diameter and throw in a piece of phosphorus. It will melt and remain at the bottom. Hold the matrass to the compound blow pipe letting the end of the pipe reach the bottom. Then let out the oxygen and phosphorus will take fire and burn under water and water will become saturated with phosphoric acid. There is danger of the glass breaking.

Experiment 9. Take a small flask and pour into it some water - lay a piece of phosphorus on the outside then pour into the water some sulphuric acid - agitate the mixture and the phosphorus will take fire.

Experiment 10. Put a small piece of phosphorus into cotton wool well filled with pounded rosin - put into a small dish and place it under the receiver or an air pump. After partial exhaustion after partial exhaustion the phosphorus will take fire and burn slowly and a beautiful cone of smoke (phosphorous acid) will rise over the dish occasionally sending up a small train of smoke towards the top and sometimes the smoke will make several convolutions.

<u>Phosphates</u>

<u>General character</u>

1. Exhale an odor of phosphorus
2. Give a phosphorescent flame by heat and before the blow pipe even without a combustible support
3. In close vessels by distillation without addition give a little phosphorus and become phosphates - and this last in the open air?
4. Detonate by heat with oxymuriate (chlorate of potash)
5. Converted into phosphoric by nitric and oxymuriatic acids.
6. Precipitates gold from its solutions - taste pungent and allicaceous.
7. Alkaline phosphate prepared only by direct combination with the acid (Silliman notes)
8. Alkaline phosphate is very soluble and crystallizable.
9. Earthy ones very insoluble but become soluble by excess of acid.
10. Phosphates do not pass to phosphates in the [????] and in oxygen gas except very slowly and after a long time.
11. In this respect differ from sulphites and also they are not formed by heating the phosphates with charcoal (Silliman's notes)

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Phosphates

Experiment. To form phosphate of lime. Put an open vessel containing lime water under a large bell glass in which put a bit of phosphorus (so as to float in a dish on the lime water) and set the phosphorous on fire. Phosphate of lime will be precipitated at the bottom of the water.

Phosphate treated of by Professor Silliman are phosphate potash - of soda - of ammonia - of soda and ammonia - of barytes – strontites - of lime – of magnesia - of ammonia and magnesia - of argil - of glucine – of zirconia - of yttria.

General character.

1. Not decomposed by igniting them with charcoal except phosphate of ammonia and of lead and zinc.
2. By ignition converted into glasses and excellent fluxes
3. Decomposed at least in part by sulphides and other strong acids which liberate from them a liquor which affords phosphorus by ignition with charcoal powder.
4. In the dry way the phosphates the sulphates etc.
5. Soluble in nitric and muriatic acid without effervescence and precipitated by lime water and pure ammonia.
6. Alkaline phosphate soluble and crystallizable - that of potash is scarcely crystallizable.

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Phosphorets - Phosphoret of Sulphur.

Experiment 1. To prepare it. This is so dangerous as to render it inexpedient to attempt for a class except to put into a small common crucible several layers of phosphorus and sulphur and put a coal into it and it will burn with a brilliant flame but without explosion.

Experiment 2. Or first melt the sulphur and then pour in a bit of phosphorus. A bright flame will result. Be on your guard in all experiments of this kind as you do not know where danger lies.

Phosphoret of lime

Experiment 1. To prepare it. Into the bottom of a glass or porcelain tube of this construction - or a mere tube will answer *[Illustration]* put bits of phosphorus and in the tube put caustic lime and apply heat first to the lime and afterwards to the phosphorus.

Experiment 2. Into a jelly glass of warm water drop some phosphoret of lime and phosphorescent hydrogen will be produced taking fire so it comes to the surface with a most offensive effusion [????]. Does not skunk emit phosphoreted hydrogen? From phosphoret of lime?

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Phosphoreted hydrogen

Experiment 1. To prepare it. Into a glass retort of a pint or quart put slaked lime and bits of phosphorus enough to half fill it. Pour in a strong solution of caustic potash or a saturated solution of pearlash previously heated. Agitate the mixture and put under it a rat-trap of coals and erelong the gas will begin to come over taking fire as soon as it comes to the surface. A beautiful ring of smoke will soon ascend from the combustion. The gas may be collected over water but must be soon used. There is danger of explosion in preparing this gas.

Experiment 2. To mingle even small bubbles of this gas is dangerous. A violent explosion took place at Yale laboratory 1822 with this experiment which injured some of the spectators.

Nitric acid

Experiment 1. To prepare it. Take equal parts (e.g. 2 pounds each of clean nitrate of potash and sulphuric acid) and put them into a large glass retort. Put a sand bath into the Black's furnace - just putting into the bottom about an inch of sand and place retort taking care not to touch the sides and fill around the side with cold sand. Connect this retort by an adapter to a tribulate receiver placed in a vessel of water and surrounded with ice - locking carefully the joining with clay. Let the stopper of the receiver be put in loosely then apply heat gradually to the retort and after the furnace is well burning close all the openings in it so that the heat may not be very intense. The retort will soon be filled with reddish fumes and the acid will begin to distill over. Two pounds of each of the materials will produce about a pint. The material may be prepared and mixed in the retort put into the sand the day before to show the process to the class. There is great danger of breaking the retort in getting out this residue (bi-sulphate of potash). Pour cautiously into warmer tepid water and do not permit it to get cool as it will then be next to impossible to prevent its breaking. The residue is put first into a dish and suffer to evaporate will produce a beautiful example of efflorescent crystallization.

Experiment 2. Pour the acid thus produced upon powder and charcoal taken fresh from the fire and first into a crucible or (which is much more beautiful) into a glass vessel. The charcoal will immediately take fire and burn in a brilliant jet resembling a volcano - the glass always breaks but no danger attend it.

Experiment 3. Take oil of turpentine (same as spirit of turpentine) and put into a wine glass. Take nitric acid as above produced and put into another wineglass tied to the end…

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…of a ten foot pole (usually adding 1/6 or 1/8 of sulphuric acid from the mixture into the oil). A brilliant flame will ensure in the glass may be broken.

Experiment 4. Placing first a quantity of nitric acid as prepared above into a wine glass or jelly glass - put a bit of phosphorus into the glass at the end of the pole and pour it into the nitric acid. In short time a violent explosion ensues. This ought to be done out-of-doors after the lecture. 4 ounces of nitric acid and a large stick of phosphorus 4 inches long were used at Yale 1825. It melted in about one or two minutes a most tremendous explosion took place wounding several persons who stood within 20 feet. the neck of a retort was used. It is best not to employ more than 1/3 the above.

Experiment 5. To decompose nitric acid. Take a large iron tube and pass it through Black's furnace into which put a porcelain tube. To one end of this fit a small retort containing nitric acid of the shops by a lot of clay and sand (fine clay). To the other end affix a glass and bend at right angles so as to lead to a small pneumatic cistern. Put fire in a chafing dish under the retort after having raised the furnace to a red heat. It is necessary to keep the end of the tube out of water a little while to avoid agitation. The product collected in the receiver may be shown to be chiefly oxygen by relighting a candle in it.

Experiment 6. To purify the nitric acid obtained in Experiment 1. Put a small quantity into a wine glass and add three or four times the quantity of distilled water. Then pour in nitrate of lead or nitrate of barytes and if sulphur or muriatic acid be present a white precipitate will ensue: a more delicate test is nitrate of silver. If a precipitate be made of all the acids by the nitrate of silver it may be decanted or filtered or if redistilled with nitrate of potash sulphur (not the muriatic acid) will be separated.

Experiment 7. Pour nitric acid upon pyrophorus and it will inflame the substance.

<u>Nitrous acid</u>

Under matrass nitric oxide gas. On the next page may be seen several methods of forming this acid and the two things are to be connected that it is only necessary here to state the properties of the nitrous acid.

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<u>Nitric oxide gas</u>

Experiment 1. To prepare it. Into a retort put bits of copper plate cut into pieces half an inch square and pour upon them the nitric acid of the shops diluted with about an equal quantity of warm water. Apply gentle heat and the gas may be collected over water. The residue in the retort is nitrate of copper and

may be preserved.

Experiment 2. Into a long necked matrass put the same materials as above. Into its neck put a smaller tube bent twice at right angles the other end being introduced into a pile of pale nitric acid. Apply a spirit lamp to the matrass and the nitric oxide gas will pass over into nitric acid and change it first to a light and afterwards to a dark green – hence - does the nitric acid go into combination with the nitric acid forming an intermediate acid or is it a mere solution of the former and the latter.

Experiment 3. Take a long glass tube fill it with cabbage liquor – invert it in water - pour up into it nitrous oxide a change ensues which shows is not an acid.

Experiment 4. Let into the tube some common air and as soon as it comes in contact with the nitrous oxide red fumes appear which is the nitrous acid - shake the tube and the cabbage liquor will become red.

Experiment 5. Take a long glass tube and half fill it with nitric oxide gas. Pour up a quantity of oxygen and immediately very dense red fumes will fill the glass. Agitate and they will disappear or be absorbed by the water and an excess of gas will remain – if of oxygen on pouring up more of nitric acid more fumes will appear - if the excess be nitric acid the same will happen on pouring up oxygen.

Experiment 6. To show how near life and death are around us. Take a full glass of nitric oxide gas and turn it into the atmosphere and dense red fumes of nitric acid will rise.

Experiment 8. Burn this gas in a small receiver.

Experiment 9. With a bent tube fill a receiver with this gas it will become nitrous oxide and may be kept several days.

<u>Nitric oxide and Nitrate of Potash</u>

Experiment 1. Fill a globular receiver with this gas and let into it a bit of phosphorus on fire and it will burn brilliantly and phosphoric acid will result.

Nitrate of Potash (see two leaves forward)

Experiment 2. One part powdered charcoal and two or three nitric ignited or thrown into a red hot crucible burn powerfully.

Experiment 3. Sulphur 1 and nitre 3 pulverized and ignited produce a brilliant combustion.

Experiment 4. The same only sulphur 6 or 8 and nitre 1 burnt repeatedly over water in a bell glass produce sulphuric acid - this is the method and the arts.

Experiment 5. Five powdered nitre one sulphur and one charcoal treated in a mortar forms gunpowder.

Experiment 6. Moisten gunpowder and mash it with a spoon on a plate until it burns only moderately upon the application of fire. Put it into an iron tube and set it on fire and put the open end into the cistern so as to collect the gaseous products.

Experiment 7. To decompose nitrate of potash – put the salt into an iron tube filling it only about the length of the finger and put it into Black's furnace taking care to elevate it 45° for it is liable to drive out the cork and explode as loud as a common gun. Connect with a lead tube to the cistern and the product of decomposition will be found to be chiefly oxygen as may be shown by putting a candle to it. This is the best way to prepare oxygen for cases of sickness.

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<u>Nitrate of potash</u>

Experiment 8. Three nitre 2 pearl ash 1 sulphur is the putins fulminous - the heat must be slowly applied to the powder laid on a shovel or an iron spoon. It must be made in mortar with the ingredients dry. Employed by the New York sportsman for firing to ensure the discharge. For this purpose it is slowly melted over the fire and stirred frequently. When the fusion is complete and it is taken off and stored cool it is then the fine powder must be kept in closed vessels.

Experiment 9. Composition for firing artillery 60 niter 40 sulphur 20 gunpowder.

Experiment 10. Chinese blue lights. 28 nitre 7 sulphur 2 argeric one half part rice - flour and water enough to form a stiff paste and turn into earthen pots and covered with canvas.

Experiment 11. Fireballs to be thrown into an enemy's camp 40 nitre 15 charcoal 3 pitch and sulphur.

Experiment 12. Powder of fusion – 3 nitre sulphur or fine sawdust mix.

Experiment 13. <u>Black's</u> <u>flux</u> - one nitre two tartar deflagrate in a red-hot crucible and pulverize.

Experiment 14. White flux of nitre and tartar deflagrate - powder for packets – (See Rees Cyclopedia Pyrotechny.)

<u>Nitrites</u>

Nitrite of potash. To prepare it. Into a common crucible put nitrate of potash and let it melt and put into it occasionally bits of burning charcoal so as to provide a partial decomposition by the formation of carbonic acid. To prove that it is now converted to nitrate pour upon a portion of the mass sulphuric acid and red fumes - or nitrous acid gas - will be emitted. If sulphuric acid be poured upon the nitrate of potash before heating white fumes or nitric acid will be involved.

This is the only nitrite of consequence.

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Nitrates

Experiment 1. To prepare nitrate of ammonia. Take a quantity as much as convenient - of nitric acid of the shops - put it into a broad Wedgewood dish – add to it carbonate of ammonia till the effervescence ceases - skim off any frothy impurities - filter if it if necessary and set it in a warm place and erelong it will be crystallized.

General characters.

1. Soluble and crystallizable by the cooling of the water.
2. By ignition detonate with combustible bodies
3. Sulphuric acid liberates from them the nitric
4. With muriatic acid produce oxygen or nitromuriatic acid
5. Totally decompose by heat and give oxygen commonly mixed with nitrogen
6. Twelve in number viz. 1. nitrate to potash 2. soda 3. Of ammonia 4. Of barytes 5. Of Stronites 6. Of lime 7. Of magnesia 8. Of magnesia and ammonia 9. of ammonia 10. Of glucine 11. Of zircon and 12. Of yttria

The nitrate mixture in the Scriptures is a carbonate of soda mentioned as a detergent and as effervescing with acids.

Nitrate of potash

Experiment 1. To prepare it mingle nitric or nitrous acid with potash or its carbonate - easily obtained from the shops (See two leaves back by mistake)

[Experiments 2-14 appear on pages 52, 53]

Experiment 15. Put a quantity of the salt into a common tea dish and pour on it strong sulphuric acid. The white fumes that rise afford an excellent destroyer of contagious expulsion in the rooms of the sick. It is not injurious to the sick.

Experiment 16. Lay a train of gun powder upon board 8 or 10 feet long – cover up with another board putting upon this last several weights. Lay a train also on the upper board connect the two trains at one end - touch the upper end of the other end and it will inflame rather slowly up on the upper board but very rapidly on the lower one showing the gunpowder enflames much more rapidly under pressure.

Experiment 17. Put the salt upon the red hot shovel or ladle and it will deflagrate with flame. Nitrates are the only instance among the salts of burning (Reference?)

Experiment 18. Put the various mixtures described above into small cuvettes and touch them off.

Experiment 19. Try the gaseous products of Experiment 6. Put in lime for carbonic acid - turn up oxygen for nitrous oxide and it if it be present the red fumes of nitrous acid will appear. Carburetted hydrogen is usually present - what remains in a gun barrel after firing several times is sulphur and nitrate of potash chiefly.

Remark on the uses of nitrate of potash and the records of its manufacture. It generally exists native as a nitrate of lime.

Immense quantities in our western caves. Whence came it?

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<u>Nitrous oxide gas</u>

Experiment 1. To prepare. Put nitrate of ammonia into a retort and place it on the retort stand by the neck of the cistern. Apply a rat trap of fire. It may be known when gas is good by white fumes like snow that fills the jar.

Experiment 2. Mix this gas with common air or oxygen to show that it will not form nitrous acid as well as the nitric oxide.

In preparing this gas it is better to have the nitrate of ammonia in crystals. The gas may be known to be good when a white fume fills the retort and white bubbles break in the retort instead of red ones. It ought not to be breathed until it has stood over water an hour to absorb the nitrous acid. It should not stand a great while however. By pouring it back I found three or four times it may be breathed immediately. From four to eight quarts is a dose and it can be breathed out of a silk bag or a bleached prepared with a stopcock 3 inch diameter or by a tube of the same dimension so as to pass under a gasometer or an air jar letting the person hold the jar and suffer it to rise and fall. Watch the person breathing in if he appears much affected do not let him proceed but twitch it away. If there appear much determination of blood towards the head and the countenances are livid and pale it shows a person to be powerfully affected. A single inspiration sometimes produces powerful excitement. If the gas be good it has a distinctly sweetish taste without acrimony. If nitrous acid be present (the only dangerous impurity apt to exist) it has a suffocating effect. It should remain colorless when mingled with oxygen.

Experiment 3. Mix 40 by volume with 50 hydrogen (or carbureted hydrogen) in a glass jar or tin pistol explodes (not violently.)

In all cases where a fluid and a powder are to be mixed next in a retort or alembic let the fluid be put in first otherwise it is difficult to mix them.

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<u>Muriatic acid</u>

Experiment 1. Into a large glass matrass (the hydrogen pot will not answer) put 3 pounds of muriatic of soda (common salt - use rock salt the best crystals that can be obtained) and two pounds of strong sulphuric acid. Take a large tin milk pail and put common water into it and place it over the over the plunger - when the water may be made to boil. If this heat be not sufficient make a brine of the water in the pan. Connect the matrass with the mercurial cistern and collect gas. It is easy to see when the gas is coming over pure by the furnace.

To make liquid muriatic acid connect the matrass above-named with a bottle of Woulfe's apparatus containing water using about three bottles and into the middle put distilled water. There is great danger of regurgitation at the beginning of the process which may be prevented by drawing out of the cork next to the lead pot. Put ice and water around the second bottle. Dip a feather in a solution of ammonia and apply it to the joinings and if any leakage a white [????] will appear. Have another lead part prepared for operation when the first becomes exhausted. There is much risk of breaking the materials in getting out the *caput mortuum [dead remains]*. Warm water must be poured in before it has time to cool.

Experiment 2. Into a long glass tube poor a small quantity of muriatic acid and add a quantity of sulphuric acid. A violent effervescence will ensue and muriatic acid gas will be liberated the sulphuric acid seizing upon the water holding the muriatic in solution. After the fumes have expelled all the common air slip a ground glass over the open end an invert it suddenly in water or cabbage liquor and the liquor will reabsorb the gas and the water by agitating the tube will rise to the very top of the tube even if 4 feet long. The experiment requires a good deal of dexterity to perform it well.

Experiment 3. Into a small glass retort put the same ingredients as an Experiment 1 and apply a rat trap of coals. Gas will come over and may be collected over mercury.

Experiment 4. To collect muriatic acid without mercury. Connect two long necked matrasses by a glass tube in the manner shown *[Illustration].* Into one put two muriate drops and one sulphuric acid and apply heat. Muriatic acid will pass over into the other vessel. This may be shown by detaching and letting up a small quantity of cabbage liquor which being agitated will absorb the gas and on removing the finger under the vessel of cabbage liquor it will fill the matrass nearly and be reddened.

Experiment 5. into a jar over the mercury containing the muriatic acid gas put a piece of ice. It will melt as rapidly as in the fire on account of the attraction of the gas for water.

Experiment 6. Put cabbage liquor into another jar. The gas will redden and then absorb the gas.

Experiment 7. Put a pendant candle into another jar and it will be extinguished.

Experiment 8. Into a tea saucer put some muriate of soda and pour on it muriatic acid and the fume that rises is good for fumigating sick rooms - more caution to be used however lest it incommode the sick.

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<u>Muriates</u>

<u>General character</u>

1. Taste in eminently saline
2. Soluble and crystallizable.
3. Not decomposed by heat especially not the alkaline ones - some of the earthy ones are.
4. Partially decomposed by sulphuric acid and wholly if the operation be aided by heat giving more than muriatic acid gas.

<u>Muriate of ammonia</u>

Experiment 1. To prepare it - Arrange an apparatus as in the preparation carbonate of ammonia (see carbonates) Into one retort put pound of soda – pound of muriate of soda and sulphuric acid. Into the other slaked lime and muriate of ammonia. Put heat under both retorts in a mousetrap - put the retort up first that contained lime in the morning and make a groove in the cork of the other retort lest it be broken. As soon as the gaseous products meet in the middle a dense white form will appear and condense forming muriate of ammonia.

Experiment 2. Into a hot iron dish put large crystals of muriate of soda and a powerful deflagration will consume almost equal to a succession of reports from pistols.

Give some account of muriate of soda - the manner of obtaining it by evaporation and the salt mines. Notice the <u>Sunday salt</u> of Scotland.

Experiment 3. Wet a sponge with alcohol and sprinkle it over with common salt and set it on fire and it will burn with a peculiar yellow flame which colour is imparted to the salt.

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Muriate of barytes an excellent test for sulphuric acid.

…added to a large quantity of muriatic acid will impart bleaching properties.

[skip to following page]

<u>Chlorine</u>

Experiment 17. Fill an open jar with chlorine and introduce a candle which will continue to burn with a red flame and much smoke.

Experiment 18. Put a fresh vegetable into liquid chlorine and in a few hours the colour will be discharged and eventually will become white.

Use of chlorine in disinfecting sick rooms. The French physicians carry a small phial of liquid chlorine or materials for making it in their pockets and let a little out in sick rooms.

Experiment 19. Into liquid chlorine put calico of various colors and after a few minutes take it out and put it into caustic alkali then into water then again into chlorine and after little time the cloth will be bleached.

<u>Protoxide of chlorine</u> (Euchlonne)

Experiment 20. Put about a teaspoonful of chlorate of potash into a jelly glass or larger longer jar and pour on it muriatic acid dipped with about as much water. The action will be until lead to be placed in a larger tumbler of hot water thus. *[Illustration]* Soon chlorine gas will be disengaged and gradually fill the tube. The same may be done with sulphuric acid which actually more powerfully and decapitates violently. Be on your guard in these cases against explosions. Have a wine glass tied to a hole for pouring in the acid.

Experiment 21. Wet a cloth with spirits of turpentine and shaking it so no drop shall fall from it let it down into the chlorine. It will take fire sometimes with considerable explosions, Ditto the same with alcohol and ether.

Experiment 22. When the jar is filled with euchlorine it may be mounted over water and it will be gradually absorbed and saturate the water which has powerful bleaching properties. Indeed a few grains of chlorate of potash (see page back) added to a larger quantity of muriatic acid will impart a bleaching property.

Experiment 23. Or water may be saturated with euchlorine by putting chlorate of potash and muriatic acid diluted into a flask that is thus arranged *[Illustration]* arranged connected with the water in a phial. Heat is to be applied as in experiment No. 22.

Experiment 24. To form the subchloride of lime for bleach and put a quantity of slaked lime and water into the second bottle of Woulfe’s apparatus and let the chlorine pass over exactly as in saturating water with it. If this liquor by keeping the loses its bleaching properties pour into it a small quantity of muriatic acid and they will be renewed.

The facts concerning the muriate of soda are greatest objection against the simple nature of chlorine.

The formation of muriatic acid by the mixture of chlorine and hydrogen is the most conclusive evidence of its simple nature.

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<u>Chlorine</u>

Experiment 1. To prepare liquid chlorine - Muriatic acid 8 or 4 of manganese. Or 8 oz. common salt (muriate soda). 3 manganese 4 sulphuric acid, previously diluted with four of water – the manganese finally pulverized. Put either of these ingredients into a lead pot (take care that this be entirely clean so that no hydrogen be produced otherwise a violent explosion may take place) or a large glass matrass and put the vessel containing the ingredients into the sand bath with a moderate heat; water bath is sufficient and connected with Woulfe's apparatus as in the experiment for liquid muriatic acid. If larger quantity of ingredients be put in so that they begin to choke the neck of the matrass pour out some of them into the fire. Apply ammonia to the corks to see if any leakage appears which may be known by the white fume as in muriatic acid. It is well to have at least two bottles of Woulfe's apparatus prepared besides the waste ones. It does not require a large quantity of the gas to saturate water. The water need not be distilled. Connect the last bottle of Woulfe's apparatus with chimney or the internal air (B. Silliman gave suggestion) It is best to mingle the acid and water the night before and let them cool. The vessel should not be more than one quarter of the materials and most of the gas that will come over without applying heat should be permitted to come.

Other proportions of the materials are 9 salt 2 manganese 4 acid and 4 water or 3 salt of manganese 2 acid and 2 water or 1 oxymuriatic acid with 3 or 4 drachnis oxymuriate of potash. When large bubbles begin to appear in the matrass stop the process.

Experiment 2. Into a retort put 6 ounces muriatic acid and four of manganese. Wait till the common air is expelled and carry it rapidly to the cistern putting a mousetrap of coal under it and chlorine may be collected.

Experiment 3. Do the same with the materials 8 common salt 3 manganese 4 sulphuric acid and 4 water.

Experiment 4. Into a large bell glass put about half full of olefiant gas. Turn up chlorine and chlorine ether will be produced.

In collecting chlorine the water of the cistern ought to be warmed lest it be absorbed by the water and the experiment must be performed shortly after the gases is collected.

Provide two or three large tumblers on other jars to collect the gas that first comes over to prevent its escape into the room as it may contain some chlorine. After filling the retort with materials put it under the flue chimney and let it stand till the gas comes over pure that is by removing it to the cistern.

Experiment 5. Introduce a piece of paper written on into the gas and the writing will be discharged. Do this in a small jar open at the top into which is poured liquid chlorine. Hold the jar in a chimney. Printer’s ink will not be so readily discharge.

Experiment 6. Into liquid chlorine pour ink - or into ink diluted from liquid chlorine and the colour will be discharged.

Experiment 7. Take a white bottle with ground stopper and fill it with ice and water or water made as cold as ice. Invert it where the chlorine from the retort may fill it and the chlorine will appear in a frozen or condensed form properly forming a hydrate of chlorine. Agitate the water after the bottle is one third or one half filled…

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…and liquid chlorine will be formed - though the water will not be saturated.

Experiment 8. Fill a globular tribulated receiver with the gas and opening it at the top let down a spoon containing phosphorus. It will take fire and burn though with less brilliancy than in common air. Do this near the flue of the chimney.

Experiment 9. Attach a rag wet with spirits of turpentine to a cork and filling a white bottle with the gas draw out the stopper and introduce the cork with the rag. Combustion will ensue and a dense smoke fill the bottle chiefly carbon.

Experiment 10. Partly fill a bell glass with chlorine and introduce into it a portion of nitric oxide gas. Red fumes of nitrous acid will appear which proceeds from the decomposition of water and the liberated oxygen uniting with the nitric oxide - the hydrogen goes to form muriatic acid with the chlorine.

Experiment 11. Fill a long glass tube with water, cork it, invert it in the cistern and fill it with chlorine. Cork it and remove near the fireplace. Open it and pour into it the antimony of the shops - or bismuth or any other metal and in most instances a combustion will result light and heat being emitted.

Experiment 12. Put olefiant (heavily carbonated hydrogen) into a bell glass and pour into it chlorine to fill the remainder (let the chlorine be put in first). A union will gradually be formed the water will rise in the glass and chlorine ether will be formed in the glass. In thus mingling these gases at Yale the whole olefiant being put in first combustion resulted and the jar was raised out of the water and the dense black substance scattered about. The chlorine being so much heavier than the olefiant gas prevented them mixing so soon as they ought and the action at the surface was so powerful as to set the whole on fire. It was tried after to put in the chlorine first and no such accident resulted.

Experiment 13. Fill an open jar with chlorine and introduce into it in the copper spoon a bit of potassium. After remaining in a few minutes it will take fire and burn with considerable brilliance.

Mr. Pelletier a French chemist lost his life by inhaling chlorine as did Mr. Roe of Ringsend near Dublin Ireland after a short illness.

Given an account of the process of Bleaching. (See Parke's Chemical Essays Vol. 2, also Rees Cyclopedia.)

Experiment 14. Mix equal parts of chlorine hydrogen in a glass bottle putting in the chlorine first and exposing the bottle to the direct rays of the sun and it will explode with a tremendous detonation. Store the vessel in a dark room and cover the bottle with towels to prevent the access of light.

Experiment 15. Mix small quantities of these same ingredients in a small proof glass and apply a candle and it will explode. Do the same with olefiant gas.

Experiment 16. Prepare a retort for making phosphoretted hydrogen and let its bubbles pass into a jar of chlorine. They will burn with a flash on coming to the surface.

Chlorine has a strong affinity for hydrogen. Does not this fact render it probable that hydrogen may be the active principle in contagion?

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Chlorate of Potash

Experiment 1. To prepare it. Arrange the lead pot and Woulfe's apparatus just as in experiment first for obtaining chlorine and conduct the process as in that experiment. Into the first bottle put water into the second a strong solution of caustic potash (pearl ash will answer) (pearl ash 16 water 2 lime). It requires a long time to saturate the solution - when it is done the solution assumes the green colour of chlorine. Being set by fire it will crystallize. Do not evaporate too much less the muriate of potash should crystallize. Evaporate not more than one half.

Experiment 2. Pour upon this salt in a jelly glass some sulphuric acid; the action is sometimes violent.

Experiment 3. Put some bits of phosphorus into a jelly glass and upon it a spoonful of chlorate of potash and fill the glass with water. Introduce nitric acid and a glass funnel and the phosphorus will take fire immediately under water throwing out the materials.

Experiment 3. Put a spoonful of chlorite of potash on a ladle off the water of crystallization then tribulate it in a mortar. Then take 2 g or pints of flowers of sulphur and one of salt and mix them together with the feather and end of a quill averting the head lest there should be an explosion. Put a small quantity either with or without a paper on an anvil and strike a smart blow upon it and a violent explosion will ensue.

Experiment 4. Saturate 5 grams salt and 2 ½ powdered charcoal – if flames - add a grain or two of sulphur unless it explodes.

Experiment 5. Put 1/2 g of the salt as above prepared into a mixture add as much phosphorus and strike them with the pistle holding the mortar so that the explosion will be from you and violent detonation will ensue. Put on spectacles and gloves.

Experiment 6. Two parts powdered sugar and some of salt – pour on it sulphuric acid and rapid combustion will result.

Experiment 7. Oxygen gas may be obtained from this salt exactly as in the decomposition of nitre in Black's furnace.

Experiment 8. Put the preparation No. 6 into a wine glass and pour in some sulphuric acid - it will inflame rapidly.

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<u>Chlorates general properties</u> *[almost verbatim from Silliman Vol. 2, p. 27]*

1. Afford very pure oxygen gas when exposed to a red heat
2. Detonate by percussion with inflammables
3. Cause them to burn when to the mixture of them and this salt (chloride of potash) nitric or sulphuric acid is added.
4. Decrepitate on trituration.
5. Taste cool and penetrating.
6. Soluble and crystallizable - generally soluble in alcohol
7. Rather heighten and then impair the brightness of vegetable colours

Subchloride of lime

See experiment No. 24 under Chlorine

Chlorate of ammonia

Exceeding difficult to form. Experiment. Half filled a long glass tube with liquid chlorine. Fill the upper part with a strong solution of ammonia invert the tube in water. A strong effervescence ensues and nitrogen fills the upper part of the tube. The chlorine seizes upon hydrogen liberates the nitrogen.

Nitro muriatic acid

Experiment. To form it. Put equal parts of strong nitric and muriatic acid into a flask and a union will take place which may be promoted by a moderate heat. If wished the flask may be connected with the cistern and the gas liberated collected which will be found to be a mixture of nitric oxide and chlorine.

This acid acts on gold platinum palladium etc.

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Iodine

Experiment 1. To obtain it in the form of a precipitate. Take the dulce (a species of *Ulva* of the shops) and burn it upon a piece of sheet iron - collect the ashes and put them into hot water and after boiling a while filter it and evaporate the solution. The salt will remain which is a hydriodate. Into a wine glass put a small quantity of this salt and having prepared a dilute solution of starch which must be previously cooled – pour some of it up on the salt. Then pour carefully in a quantity of the acid letting it run down the sides of the glass. Immediately a deep violet precipitate of iodine will appear. This admits of the addition of a large quantity of water and the colour will not be much impaired.

Experiment 2. Into a retort connected with a globular glass receiver put the salt obtained from [????] and pour on it sulphuric acid and put under a little heat and iodine will be liberated and will collect in flasks upon the sides of the receiver. Do not? put in the stopper of the receiver entirely tight.

Experiment 3. Into a jelly glass put a small bit of phosphorus and upon it a teaspoonful of iodine. The phosphorus will take fire and burn brilliantly.

Experiment 4. Put a small quantity of flowers of sulphur and iodine into a lime glass. Turn the glass up on one side and apply a gentle heat. The sulphur will inflame sulphuret and iodine or iodide of sulphur will remain.

Experiment 5. Take a small flask and put a piece of potassium into it covering it with iodine and in a short time combustion will take place and an iodide of potassium will be produced. The flask will probably be broken without danger.

Experiment 6. Into a long tube put a quantity of water and chop in a bit of phosphorus then put in iodine and soon a dense vapour will rise through the water which is hydriodic acid.

Experiment 7. into a diluted portion of nitrate of silver or nitrate of lead pour some of the hydroiodic acid and a most beautiful orange yellow precipitate will be thrown down.

Experiment 8. Into a large matrass put some iodide and hold it over a fire until the whole flask is heated and a most beautiful violet colour will fill the flask which after a time will condense and crystallize on the sides.

Experiment 9. Put a little iodine (if pounded better) into a wine glass and pour in a strong solution of ammonia and a fulminating compound will be formed. Let it dry out on a filter and it will explode violently. Do not more than one or two grains. It is better to put on several filters.

Experiment 10. Take a glass jar of this form *[Illustration]* with a ground stopper and press it down into a jar of mercury until it is nearly full - lay a bit of phosphorus and iodine in the neck upon the mercury and stop the neck and raise the jar gradually and hydriodic acid will be formed by the action of the phosphorus and iodine.

Experiment 11. Into of the phial put a little chlorate of potash and let down some iodine in a metallic spoon and as soon as they come in contact euchlorine will be disengaging and iodic acid will be formed.

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<u>Fluoric acid</u>

Experiment 1. Prepare it by distillation. Into a lead or silver alembic put 2 ounces of fluorspar and 4 ounces strong sulphuric acid. Attach the lead or silver receiver and apply heat directly in a mousetrap if the alembic be silver but with sand or water bath gift of lead and the fluoric acid will distill over slowly. Put the vessel where the fumes will pass off up the chimney and use tongs and gloves in moving the alembic for these fumes are dangerous if they come in contact with the skin and a quantity of the acid falling on the flesh might prove fatal. The *caput mortuum* (sulphate of lime) may be dissolved and the carbonate of potash by double affinity forms carbonate of lime and sulphate of potash.

Experiment 2. Cover a plate of common window glass with bees wax and write up on it whatever you wish and on it this acid (or hold it so that the fumes reach it) and the glass will be etched which may be shown by rubbing off the wax. Engraver’s [????] is better. The acid must be very much diluted so that it will not smoke and it may be put on with a feather.

Experiment 3. Darken the room and exhibit the phosphorescence of fluorspar. Cast iron plates should be used.

Experiment 4. Pour the strong acid on water - it will hiss.

Experiment 5. Pour it into a wine glass to see how it corrodes.

Experiment 6. Pour some into a wine glass and drop in a bit of potassium - it will burn brilliantly

Fluo liberated acid[?]

Experiment 7. To obtain it. Into a glass retort put pounded fluorspar and pounded glass and pour in strong sulphuric acid and apply heat. This gas may be collected over mercury. It is no means so dangerous as the strong fluoric.

Experiment 8. Give up some cabbage liquor into the jar containing this acid. It will become red and absorb the acid and silex will be precipitated. Not a bad way to obtain silex.

Experiment 9. Let the mouth of a retort prepared as Experiment 7 be put into a small flask of water and the gas will be absorbed and the silex deposited.

Fluo Boracic Acid

Experiment 10. Into a glass retort put boracic acid one part fluorspar two parts and sulphuric acid 12 parts apply heat. This gas may be collected over mercury. It attracts moisture providing a very dense fog as it comes in contact with the air.

Fluorine has never been proved to have existence.

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Iodine

Experiment 11. To 48 grains of iodine and one ounce of alcohol and an alcoholic tincture will be formed. A remedy for goiter and other glandular obstructions.

Experiment 12. Fill a long tube with water and put one drop of the above tincture into it. Then add a solution of starch and a beautiful blue colour will appear through the whole water.

Experiment 13. Put four iodine and one phosphorus into a small retort and moisten it from time to time and hide hydroiodic acid may be collected over mercury.

Experiment 14. Into a vessel containing dry chlorine introduce some iodine and chloridic acid will be produced.

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Boracic acid

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CHEMISTRY LECTURE NOTES

[Edward Hitchcock classroom lecture notes, "Introductory Lecture On Chemistry," 1826, EOH, Box 10, Folder 3.]

Introductory Lecture On Chemistry

Delivered in Amherst College

In

1826 (twice), 1827, 1828, 1829, ~~1830~~, 1831, 1832, 1833, 1834 (twice), 1835, 1836, 1837, 1838, 1839, 1840, 1841, 1842, 1843

Introductory on Chemistry

Gentlemen,

Since we are accountable beings there is great propriety before we engage in any new pursuit in pausing and enquiring whether its value and importance be such as to justify our efforts. In every circumstance and relation of life we are sacredly bound by that most comprehensive rule which revelation discloses and reason approves – "whether ye eat or drink or whatsoever ye do, do all to the glory of God." The question then that forces itself upon our attention this morning is, can we observe this rule in the study of Chemistry. To answer it aright we must enquire into the uses of this science: and to the examination of this point I shall confine myself in this introductory address.

See page 2d commencing – "I know indeed that we are but poorly etc."

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Gentlemen,

There is a peculiarity in the circumstances that have brought me into my present situation, which I shall suffer to give a direction to our reflections on this occasion.

God, in his righteous Providence, has seen fit to render me through bodily debility incapable of properly performing the duties, and sustaining the cares, of a profession that yields to none in importance and sacredness, and in which, therefore, I could have wished to spend the remnant of life. But though Providence may remove us to another sphere of action, no change of circumstances or relations, can release us from the observance of that most comprehensive rule revelation discloses - *whether ye eat or* *drink or whatsoever ye do, do all to the glory of God.* No one therefore, especially no one who has stood as an ambassador between God and man is at liberty when disabled for one situation to engage…

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…in any other pursuit, in which he cannot observe this rule. In entering upon the duties of this new station then, the first grand enquiry is, whether the subjects that appropriately belong to it, are of sufficient importance to receive that laborious and constant attention teaching of them demands. Or in other words, of what use are Chemistry and Natural History? This enquiry on the present occasion, will be limited to the first of the sciences, upon whose investigation we are now entering.

I know indeed that we are but poorly qualified to judge the value of a science until we have taken it step-by-step through its various relations - and upon such a degree of knowledge we have no right to presume in the beginning of a course of instruction. Some general utilities, however, may even under such circumstances be rendered intelligible, but less striking than particular instances. There is a difficulty too, in pointing out the insulated value of any single science, because much of its use may consist in its subservency to other sciences, more immediately beneficial. Hence it happens, that a part of the value which attaches to knowledge generally, is predicable of each particular science: since they form the links of a continuous chain, each one of which is essential to the beauty and strength of the whole.

And here I cannot but remark, in passing, that it is because men, whose faculties have never been sufficiently expanded, do not take this comprehensive view of the branches of knowledge - it is because they are ignorant of this *quodam commune vinculum* [common bond] of the sciences - this *quasi cognatione quadam inter se* [as a certain relationship] - as Cicero calls it - that they come to look upon particular branches of knowledge as useless speculation. Such minds (and the world is full of them) generally limit their views of utility by the bearing any particular object or pursuit has upon their property, their fame, or their animal gratifications and whatever does not directly advance one or all of these grand objects of pursuit, is regarded by the mass of mankind as useless labor. Hence it is, that men are so prone to enquire with a sort of sarcastic triumph into the utility of particular branches of science. And it is because those conversant with them cannot exhibit the connecting chain of knowledge to minds incapable of estimating merely intellectual utility, that particular branches cannot be rescued, in the opinion of such, from the imputation of uselessness and vain philosophy. From such contracted views as these we may, indeed, calculate that the young gentleman in a public seminary, like this, will be liberated. And yet, a remnant of such feelings, in disguise, often lingers a long time among persons of intelligence. A student before he enters college, has perhaps chosen this profession for life; and as the various branches of study are presented to his attention, he naturally enquires, what bearings they have upon his ultimate object: and asks of what use will this or that branch of study be to me in the profession I have chosen? And if he desires none, he is apt to resolve to pay no more attention to it, than it is necessary to avoid censure. In coming to such a conclusion the student forgets that the discipline of mind ??? [torn corner, missing text]

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…science he rejects might impose upon him, may be absolutely essential to his success in the profession he has chosen. He forgets too, that with all his efforts to enter that particular profession, many unforeseen vicissitudes may compel him, as they have thousands before him, to engage in a course of life very different. In adopting such a conclusion too, he prefers his own opinion of the utility of a science he has never studied, to the judgment of those who marked out his course of study, and who have reexamined all its relations and taken a comprehensive view of the whole. They are aware, that all the parts of a collegiate course do not have an immediate relation to each of the three learned professions: but they know that every professional man who will be respectable in any of these, ought to possess a general and accurate knowledge of the departments of science embraced in such a course. And they augur well about that young gentleman, in whom they perceive a noble enthusiasm urging on to the acquisition of knowledge, and who studies are regulated more by an eager curiosity and the ardent love of science, than by a calculation of utilities: while they fear greatly that he who aims at no higher acquisitions than just sufficient to obtain the baccalaureate diploma, and their professional license, will never have his name enrolled among the resolute few who give a character to the age in which they live and constitute the pioneers of human improvement.

In proposing an examination into the value of chemical science, I have not, therefore, referenced solely to the satisfaction of my own…

Skip to Page 6 for covering page

…There is another conclusion to which the student sometimes comes not less fatal to his progress than the one just mentioned. As he passes over the various branches of study he perceives that a perfect knowledge of the minutiae of every science is altogether beyond his reach and he knows that such an attainment is not expected. He therefore relaxes in his efforts and contents himself with loose and vague notions of the different branches of study in which he engages. I shall gain says he without any extraordinary efforts as much acquaintance with this or that branch as is expected as much as most of those who graduate acquire and this will be sufficient.

Now the difficulty in this case is that by such a sort of reasoning the student lowers exceedingly the standard of his attainments: and he shows that he does not pursue knowledge because he loves it. And whoever pursues learning with a low standard of attainment in view and feels that every effort is a task - a drudgery - will certainly make but a contemptible advancement. He may indeed acquire a general and vague notion of the sciences: knowledge and order to be greatly serviceable must as Shakespeare says not be merely seen: it must be tasted - it must be brought into the very soul and become a part of the man or it will soon be effaced. True it is not expected that anything short of a prodigy of genius can in a four years collegiate course acquire a complete acquaintance with the circle of science and literature. But a student can be accurate and thorough so far as he goes: if he cannot find time to investigate more than one in ten principles of a science it is far better for him to understand that tenth principle thoroughly though ignorant of the other nine than to take a loose and unimpressive view of the whole. In this way he will acquire the habit of patient investigation which will be of incalculable service to him in after life and he will also thus fix in his mind so long as he lives at least a portion of knowledge: whereas in the other mold all his ideas will be so vague and indefinite that he can never apply his knowledge to any useful purpose. But there is no need that we should cramp ourselves beforehand in the pursuit of knowledge by calculating to a hand's breadth the range of our enquiries and sit down contented because others have gone no farther. A better rule is one that has roused of late so mightily the energies of the religious world viz. expect great things - attempt great things. I would not encourage unhallowed ambition and emulation but I would have every man aim high and resolve to be thorough in order that he may be useful in the world.

In proposing an examination into the value of chemical science, I have not therefore referenced solely to the satisfaction of my own mind. For if this science be destitute of utility you ought certainly to bestow no attention upon it - but if it have an important bearing upon the interests of society upon the progress of human improvement and happiness and upon intellectual cultivation, it ought to have from you what a thorough knowledge of it demands, a close and persevering attention.

I proceed then, to exhibit evidence of the value of chemical Science,

1. From its nature
2. From its history

1. From its nature. If Natural Philosophy embrace, as its most comprehensive definition implies, all those sciences which take into consideration the properties and affections of matter, then it includes Chemistry. The two branches, however, are generally considered as distinct; although accurately to draw the line between them is no easy task. It is said, however, that the events that are referable to Natural Philosophy, or as it is now more appropriately denominated, Mechanical Philosophy, are always attended by sensible motion; while those of Chemistry frequently take place without such motion. From hence some have deduced a definition of Chemistry, as if it treated of *those events and changes in natural bodies which are not accompanied by sensible motions* (Thomson). But if this be not always true, as…

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Same as page 6 but with inserted page [Possibly a paragraph omitted?]

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…will be abundantly shown in the progress of this course, then this definition of D. Thomson is defective. Perhaps the best definition of the science is that of Dr. Henry, who calls it the "science the object of which is to discourse and explain the changes of composition that occur among the integrant and constituent parts of different bodies." It is not difficult in practice to determine concerning any particular event in nature, whether it belongs to the province of Natural Philosophy or Chemistry. But it is no easy matter to frame a single sentence that shall generalize such an immense mass of facts as belong to the latter science (Chemistry).

From this view of the nature of this science, it is obvious that it has a most comprehensive range, and embraces an almost endless variety of phenomena. Nor are the changes with which it is conversant like those of many sciences remote from common observation. Every man witnesses an abundance of them on every side: and indeed every man is a practical chemist; and the world is a vast laboratory, where immeasurable chemical processes are going forward in ceaseless succession. Yet so silently, and often imperceptibly do these operations proceed, that even those intelligent beings whose comfort and even existence are dependent upon them, are scarcely aware of their occurrence: much less do they perceive their causes, until Chemistry comes in to turn their attention to the phenomena, and to develop the beautiful laws that produce and regulate them. Who that is conversant with modern chemistry, does not recollect what an entirely new and interesting aspect the objects of creation around him appeared, when first the brilliant discoveries about science were opened upon his mind! He had seen the plants spring up, expand and ripen, and again decay. He had seen the snows of winter and the showers of summer, and felt the attendant cold of one and the raging heat of the other. He had observed the growth, decay and dissolution of animals; and he knew that certain kinds of food were essential to their existence. He was familiar with bodies around him, solid and gross as is the great mass of the earth; regular and beautiful, as in the various crystalline forms: yielding and yet tangible, as in the different liquids, elastic and evanescent, as in the atmosphere and vapours: and he had often witnessed matter successively assuming these different forms. But he knew not, until chemistry showed him, by what invariable laws, the innumerable changes are affected. All that beautiful play of affinities, and that nice balancing of attraction and repulsion, by which the processes of nature are carried on and the regularity and order of the system are preserved, are hidden from his view. But modern chemistry lifted the veil by which they were concealed, and showed him their operation, not only in the production of the ordinary vicissitudes of the material world, but in ten thousand curious changes, too delicate to arrest the eye of common observation. And if his mind was not sunk into that beastly apathy, which views with equal emotion beauty and deformity, order and confusion, wisdom and ignorance, it must have kindled with admiration and delight, as this world of wonders opened before it.

Now if the disclosures of chemistry were applicable to none of the useful arts of life, still it seems to me that this flood of knowledge concerning the works of God which pours in upon the soul would establish its claim to our attention. If the knowledge of the works of man be acknowledged important then…

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…for intellectual and moral discipline, and it is to this kind of knowledge that men devote the greater part of their time, why should not the works of God demand at least a share of attention! The works of God, which are so much more perfect, so much better models for forming the case, and so much better calculated to leave the mind to love divine perfections! Other sciences may unfold scenes that impress us more with the energy of almighty power, and excite sublimer emotions than chemistry; but no science equals this in the number, and not exceeds it in the beauty, of its exhibitions of divine wisdom. It exceeds all other sciences in the immense number of changes that are wrought upon a few simple substances, producing, by a slight variation of proportions, compounds of the most opposite qualities, and showing in a striking manner how far divine exceeds human wisdom. He that can witness the development of the principles of the science, and not read in them the handiwork of God nor see the marks of infinite wisdom, must have a heart long since dead to moral sensibility; a heart that would retain its atheism though favored, like Paul, with a vision of the third heavens.

Does anyone here enquire, why it has happened then, that the ranks of chemistry have contained not a few who could see nothing in her operations but the repetition of an eternal series of events, dependent on no first cause, and whose opinion of chemical changes was nevertheless so exalted they regarded animal life as merely the result of one of them, and the human soul, of another? I reply that such men did not learn their atheism from chemistry: but coming to the study of it with atheistical hearts, they were forced either to acknowledge the wisdom of Jehovah in its beautiful laws, or to exalt their favorite science to the rank of supreme divinity. They chose the latter course, because they thereby free themselves at once from every moral obligation, quelled the fears of future retribution, and laid asleep the unwelcome voice of conscience.

If I mistake not, there are one or two religious principles of prime importance, which are more forcibly impressed by chemistry than by any of its kindred sciences. I refer here to the constant superintendance of Divine Providence, and to man's dependence upon it for life and its comforts. The more mathematical sciences have often been thought so completely to explain natural phenomena by second causes, as to divert the mind from the agency of the great First Cause. But some of the discoveries of chemistry show us that the most deadly energies are on every side of us and even within us ready to burst from their fetters the moment a link is broken; and life and death, safety and destruction, are shown by the science, to be separated by narrow limits. In illustration of this sentiment, I can hardly refrain from referring to the different combinations of oxygen and nitrogen; although these substances have not yet been presented to your examination. Mixed together in proportion of one part of oxygen and three of nitrogen these gases constitute the air we breathe and without which we could not exist. Invert these proportions, that is less than three parts of oxygen and one of nitrogen be united and nitric acid will be formed; a gas exceedingly hostile to life, and a most powerful agent in the destruction of vegetable and animal substances. Vary the proportions yet differently, and the result will be nitrous oxide; a gas most remarkable for its exhilarating and intoxicating qualities, and which therefore would be almost equally unfit for respiration. In still different proportions other suffocating gases would be formed, whose prevalence would be destructive of life. Add to all this, that were an electric discharge sufficiently powerful to be passed through the atmosphere, all its oxygen would combine with a portion of its nitrogen…

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…and form nitric acid, and the excess of nitrogen being mixed with it, the total destruction of animal life would infallibly and ensure; this fair world teeming with life, would become a *universal death*. The hideous description of the poet might well be written upon it:

The world is void -
The populous and the powerful is a lump
Seasonless, herbless, treeless, manless, lifeless -
A lump of death - a chaos of hard clay. [Source: Poem by Byron, 1816]

Or suppose another possible case. Suppose even a thousandth part of that most deadly of all gases, the chlorine contained in the ocean, to be freed from its imprisonment, and suffered to mingle with the atmosphere: how short and dreadful would be the destruction of every living thing! Chemistry is almost yearly disclosing some new agent of tremendous energy, which needs only to be set at liberty to convert the order and harmony of the world into chaos. These destructive substances are disarmed of their power to destroy and made subservient to human wants and comfort only by their mutual attraction and repulsion, producing a happy balance or neutralization of energies. Now the effect upon the chemist who witnesses the almost uncontrollable power of these agents in a free state, if foolhardiness have not blunted his moral sensibilities, will be, to make him deeply feel that if there be not some constantly superintending and almighty power to preserve this balance and control these agencies, they would spread havoc and death over all the earth. When he considers how slight a variation in what now constitutes the elements of life would convert them into the elements of death, he could not but feel safe, if he did not believe that they are under the control of One whose wisdom and power and goodness, afford a certain pledge of protection.

Let not a cheerless scepticism endeavour to dissipate this impression of the Providence of God, and of man's dependence, by saying that the laws of nature, and not the interference of the Deity, are our security against the rage of elements. This effort to remove God away from his works is effectually destroyed, if we ask with true philosophic spirit, what is the difference between God's acting according to fixed laws and his special interference – or what is the difference between the laws of nature and the agency of God? Are they not essentially one and the same thing? Is it not God who acts as much in the one case as the other?

The science of Chemistry then, is well fitted to exert a favourable influence upon our religious knowledge and our religious affections - the most important of all influences. True, we may attend to it, and feel none of this influence: nay we may make it an occasion for increasing our pride and scepticism. But this is not the fault of the science - but of our hearts. Could this science in its present state have been developed in the mind of a David, or a Solomon, or a Job, what a glow would it have imparted to their devotional feelings! What a sense of dependence and of the glories of the Divine Character would have filled their hearts! But at this day it is to be feared there is among men of piety, too much of a jealousy of material science - too much of a divorcement between natural and revealed religion. And no wonder it is so: since infidelity and atheism have so long perverted the laws of nature and attempted to sway them in opposition to revelation. But this triumphing is short and it is now beginning to be clearly understood, that the voice of nature and the voice of revelation are in unison.

If the object of chemistry be to investigate and explain the changes that are going on in the natural world around us, then as already remarked, its cultivation must be important regarded merely as a source of knowledge concerning those laws by which the Creator balances the material universe! An acquaintance with the various inventions of men of superior genius for facilitating the operations of science and art is regarded by all as desirable: how much more then a knowledge of those curious laws by which the Supreme Architect keeps in harmonious play the countless agencies of nature!

In human works though laboured on with pain,
A thousand movements scarce one object gain:
In God's one single can its end produce,
Yet seems to second too some other use. (Pope) [Source: Pope, Essay on Man, 1733]

The often quoted sentiment of the poet, *The proper study of mankind is man, w*as not intended as it has been often understood to represent every other kind of knowledge as useless: but only to imply that it were much better for men to employ themselves in studying their own nature relations and destinies than in unprofitable speculations upon the unsearchable things of God. True, self-knowledge is the most important of all sciences; especially if it comprehend religious self-knowledge; and we need not be surprised that the ancients should say

E caelo descendit γνώθι σαυτόν [Descend from heaven; know thyself]

But who will say that this is the only kind of science that is useful! Nay we cannot understand the material part of ourselves, without an examination of the laws of nature; and he would be thoroughly conversant with his own frame so as to feel the force of the Psalmists exclamation, *I am curiously and wonderfully made,* must be acquainted with the laws of chemistry. And without some knowledge of these laws, who could discriminate between the operations of matter and of mind, where the unison of the two things is so intimate as in man!

We should readily infer from the nature of chemistry, that it has a most important and intimate connection with the science of medicine; and such is the fact. Indeed, the superiority of medical science at this day, above that of preceding centuries, is to be ascribed chiefly to improvements in this science. The operation of medicines upon the human constitution is in a great measure…

[Same as page 10? Possibly some paragraphs omitted]

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…chemical; and though sometimes a complicated process, yet in many cases, the precise effect of the different articles of the *materia medica* may be calculated beforehand. Formerly, and it is so at this day among the multitudes, medicines were supposed to possess certain occult and mysterious qualities, and the greater the number of simples united in a remedy, the more valuable it was thought to be. But now it is known that substances of opposite qualities are apt to neutralize one another, and hence it has been an important aspect to simplify the articles of medicine, and to employ chiefly those whose effect can be calculated by the laws of chemistry. The intimate connection of this science with success in the medical profession, will, however, be more obvious when I come to speak of its history.

From the definition I have given of chemistry it likewise appears that most of the arts would contribute so much to the comfort and convenience of civilized life, are little else than practical chemistry. The history of the science, however, will more clearly exhibit this fact: and to a brief statement of that history, I now proceed, in the second place, as proposed.

If I do not mistake, this is a convenient method of showing the utility of the science: for if we find the useful arts, with which it is intimately connected, to have advanced *passibus aequis* with the science, it will show their dependence upon its discoveries.

The arts, however, usually precede the sciences at their commencement: for they are in part the offspring of necessity, and this is the great spur to ingenuity. Accordingly we find that the ancients carried some of the arts, which may be called chemical, to a considerable degree of perfection; although chemistry properly so called is quite a modern science. The name is indeed derived from remote antiquity; and claim an Egyptian origin. But in early times it seems to have comprehended the whole of natural philosophy. In time, however, it became limited to the single art of working with metals. This was regarded by the ancients as superior in importance to every other art, and the adepts in it were honoured as the greatest benefactors of the human race and finally enrolled among the gods.

There is one art - that is embalming the dead - which was extensively practiced in quite early times among the Egyptians; and which although eminently a chemical process, seems to be in a great measure lost. Its discovery was probably accidental, and therefore does not prove an advanced state of chemistry at that period. Nor can its loss be regarded as a calamity, by any one who has seen that most disgusting spectacle, an Egyptian mummy. I know not that such an object makes an impression upon others as painful as upon myself: but I cannot conceive that to have the nearest friend on earth preserved in this manner, after the departure of the animating principles in the immortal mind, would excite any other emotion…

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…than those of disgust and horror, unattended by any beneficial influence, and calculated to arm death with new and needless tears.

But to return: chemistry after signifying for time merely the art of metallurgy became still more limited in its meaning, implying the art of making gold and silver: or rather, alchemy, by which term this art was designated, was separated from chemistry, and for many centuries became the chief object of pursuit among the learned, and of wonder and imposition among the ignorant. This conversion of other substances into the precious metals was to be effected either by synthesis or transmutation: and the substance by which the latter process was to be performed was called the elixir, or medicine of metals, the tincture, the powder of projections or philosopher's stone. This has long been a subject of ridicule, and has been sarcastically denominated *ars sine arte, cujus principium est mentiri, medium laborare, et finis mendicare* (Harris) [It is an art without art, which has its beginning in falsehood, its middle in toil, and its end in poverty]. Even the titles of the early works on the subject can scarcely be recited without a smile: for example, "Zosimus of Panopolis on the sacred and divine art of making gold and silver in 24 books; John the high priest, in the holy city, concerning the holy art; Theophrastus on the divine art; and Hierotheus the philosopher on the philosopher's stone." He however who will attentively examine the chemical theories of early times, will not be at all surprised, that even men of science should have sincerely believed the object of alchemy to be attainable. He who reflects how strong passions in the human heart are the love of scientific discovery and the hope of acquiring sudden wealth, will not think it strange that the science should have been pursued century after century with the most unreserved assiduity, and that men should have sacrificed to it their property and their lives. And he who has a just sense of human depravity, and considers the fine opportunity this science would offer in times of ignorance for imposition, might expect that designing men would have made it a powerful engine in promoting their fortunes and gratifying their lusts. The history of alchemy is indeed exceedingly curious and instructive, not only from its intimate connection with modern chemistry, but from the deep insight it gives into the human character, and the danger it exhibits of suffering mere inferences from theory to control our practice where much is at stake.

Although the philosopher's stone was the grand object of pursuit in alchemy, yet there was another incidentally connected with it; and which came at length to absorb the attention of the chemical world. This was the discovery of the panacea or universal medicine, that should cure all diseases and confer an earthly immortality upon our race. Chemists had often hinted at such an acquisition, as if it lay hid among the arcana of their science; and when the philosopher's stone had become an object of ridicule among the literati, and of contempt among real philosophers, and when the impositions and tricks of the alchemist had roused against them the arm of civil power and the indignation of the public…

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…then some of them professed that this philosopher's stone was itself the panacea, and others pretended to have discovered it somewhere else. This extravagant notion was carried to the upmost pitch of absurdity by Paracelsus, who flourished in the beginning of the 16th century; and by peculiar and somewhat extraordinary talents, excited the attention of all Europe to these subjects. But after ruining a strange career of popularity, absurdity and debauchery, he died at the age of 47, the victim of his excesses and by thus showing the powerlessness of his boasted infallible remedies, to prolong his own life, he satisfied the most credulous that all was imposition; and from that time, the panacea and the philosopher's stone rapidly lost their hold on human belief and their power to impose upon the world. Men could not but perceive that if the power of converting everything into gold could not preserve the possessor from extensive wretchedness and poverty, it could not be an art of much value and if those who could prolong life indefinitely were themselves brought to a premature grave, they must feel it to be a privilege to be ignorant of such a remedy.

But though such heuristic dreams as these were driven away before the advancing light of science, yet in two respects at least they have been of immense benefit to society. In the first place many of the alchemists were good experimental chemists, and the facts they communicated to the world although covered up in enigmas, have been of the utmost importance in establishing the science on its present foundation. As soon as men began to apply the inductive philosophy of Lord Bacon to these facts, they perceived how groundless were the pretensions of the alchemists, and began to lay a foundation for chemistry which would in time elevate it to the rank of an exact science. On such a basis and with such materials, have able men in modern times erected the grand and beautiful superstructure chemistry now presents.

A second beneficial effect of the study of alchemy was the application of its discoveries to improve the science of medicine. The idea of universal medicine was soon exploded, yet discerning physicians saw that their profession might be benefited, though not rendered absolutely perfect, by the discoveries of chemists. The first person who made a formal application of chemical principles to medicine was Basil Balentine, in the beginning of the 15th century. His celebrated treatise entitled *Currus Triumphalis Antimonii*, proved indeed a triumphal precursor of better days for the long abused profession of medicine. For centuries it had been connected with astrology, necromancy and a blind superstition. But from this period it began to be divested of its frippery; and though the empiric, who envelops himself most in mystery, and pretends to possess infallible remedies, whose occult qualities none but himself have discovered, though such a man still gains much credit among the ignorant, and often supplants the scientific honest physician, yet medicine…

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…as it now exists among the intelligent part of the profession no longer contains any secrets, but is regarded as a regular science, as much dependent upon fixed principles as any branch of philosophy. Physicians now understand that the human frame is a living machine, whose operations are regulated by the laws of hydraulics and mechanics, as much as any machine of human contrivance, and that the processes by which this machine is kept in motion are as purely chemical as the experiments of the laboratory although they are more or less modified by the principle of life. Hence they infer that every medicine operates chemically, and therefore they can often predict the salutary effect of certain substances upon particular diseases, and thus discover new medicines, as it were *a priori*. To modern chemistry medicine is indebted for the discovery of this simple yet important principle, and whoever will compare the present state of medicine with its condition less than a century ago, will perceive of what vast use has been the application of chemistry to its improvement. And since new and powerful substances are almost yearly brought to light by chemical analysis, we may predict that these are yet to be brought into the service of disordered human nature. Indeed such discoveries are by no means uncommon; and a comparison of recent with former bills of mortality in the civilized parts of Europe, indicates that the average length of human life is increasing. And this too amid all the complaints that are made of degenerated constitutions and the multiplication of diseases. We have reason therefore to suppose this cheering result to be imputable in part to the progress of medicine. It would be folly indeed to expect from thence that the physician will ever be able to rescue man from the power of death. For the pen of inspiration has written, “it is appointed unto men once to die - there is no discharge in that war”: and besides, there is a period when the human frame without the aid of disease, like a worn out machine, refuses to perform its offices and yields itself to dissolution. We may however anticipate that future discoveries will bring diseases much more within the power of the physician’s skill, and render much more numerous the instances, in which men attain to venerable old age, and sink at length through mere decay. There are some expressions in the Christian scriptures, that intimate a lengthening out of human life in the time of the millennium: says the prophets, “There shall be no more thence an infant of days, nor an old man that hath not filled his days: for the child shall die an hundred years old…And they shall build houses and inhabit them; and they shall plant vineyards, and eat the fruit of them. They shall not build, and another inhabit; they shall not plant, and another eat: for as the days of a tree are the days of my people, and mine elect shall long enjoy the work of their hands.” May we not expect, since God usually operates by means, that this addition to the present term of human life will be in part the…

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…result of improvements in medicine? (Though doubtless an increase of temperance will powerfully contribute to the same result.)

Such has been the salutary influence of modern chemistry upon medicine. So bright is the light thence reflected upon the physician’s path that it seems scarcely possible the world should ever revert to the darkness of those Utopian ages when the panacea and the philosopher’s stone awakened the eager pursuit of the prince on his throne and the peasant in his cottage - of the supreme Roman pontiff and the secluded monk in his cell. To envelop the human mind again in so dark an eclipse and obliterate the lines of science so deeply ingrained there will surely require the return of an age ten times darker than that through which Europe has already groped and groaned her way.

Nor is the connection of chemistry with the arts less intimate, or its influence in their improvement less powerful and visible. Indeed the principles on which most of the arts are founded, are derived either from mechanics, or chemistry - and hence some are denominated mechanical, and others chemical arts. Discoveries and improvements are indeed often made in these arts by men who are but imperfectly acquainted with the sciences on which they are founded. But it is men, who to a thorough acquaintance with practice, have joined in extensive knowledge of the theory, that the arts are indebted for their most valuable improvements: we may chiefly attribute the present advanced and rapidly advancing state of the arts to the diligent cultivation of their correspondent sciences.

Among the arts that must look to Chemistry for extensive improvement, may be named agriculture, confessedly the most universally important of any other. That so little advancement in this art has been made heretofore may be imputed in part to the few chemists who have been agriculturalists - in part to the peculiar difficulty attending the investigation, and in part to the looseness of the language used in the description of experiments. But if ever agriculture shall make any important progress, she will be indebted directly or indirectly to chemistry for the clew to her improvement. For the whole process of vegetation is a chemical process; and all that it is wanted for greatly increasing the produce of the soil, is to discover a mode in which the chemical agencies of that soil shall be made to lend their greatest energy in supporting vegetable life.

The art of working the ores and their metals, denominated metallurgy, is greatly dependent on chemistry. And when we consider how extensive is the use of the simple and the combined metals, among almost every class of men - how they facilitate the operations of nearly every art and reduce the amount of labour, we cannot but see how valuable must be that science which in this among a multitude of ways has contributed so much to promote civilization with its accompanying blessings. Take away the metals from mankind and you throw back the world into all the misery and barbarism of a state of uncultivated nature...

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…In connection with metallurgy I cannot but refer to Sir Humphrey Davy's important and beautiful discovery of the safety lamp. Its object is to preserve miners from certain explosive gases they frequently meet in their subterranean labours, and by the fearful energy of which hundreds of these unfortunate men were till this discovery yearly and suddenly precipitated into eternity; and whole villages thrown into the deepest affliction. It is a discovery moreover finally illustrating the principle that researches in science, apparently trivial and unimportant, often lead to the most valuable and beneficial results. Suppose a man of limited views had seen Davy in his laboratory busily employed in attempting to prove that inflammable gases would not easily take fire through small tubes. With what sneering triumphs would such a man have asked, *What if he does prove this? What then? Where is the cui bono? What effect can it have on human happiness?* Yet the result of this very research was the safety lamp, for which he received not merely a large pecuniary reward from the English government and the mines, but the heartfelt and lasting gratitude of all who are engaged in these dangerous and disagreeable operations.

Those numerous arts by which the various salting bodies most in use are produced, are dependant for their mode of operation upon chemical science. Yet how few are those who when enjoying such conveniences as sugar, sea salt, the mineral and vegetable alkalis - alum nitrile vitriol borax and the like have any idea that they are indebted for them to processes and laws purely chemical. I might make this remark with still greater propriety in regard to glassmaking and the manufacture of pottery and porcelain. Many a housewife, who would feel herself undone, were she deprived of the common earthen utensils so useful in culinary preparations, could hardly be made to believe that she has any interest in the cultivation of chemistry. Nor does the delicate lady who sips her tea from the finest porcelain - whose sideboard sparkles with the most brilliant products of the glass house and whose parlor is hung round with splendid mirrors, little does she think of her indebtedness to the patient labours of the chemist. Yet let the arts be deprived of all the benefits they have derived from chemistry and the airy splendid shell and parlour must have only the sombre light of wooden windows and the glass and porcelain of the table and the sideboard be exchange for the rudely carved wooden bowls of centuries long since gone by.

Among ancient writers, especially in the holy scriptures, a dress of clean and white linen is frequently referred to as an emblem of innocence and purity. And such a dress was then comparatively uncommon – just as innocence and purity have always been - and therefore the illustration was pertinent. But since the introduction of the chemical method as it has been distinctively called – or the use of chlorine into the bleaching process, it is now in the power of almost everyone to put on the outward emblem of purity, even though it covered, like the mantle of charity, a multitude of sins.

I might much enlarge this list of the arts greatly dependent upon chemistry for their improvement, but the details would I fear be tedious at this time. These will…

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…however be resumed in the proper places; and I shall always endeavour to connect economical with experimental and theoretical chemistry. In this application of the science to the arts, no nation has ever exceeded the French. During the period of their revolution the government patronized men of science and it was in a great measure owing to the development of new internal resources by the chemists, that they were enabled even in their distracted state to resist the powerful combinations of their enemies: and when these internal energies were brought into full play, they were seized by ambitious hands and hurled with terrible effect over prostrate Europe; thus showing us, what an amount of good they might have been the means of accomplishing under the guidance of justice and benevolence.

In this that's considering briefly the nature and history of chemistry, I trust it will be admitted that I have shown at least that its value in the cultivation of the intellectual and moral faculties and in promoting civilization and comfort is so great as to entitle this science to a place among those that are indispensable in a liberal education. The science then must be taught in our public seminaries. And now the question arises by who shall it be taught? Shall those who regard religion as the grand object of all education, leave this branch of science as it has often been done in the hands of the sceptic and the infidel? It is not so well known as it ought to be, that some of the deadliest and most fatal trusts that ever religion felt have been made…

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Indeed at the present day in such a country as ours when almost every intelligent man studies chemistry he who should leave college walls unacquainted with it and without having studied it or seen a course of experiments upon it will find that no baccalaureate honors can save him from the contempt of the common man who finds him with all his [????] of knowledge ignorant of those laws which lie at the basis of nearly all the useful arts which give to nature all her variety and produce her ten thousand transmutations of beauty and utility by which the countless wheels and spring of our own bodies are kept in ceaseless play and which stripping off the veil from all the internal world shows us the right hand of the creator regulating and harmonizing all. The student will find as he goes into the world that his fellow man will expect and demand of him a knowledge of the subject and if they find him ignorant of it they will turn to others who understand it. It was not so a few years ago but it is so now.

Let me add here that if the operations of nature are so full of Deity as we believe then it becomes the duty of the scientific instructor to point out those striking illustrations of moral religious truth that rise up in his path. He is responsible and…

…from the professional chair of the philosopher, the chemist, and the naturalist. By presenting a partial and distorted view of natural phenomena, and calling in the aid of ridicule, such men have made an impression on the minds of the young which neither argument nor persuasion nor conscience could ever remove. For scarcely can a heat be more braced against the influence of piety, than that of the young man who with a smattering of philosophy has imbibed from the life of some able master, a prejudice against religion. If there be any of any of whose future piety we should despair, such would be the youth. Yet have we reason to believe there are many such in the seminaries of learning whose instructors have clear heads but corrupt hearts.

To prevent such a fatal result as this how then can the religious man regard as incompatible with his obligations to glorify God in all his ways, or as an employment comparatively unimportant, to devote himself to the study, and instruction of physical science. For the truth is, philosophy if rightly understood and properly consulted, utters no insinuations against revealed truth but being the work of the same God, their responses are in unison. It becomes therefore the duty of the scientific instructor to point out to his pupils, those striking instances that may occur, in which moral or religious truth receives a confirmation or illustration from science; and to show how apparent discrepancies may be reconciled. He is responsible to the highest of all tribunals for the moral influence of his course of instruction. It is not indeed his business to…

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…teach religious truth directly; nor should he be hunting after remote and indistinct analogies between physical and religious truth so frequently moralize as to weaken the force of striking illustrations and disgust those whom he would win. But how can he answer it to his conscience if he goes over the whole temple of nature, exhibiting to his class its beautiful arches and columns, nay lay open the holy of holies, and yet remain silent concerning the Supreme Architect, who built and adorned it.

In such a manner, and with such motives, gentleman, do I wish to commence a course of instruction in chemistry: for in no other mode can I hope to feel the approbation of my conscience and my future judge. Satisfied of the utility of the sciences I could wish to render its truths as impressive and interesting as possible.

[Insert]

With many embarrassments however in the way which it is needless to mention arising from the newness of this establishment and the enfeebled state of my health which has prevented me from making all the previous preparation I could have wished, I am greatly apprehensive I shall fall far below this standard. But while I make every reasonable effort in my power to ensure success and gives a lucid and experimental illustration of chemical principles, I do not fear but allowance will be made for unavoidable failures. For it ought to be understood by everyone who attends experiments upon chemistry that in spite of all which industry and caution and sagacity and long tried experience can effect, failures will happen and that too not infrequently where least expected.

But alas! I enter upon this duty with a failing heart and a heavy heart; such are the difficulties under which I labour that I greatly fear instead of exciting within you a deep interest I shall produce in your mind an incurable disrelish for a valuable science. To say nothing of enfeebled health. Those of you who may have seen enough of chemical manipulations to know how the success of an experiment often depends upon the most trivial circumstances, will be able to appreciate something of my embarrassment from being obliged to proceed without a laboratory. And then, too, whereas in this instance almost every ingredient must be obtained new, it would be very strange if some of them should not prove defective and useless. Indeed were there not a sort of necessity lying upon me to attempt something in this department the present season, I could not consent to it. It cannot be expected that with the little time and strength I have had for preparation I should give a written course of lectures: but rather a select course of experiments. Yet I would hear remarked that in my opinion little benefit is to be derived from reading to a class elaborate essays upon chemical theories or entering largely into chemical controversies which the student can better learn in set treatises. The principal object of lecturing on the subject appears to me should be to illustrate the principles of the science by experiment and to supply any deficiencies in the text book. It is the determination of the Trustees and Faculty of this college that such a course should be as complete and satisfactory here as in any of the colleges of New England, and the knowledge of this intention increases my embarrassment and solicitude.

I make not these remarks as an apology for incompetency: being well aware that this admits of no apology. But I make them to induce you to grant all reasonable allowance for my situation; and to prevent you from being disappointed even if the difficulties before me should prove so great as to compel me to altogether abandon the undertakings: and I am not without apprehension that such may be the result.

In concluding these introductory remarks, permit me to suggest a single caution. It is a caution against indulging to exalted an opinion of human knowledge…

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…and fostering a learned pride. When the first brilliant discoveries of modern science open in rapid succession upon the mind, blighted and dazzled with their beauty, we are apt to fancy that we take in a much wider range of knowledge than in fact we do. The reason of this deception is, that we are so occupied with looking upon the objects immediately around us, that we are prevented from surveying the immense field that lies beyond. We seem, as it were, to be placed at the center of a small sphere, whose surface is studded with a few stars, so brilliant as to prevent our seeing the innumerable suns and worlds scattered in glorious profusion beyond it. Or as the poet expresses it, in a simple, the best, according to Dr. Johnson in English poetry:

So pleased at first, the towering Alps we try,
Mount o'er the vales, and seem to tread the sky,
The eternal snows appear already past,
And the first clouds and mountains seem the last;
But those attained, we tremble to survey
The growing labours of the lengthened way;
The increasing prospect tires our wondering eyes,
Hills peep o'er hills, and Alps o'er Alps arise.

[Source: Alexander Pope, Essay on Criticism, 1711]

"The first year I studied philosophy," said a distinguished man of science, "I imagined I knew everything. The second year, I thought I knew something: but the third year, I found I knew nothing." He did not mean that he did not become acquainted with many facts relating to a great variety of subjects; nor that a universal scepticism in regard to all truth, had seized his mind. But he meant that as he became more and more acquainted with the narrow boundaries of human knowledge and could see something of those vast untrodden regions that lie beyond, there was no comparison between the hand breadth of the one and the infinity of the other. And so will everyman find it who, not content with a superficial view of science, continues year after year with patient steps to climb higher and higher towards the pinnacle of his temple. The higher he rises in reality, the lower will he sink in his own estimation. Peculiarly important then is it for the youthful votary of science, to carry with him into all his research a spirit of humility. However the pride of science may strive to find a lodgment in the breast, let him remember that there is no spectacle more disgusting than that knowledge which is inflated by the leaven of vanity and self-importance; and on the other hand, no union more beautiful and as attractive to the eye of men and angels than that of learning and modest and unaffected humility. The phrase pride of science is rather a solecism in terms: for the fact is every branch of science, physical as well as intellectual, teaches us a lesson of modesty and meekness: hence there is no such thing as pride in science: it grows in a more fruitful in man's depraved heart: so that it needs something more than science, with all his humbling lessons, to root it thence. Let the man of mightiest intellect only turn his thoughts from time to time upon the unspeakable and glorious being who formed the laws of nature and guides our operations and compare his…

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…attainments with infinite knowledge, and every inflated feeling of self-importance and mental superiority must subside; and he will be forced to explain with the son of Sirach, "why is earth and ashes proud?" [Eccl. 10:9] When we look around upon our fellow men, it is easy to find those who are apparently much more ignorant than ourselves; and the comparison is apt to feed our vanity. But when we look up to God, only wise, we cannot but feel that our knowledge is ignorance, and our wisdom folly. Frequently then to turn our thoughts upon his character, while we are exploring his works, will serve to reduce to a proper level our too exalted conception of our attainments, and bring us into the humble attitude true wisdom produces. And while thus taught how circumscribed is the sphere of human learning, how indistinctly the soul looks out from her prison house of clay, and how distorted is often the picture of truth, apprehended by sense, we shall be led to sigh after a purer world, where no grossness will intercept the says of truth, no limits bound the soul's free range, and no termination be made to her delightful researches.

Notes on Chemistry

[These notes are on smaller paper and the dates indicate that they were added in the 1840s.]

See Turner's Elements Fifth American Edition

General properties of matter: or such as belong to all matter

Extension
Impenetrability
Mobility – viz. inertiae
Divisibility. Grain of gold divisible into 2 millions of visible points – On silver wire 12 times more extended. A grain of iron in solution divided into 24 million departs. Daniel p. h9.

[Probably refers to John Frederic Daniell, British chemist]

Stones - from a primitive and τέμνειν to cut - that is indivisible.

Gravitation
Porosity
Indestructability

Secondary properties of matter such as are found only in some bodies; e.g. opacity transparency softness elasticity solidity fluidity etc.

All matter subject to two forces - attraction and repulsion - the first cohesion - the other caloric.

Chemical attraction or affinity
Integrant particles
Component parts

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This the cause of all chemical changes. Hence chemistry examines the relation established by affinity - the compound produced by it and the laws of such combinations.

Compound bodies contain more than one kind of ponderable matter
Simple bodies only one kind - 54 for these
Analysis and synthesis e.g. water
Imponderables - heat light electricity – add magnetism and attraction

Affinity

Admixture the most simple example of chemical combination
Explain table of decomposition e.g. sulphuric acid
Barytes of strontium
(Ref? Des Vree's Dict.?)

These tables do not prove the relative strength of the affinities to be in the same order. For example pour hydrogen over red hot oxide of iron and it separates into oxygen. Pass vapors over red hot iron and the oxygen abandons the hydrogen. Modifying circumstances come in to effect the decomposition.

Show how double electric affinity may be represented by a diagram

*Elements Notice the doctrine of <u>elemental isomerism</u> which supposes the elements to result from the repetition of some one real elementary substance. Proposed first by Professor John Stone in 1837 - Sustained as yet by no experiments but by several probabilities. Ed. New Phil. Journal Ap to July 1844 p. 1

Difference between abstract and natural science - mathematics and chemistry: the former may be wrought out by reflection the latter demands experiments. Reference: Daniell Chemistry Philos. P. 2

The latter made no progress till Lord Bacon.

Newton and Borciricki opinion of matter. Same work, p. 7. Borciricki's theory explained Rees Cyc. Art. Matter Exp. Breaks Respects Drops and explain.

Every particle of matter under the influence of several forces.

We get our idea of force from the muscular effort we make to overcome obstacles. This is muscular force – or a sixth sense - when the forces are in equilibrium rest is the consequence, when one predominates motion.

The laws of the forces of nature we can ascertain but their origin is inscrutable - even to the muscular form.

Force divided into the principal kinds…

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…Attraction and repulsion: gravity electricity and magnetism are external forces: cohesion and affinity are internal or molecular forces

Heterogeneous adhesion exists between bodies of different kinds and between all bodies though with different degrees of force.

E.g. humectation of bodies of water.

E.g. a polished blade of a knife will not adhere to Mercury.

The action of cement is one example

<u>Capillary attraction</u> is another example. Water in a small tube will rise around the side, Mercury will sink.

Filtration depends upon capillary action.

Capillary action exerts a prodigious force as a slug of wood driven into a hole and then set. Rocks are split in the manner in Germany Darnell p. 6

Adhesion takes place between gases and solid bodies

E.g. sprinkle magnesia upon a jar of water it will sink because the air does not adhere to it much.

E.g. sprinkle iron filings in the same manner they will swim because the air does adhere.

Absorption of gases by charcoal. Perform the experiment. Ref. Table Daniell p. 66

Absorption by hair category and other substances - hyperscopes or hygrometers.

Absorption of air by water of great importance

Solution results from heterogeneous adhesion - this is limited by cohesion and that equilibrium produces saturation.

Mixtures result from the same force.

Experiment sulfuric acid and water – solution reduced by intimate combination

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Endosmosis or flowing in and immersion and exosmosis or flowing out depend upon heterogeneous attractions. In this case one of the liquids is more capable than the other of wetting the solid which separates them.

E.g. water wets bladder more than alcohol hence if a tunnel be tied over the mouth with the piece of bladder and inverted in water after the tunnel is filled with alcohol the water will enter the tunnel faster than the alcohol will go out and force the liquid up a tube several feet long. Sirceeds Oct. 1844

Mixture of gases - describe it very important - 1 to prevent animals from being injured 2 To afford carbonic acid to plants

Dalton says "one gas acts as a vacuum with respect to another." Gas is capable of endosmosis and exosmosis.

<u>Electric attraction</u>

E.g. precipitate camphor by water

Evaporate things in heat to overcome the force of heterogeneous attraction between the solvent and the solid dissolved.

<u>Crystallization</u>

This takes place when there is a balance between homogeneous and heterogeneous attraction – or rather when the latter begins to predominate.

Primary forms have cleavage parallel to all their faces - they are six.

Two theories as to the form of the integrant particles. The first supposes this force that of the primary - the theory of Marcy.

The second by Wollaston proposes the ultimate particles to be spheres or spheroids - show crystals partially solid Reference. Daniell p. 87.

Dimorphism

Change of crystalline structure by heat and agitation pressure etc. Does wrought iron become crystalline by the tremulous vibrations on railways.

Affinity or chemical affinity the highest form of heterogeneous attraction. Distinguish from adhesion.

1 By acting best when the substances are most similar whereas adhesion seems to depend on a certain [????] of…

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…nature. Then to dissolve a metal we need another metal in a liquid state and alcohol and ether dissolve in flammable liquids as serious facts etc. while water dissolved salt in the air.

2 To adhesion does not destroy the properties of the simple United affinity does.

3 it is far more energetic than adhesion

Describe the simple substance 55 - 42 metals 13 other substances

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[Page inserted on page 18. It is not clear where this was intended to be inserted.]

GEOLOGY

[Edward Hitchcock classroom lecture notes, "Geology", EOH, Box 10, Folder 10.]

[For pages 13-44 only headings are transcribed]

Gentlemen,

We are now to direct our attention to those vast mineral masses that constitute the mountains the crust and indeed in so far as they have been penetrated the internal parts of our globe. By attending to mineralogy you have acquired a knowledge of those simple or homogeneous minerals that either singly or united to one another compose those extensive and solid deposits around us denominated rocks. To apply a lively remark of the Abby Hauy you have not yet seen nature but mineralogy has furnished you with eyes for (her) the examination.

If any have felt that in mineralogy there is a want of amplitude and too much confinement of the mind to minute objects he will find in geology a field wide enough to give scope to all his faculties. Indeed comprehensive views and the power of accurately comparing facts are essential…

Page 2

…qualifications in the geologist. And a deficiency in these faculties has been a grand cause why more men have failed in geological investigations than in any other department of natural history. The mineralogist the zoologist and the botanist by learning to fix his eye intently upon a few distinctive marks may with ordinary industry and abilities attain to a good degree of certainty in his conclusions. But the geologist has peculiar difficulties in his way. He does not find in the first place that well marked distinction between different rocks which exists among different species of animals plants or even minerals. He finds rocks so gradually passing into one another that in many cases the extremes meet and he cannot tell to which side a given specimen belongs. A second difficulty arises from those modifications which rocks have undergone since their original creation by the agency of air water and fire whereby not only the external aspect but the internal structure is changed. A third difficulty in this science is the great number of facts requisite to be known and the vastness of the field necessary to be gone over in order to arrive at a just conclusion. It is not enough that a man examine his own district. He must know what are the appearances in other regions and in every quarter of the world that has been examined. Multitudes mistaking their own narrow sphere of observation for the world have gravely made inferences and framed hypotheses which served only to show their ignorance of other regions and to bring their labours into neglect and contempt. A fourth obstruction the geologist finds lies in the difficulty which often attends his investigation of facts. The only point which can unravel the apparent chaos of a complex region of country may be covered up by the loose soil too deeply to be investigated or that point may be buried in the oceans unfathomable depths. Finally no small difficulty exists in the influence of theory over the judgment of the geologist causing him to see facts in false colouring. I ought thus early to state that no science has suffered so much from the trammels of hypotheses as this. The Baconian method of…

Page 3

…induction was in this branch for a long time overlooked and although ponderous volumes were written upon geology they now exist only as beacons to warn succeeding geologists of the danger of erecting systems without a foundation. There is however in this science an almost irresistible propensity to revert to the modus operandi when we observe particular facts. And as it has till very recently been usual to base this science upon one or the other of two conflicting hypotheses that have divided the learned world we cannot but perceive the influence of these systems upon the ablest geologists.

But notwithstanding all these difficulties no science whatever has within a few years made more rapid progress than this. It is in fact one of the latest of the sciences and although many a wild theory of the earth was with much travail ushered into the world a century ago yet legitimate geology cannot claim an age of half this duration. But the novelty of many of its discoveries has allured to its examination many of the most distinguished philosophers of the age and in this field they have gathered some of their richest laurels. It has excited attention too because it furnishes so interesting an object for the traveller enlivening the tediousness of his roughest paths and giving in an air of learning to his pages. Still greater attention has been attracted to the subject in consequence of the bearing many of its discoveries have upon the Christian revelation. Geology has long been regarded by the infidel as his vantage ground and not a few defenders of the Bible have to say the least ably contested the field.

This relation of geology to Revelation renders it very desirable that every man who wishes to be thoroughly acquainted with the evidences of Christianity should be conversant with this science. For I hesitate not to say that the Christian ignorant of the subject cannot defend the Mosaic history against the attacks of the infidel geologist.

I have not yet given a formal definition of geology and perhaps such a definition will not be of much utility. It examines the arrangements and relation of all those mineral masses of the globe that constitute rocks. And in this term I include not merely those masses…

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…that are consolidated but also the various strata of sand clay and gravel with which the more solid parts of the globe are invested. Geology goes farther than this. It investigates the mutual actions upon one another of the different agents found on the globe such as solids fluids gases light heat and electricity. It considers too the various changes that have taken place in the crust and on the surface of our globe the different successions of animals that have inhabited it and been overwhelmed in the catastrophes to which it has been subject and thus the science opens a new source of information in regard to the early history of the world.

I have already stated it as an important distinction between mineralogy and geology that the former gives an account of those minerals only that are simple or homogeneous in their composition while the latter takes cognizance of those that are compound or composed of two or more simple minerals. This distinction however does not hold throughout. For several simple minerals occur in such large quantities as to constitute extensive beds and even mountain masses and in such cases it falls within the province of geology to describe their relative position and connection.

In mineralogy as in zoology and botany we are able to a considerable extent to group the different objects into genera and species. But in geology the case is different. Most rocks consist of several simple minerals united in every possible proportion in different rocks often passing into one another by insensible gradations. Exact specific distinctions therefore seem impossible. The presence however of certain predominating ingredients and the mode of their arrangement will enable us to describe rocks as of different kinds or sorts. Such a classification has been attempted by many learned geologists with considerable success. On this plan the number of rocks which are found to be sufficiently distinct to receive a separate name is few. Among all the difficulties of the science this must be regarded as an advantage as we are not compelled to burden the memory with mere names as much as in other departments of natural history. The varieties of rocks however are indefinitely great though few of them are thought deserving of distinct names.

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In nearly all the systems of geology that have been published and in every course of lectures I have heard or read it has been thought necessary to commence a description of the science by giving an account of several of the leading systems devised by ingenious men for arranging rocks and accounting for their origin. I shall reverse this order and first give an account of the rocks themselves and afterwards of the hypotheses concerning them which have from time to time appeared. My reasons for adopting such a course are several. First it is undeniable that the influence of these geological systems has been unfavorable both in acquiring the knowledge of the science and in efforts for its advancement. Secondly every man on merely hearing opposing systems stated on any subject in which he feels any interest will become unduly prejudiced in favor of one side or the other. Let any man witness the conflict between two pugilists whom he never saw and it will be impossible for him not to acquire a prepossession in favor of one of them and a desire that he should be the conqueror. But in the third place it cannot be supposed that the student is as well qualified to judge of the merits of opposing systems in a science when he commenced the study of it as when he shall have acquired a knowledge of facts. Self-evident as is this principle, it has been customary not alone in geology but also in other important sciences to act in direct opposition to it. In the grand argument in favor of first stating a hypothesis in such cases is that otherwise the student cannot arrange the facts that are stated to him and therefore cannot retain them in his memory. But is it not better that he should never learn the science than to acquire ideas of it entirely erroneous? Yet in the case of geology I do not believe the objection to have much weight. There are not more than 30 or 40 distinct and well marked sorts of rocks and whether these are disposed with or without regular order their names and leading properties cannot greatly affect the memory.

But rocks are not altogether without natural order in their relative position though many of them it must be confessed are extremely anomalous. Let us go forth into the fields for examination. In most places we first meet with a covering of soil…

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…a few feet in thickness (sometimes a few hundreds) composed entirely of fragments of rock more or less finely divided and mixed with animal and vegetable matter. We dig through the soil and meet with gravel sand and clay arranged in regular alternating layers. Next we come to the solid rock. Penetrating the first rock we meet we come to a second kind - to a third – to a fourth – and at length we to one whose bottom we cannot reach. Now why not commence with this rock which appears to be fundamental and after describing it examine that which usually lies next above it? True this fundamental rock often protrudes to the surface and no other rock is found above it and sometimes the one most usually superimposed upon it is wanting and some other rock it may be the third or fourth or the twentieth in the usual order of succession lies next to this lowest. But all these variations can be stated as we proceed in the description. We can still follow the most usual order of succession until we come to the rocks which are subject to no certain order of superposition and these we can describe under…

[this picks up with page 10]

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[Pages 6-9 seem to be extra sheets inserted later]

*Show the distinction between Theory and Hypothesis in Geology.

Theory is a legitimate inference from established facts.

Hypothesis is an assumption of facts for the explanation of appearances.

E.g. Upon finding shells fish and animals embedded in solid rock it is a legitimate theory to infer that these shell fish and animals once had a real existence: but to attempt to account for their occurrence in a petrified state by calling in the aid of a volcano is hypothesis.

Give a general account of the strata of rocks met with on descending into the earth.

1. Alluvial
2. Diluvial
3. Tertiary
4. Secondary
5. Primary
6. Overlying rocks
7. Volcanic rocks

Refers to the division of rocks into superior, supermedial, submedial and inferior.

Valleys

<u>Mountain valleys</u> - either longitudinal (ranging in the same direction as the mountain chain) or transverse (across that direction) (example New England passim

Land valleys - their bottoms are undulating and depth inconsiderable

Broad Flat bottomed valleys - Level plains bounded by mountain ridges (example Valley of the Connecticut)

Valleys of dislocation - those produced by the dislocation of strata.

Valleys of elevation - those produced by a fracture of the strata by a force acting beneath the valley by which the strata are elevated and made to dip from the valley.

Valleys of denotation - Strata nearly horizontal on each side and corresponding. Obviously the result of denuding agencies (example between Mount Toby and Sugarloaf)

Ravines and gorges - not very different - (example between Niagara Falls and Lake Ontario)

Terrorist valleys - broad flat bottomed valleys though which through which a stream flows whose banks are eroded. (Example Valley of the Connecticut and of Deerfield and Westfield rivers)

Origin of valleys

1. The various elevations fractures and dislocations which the strata have undergone
2. Diluvial agencies
3. Action of the retiring ocean when the strata were elevated
4. Alluvial agencies - rivers bursting of lakes etc.
5. earthquakes and submarine volcanoes

Valley of the Connecticut

Not formed by the river

The Connecticut has excavated its bed about 100 feet

A shallow lake probably once extended from Turners Falls to Middletown

[insert]

Means of ascertaining the geological structure of the interior of the globe

1. By mines

The deepest at Truttenberg in Bohemia exceeds 3000 feet about one four thousandth of the Earth's radius

2. Wells –

Boring for water coal salt etc. rarely extend more than 1500 feet

3. Roads, canals, tunnels

The two former superficial. At Lockport the limestone for two miles has been excavated about 30 feet deep. The tunnel between Himmerfield and Manchester is approximately 3 miles long and 660 feet below the surface.

4. Rivers - valleys - cliffs – promontories

These expose the strata to a considerable depth and by their…

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…abrasive agency very much assist the geologist.

Notice the passage of the Niagara River between Ontario and Erie - of the Shenandoah through the Blue Ridge and of the Connecticut through its barriers at Bellows Falls, Mount Holyoke, and below Middletown.

5. Inclination of the strata

A principal source of information. In this way the edges of the rocks probably in some instances several miles deep are brought to view.

Figure and density of the earth. Dela Beche Geology

Temperature of the earth. Same work

Page 9

Page 10 right side

…their true characters as occasional or anomalous rocks.

This is the course I shall adopt in the following lectures and I do not see why in this way I shall not exclude hypotheses entirely until I have stated the leading facts of the science. For whether one rock lies above another is a question of fact not of theory.

I would not be understood however as wishing to prevent you from forming an opinion concerning the controverted points and systems of geology. It is difficult and not desirable to avoid forming such opinions though in the present state of the science allow me to say that they should be maintained in good temper and with modesty. But my only object is to prevent them from being formed prematurely.

*There are several terms peculiar to geology which are indispensable in description. These I shall take occasion to describe as I find it necessary to employ them.

Before proceeding to the description of rocks I wish to call your attention for a moment to the simple minerals entering into their composition. These amount to about 23 although several of them are found in…

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…rock masses only to a very limited extent. The following list shows what these simple minerals are and of what rocks they form a constituent part.

1. Indurated Clay

In claystones
Porphyry and Amygdaloid
Basalt
Argillaceous slates
Shales
Limestones

2. Clinkstone

A simple rock - sometimes porphrytic and amygdaloidal

3. Compact feldspar

In Gneiss
Porphyries

Amygdaloids
Syenites
Greenstones
Augit rock
Hypertheme rock
Granite - rarely

4. Quarts

In quartz rock
Granite
Gneiss
Mica slate
Chlorite slate
Talcose slate
Argillaceous slate
Sandstones
Porphyries
Sienites
Greenstones rarely

5. Feldspar

In Granite
Gneiss
Chlorite slate
Hornblende slate
Actinolite slate
Quartz rock
Micah slate

In primary sandstone
Old red sandstone
Greenstone
Syenites
Porphyries
Porphyritic pitchstone

6. Carbonate of lime

In Limestones
Gneiss
Mica slate
Sandstones
Amygdaloid chalks

7. Mica

In granite
Gneiss
Mica slate
Quartz rock
Sandstones
Shale
Limestone
Claystones
Green stones
Syenite cyanide – rarely
Porphyries

8. Chlorite

Slate
Gneiss
Granite
Actinolite slate
Argillaceous slate

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[FROM HERE ON ONLY MAJOR HEADINGS ARE SHOWN]

Pages 13-18: Granite

Pages 18-19: Gneiss

Pages 20: Mica Slate

Pages 21: Talcose Slate

Pages 22: Hornblende Schist

Page 23L: Quartz Rock

Page 23R: Red Primary Sandstone

Page 24L: Diallage Rock

Page 24R: Serpentine

[See Shells Notes, p. 6, where a list of rock types begins with #12, Compact Feldspar]

Page 25L: Organic Remains

Page 25R: Vermes or worms

Page 26L: Mollusca

Page 26R: Gestacea shells

Pages 27-29: Multivalve shells, bivalves, univalves

Page 29R: Crustacea, corallia

Pages 30-31: Zoophyta

Pages 31-32: Vegetable Remains

Page 32-33: Animal Organic Remains

Pages 34-42: Tertiary animals and plants fossilized

Pages 42-44: Beds or pseudostrata

MINERALOGY NOTES

[Edward Hitchcock classroom lecture notes, "Mineralogy", EOH, Box 10, Folder 12.]

Page 1

Gentlemen,

So confusedly blended are the inorganic materials of our globe to the eye of common observation and so defaced are the surfaces of rocks and minerals by the hand of time that it would seem improbable such a science as mineralogy could ever exist. Yet when careful observation turns its keen eye upon this department of nature and reveals the internal structure of the mineral masses of our globe, a scene of beauty and order is laid open little expected exhibiting the same evidence of Divine wisdom as is found in the animal and vegetable world. It was not however until very recently that mineralogy has assumed any thing of a scientific form. Although the ancients were acquainted with some of the precious stones and the more common and striking metals and ores yet no attempt at systematic arrangement was made by them that deserves notice. Nearly the same may be said concerning the few attempts at classification of minerals that were made previous to the time of Werner. Cronstedt indeed and Lehmann and Vogel and Wallerias had done much for the age in which they lived: but so vague was the terminology they employed that their descriptions were almost unintelligible and Werner…

[Abraham Gottlob Werner, German geologist; Axel Fredrik Cronstedt, Swedish mineralogist; Johann Gottlob Lehmann, German geologist]

Page 2

…may with propriety be termed the father of systematic mineralogy.

Abraham Gottlob Werner flourished about 50 years ago at Freiburg in Saxony as a lecturer on mineralogy. Although his name is so intimately incorporated with every part of mineralogy and geology it is a little singular that he published almost nothing himself. But his pupils were in the habit of writing out his lectures and he often revised them himself and several of these pupils afterwards published his views of these sciences. He had a strange aversion to the mechanical part of writing which increased at length to an extravagant degree. To avoid the pain of repeated refusal to answer the letters of his correspondence he came to the resolution of neglecting to break open his letters addressed to him and the first notice he had of his election as an honorary member of the French National Academy of Arts and Sciences – an honor conferred only upon eight men in Europe - was by observing it in the Almanack. A valuable manuscript of a learned man which has long been lost was brought to light after his death among his papers where it lay among the hundred other unread. And worse than all a messenger from his sister was obliged to wait two months at the public house before he could obtain the signature of Werner's name to some paper records relating to family concerns in which it was indispensable. These eccentricities and the fact also that he was never married I mention not to attribute not examples of imitation but rather as showing how ridiculous and even criminal a man may become by indulging that disposition for singularity which is so apt to possess the mind of the student. Singularity is certainly no evidence of superior genius but rather an evidence of an uncommon share of vanity and ~~unhallowed ambition~~ self-conceit.

Werner's improvements in mineralogy are probably more important than in geology. His method of describing the external appearances of minerals though at first sight a little tinged with pedantry and excessive and useless nicety has been applied with remarkable success. He divides mineralogy into five parts 1. Oryctognosy or the description of minerals their nomenclature and systematic arrangement, 2. Chemical mineralogy which describes the chemical characteristics of minerals and gives an analysis, 3. Geognosy which teaches the structure position and situation of a mineral as found in the earth and indeed everything relating to the mineral constitution of the crust of the globe, 4. Geographical mineralogy or an account of the minerals found in any particular region of the earth, and 5. Economical mineralogy which shows the various uses of minerals in the arts, etc. These distinctions are not all retained by the French and English writers. The whole subject is divided by the most approved instructors of the present-day into mineralogy and geology.

Mineralogy is the science that has for its object a knowledge of all those bodies destitute of organization which exist within the earth or on its surface.

Minerals are of two kinds, simple and compound. Simple minerals are those that appear homogeneous…

Page 3

…and uniform in their composition.

Compound minerals are such as are evidently composed of two or more simple minerals. These compounds are usually denominated aggregates or rocks.

Mineralogy in its most limited sense embraces only the simple minerals and in this sense the term is ordinarily used.

Geology embraces a description of the compound minerals and cannot be understood without some knowledge of simple minerals.

A person is not properly qualified to attend successfully to mineralogy unless you have a previous acquaintance with chemistry and natural philosophy since the aid of the sciences is often needed in the determination of a mineral. External characters are more fallacious in this branch than in any other department of natural history. Indeed so closely are mineralogy and chemistry united that some distinguished writers regard the former is only a branch of the latter.

Simple minerals in their most perfect state exist in the form of crystals: though a few species have never been found in that state. Crystallography is an extremely important and interesting part of mineralogy. In treating of chemistry I have already given an outline of the science. But a more full account of the subject was reserved for this place. I need not however repeat the definition of the crystal nor describe those attractions by which they are produced. It is proper however to observe that these laws have operated not merely in the laboratory of the chemist and where solutions are made artificially. The same process has been most extensively carried on in the great laboratory of nature and there an immense variety of crystals have been produced far exceeding in splendor and perfection those in which human art has been concerned. These crystals vary in their size from 2 feet or more in some other dimensions till their form cannot be determined without the aid of a microscope.

The laws that regulate the crystallization of matter are so uniform that wherever we find a particular mineral substance in the state of a crystal the same variety of form has the same constant quantity in its corresponding angles: and this though the crystals be small or great - whether found in one rock or another. Further this constancy remains even where from accidental causes the faces have changed their dimensions or number of sides. Indeed such is the constancy that obtains in this curious process that the measurement of the angles of crystals is now employed as one of the most certain means of ascertaining the…

Page 4

…species.

This remarkable uniformity and constancy in the angles of crystals will be made more obvious by an explanation of what is called their primary forms. It is found that crystals are made up of an immense number of layers of matter superimposed upon one another in a variety of ways. These layers can be separated from one another leaving a smooth surface if the edge of a knife be applied in the direction in which they run. This is called the cleavage of a crystal. And it is found moreover that these cleavages may be made in a variety of directions. If we take a very complex crystal or one with many sides and cleavages in all the directions in which its layers will separate we shall change its form and at a place bring it to the state in which cleavages can be made which shall be parallel to all its faces. We have now reduced the crystal to what is called its primitive or perhaps more properly its primary form. The form which it had before the cleavage was begun is called its secondary form and hence we have this well marked distinction between a primary and a secondary form: a secondary form is never divisible or has no cleavages parallel to all its sides: whereas a primary form has a cleavage parallel to all its sides.

The immense variety of secondary forms that exist among minerals may all be reduced by cleavage to a very few primary ones. Their number is differently stated by different authors: from six to fifteen. This disagreement however is only apparent. Some make those distinct primary forms which others regard as mere varieties. I am now able to illustrate these forms according to the most approved writers by models.

Professor Cleaveland mentions seven

1. Cube
2. Regular tetrahedral
3. Dodecahedron done with rhombic faces
4. Octahedron with triangular faces
5. Rhomb
6. Four-sided prism
7. Regular hexahedral prism

[Possible reference: Cleaveland, Parker. 1822. An Elementary Treatise of Mineralogy and Geology]

In these primitive forms the cube, the tetrahedron, and dodecahedron admit of no variation in the angles of the faces and consequently the faces always remain similar and equal. But in the octahedron the rhomb and the four sided prism the angles admitting of variation without changing the character of the solid a great number of primary forms differing slightly from each other will be the result. Some writers however reckon some of these varieties as distinct primary…

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…forms and make a little different classification of the whole subject. Mr. Brooke one of the latest and ablest writers on crystallography reckons the following as primary forms.

1. The cube
2. Regular tetrahedron - surface four equilateral triangular planes
3. Regular octahedron
4. Rhombic dodecahedron - 12 rhombic planes
5. Octahedron with a square base
    1. Plane angles at the summits less than 60°
    2. Plane angles at the summits greater than 60°
6. Octahedron with a rectangular base. The planes are generally isosceles triangles but not equal the angles at the summits being more obtuse in two of the opposite planes and in the two other opposite ones.
7. Octahedron with a rhombic base. The planes are eight equal scalene triangles.
8. A right prism with a square base or right square prism: the height of the prism being always greater or less than one of the sides of the base. If equal the figure would be a cube.
9. A right prism with a rectangular base. The opposite planes only are equal.
10. A right rhombic prism whose base is a rhomb and whose lateral planes are equal.
11. A right oblique angled prism or a right prism whose base is an oblique angled parallelogram and whose adjacent lateral planes are unequal. One of these planes must be a rectangle the other may be either a square or rectangular.
12. An oblique rhombic prism or oblique prism whose base is a rhomb and whose lateral planes are equal oblique angle parallelograms. If they were equal rhombs the solid would be a rhomboid.
13. A doubly oblique prism whose bases and whose lateral planes are generally oblique angled parallelograms. Each pair of opposite planes is equal and this is all the equality between the faces.
14. The rhomboid - a solid contained within six equal rhombic planes - having two and only two of its solid angles composed each of three equal plane angles.
15. The regular hexagonal prism or right prism whose bases are regular hexagons.

Integrant particles

The smallest particles into which the body can be reduced by decomposition are called their elementary or constituent particles.

But a body which is a compound may be very minutely divided by solution while the particles still retain their compound nature. And the smallest particles into which a body can be reduced without destroying its nature are called integrant particles. It is these which make up the crystal and it is…

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…a natural inquiry whether their forms can be determined. We can never actually obtain one of these particles so as to bring it under the inspection of our senses since in reference to the senses they are infinitely small. But we can divide a primary form as far as division is practicable and we may conclude that the solid we thus obtain is the form of the integrated particle. Now the primary form in all cases may be thus reduced by cleavages parallel to its sides: and some of them also by diagonal cleavages. It is evident then that some of these integrant particles will have the same figure as the primary form and others a different figure. The forms of integrant particles so far as is known are five viz. 1. the cube, 2. The rhomb, 3. the four-sided prism or the tetrahedron, 5. the triangular prism. These integrant particles are sometimes called molecules and according to Mr. Brooke the molecules of the different classes are primary forms are as follows

$$\left.\begin{array}{l}\text{The cube}\\ \text{Regular tetrahedron}\\ \text{Regular octahedron}\\ \text{Rhombic dodecahedron}\end{array}\right\}\quad \text{Molecule a cube}$$

All quadrangular prisms - molecules similar prisms
Octahedron with square base - molecule a square prism
Octahedron rectangular base - molecule a rectangular prism
Octahedron short rhombic base - molecule a rhombic prism

Rhomboid - molecule is similar rhomboid
Hexagonal prism – molecule is an equilateral triangular prism

It will be seen that Mr. Brooke does not reckon the tetrahedron among the integral molecules of crystals. But he has a new and peculiar theory on the subject which lead him to the above arrangement and which I have no time to discuss or even to explain.

Exhibit models of the integrant particles and also cleave a primary form so as to obtain the integrant particle.

Secondary forms

I have already defined a secondary form of a crystal to be one which does not admit of cleavage parallel to all its faces. The secondary forms are extremely numerous all arising from some modification of the primary forms and hence crystals with secondary forms have usually a greater number of sides than those with primary forms. It is calculated that the crystals of carbonate of lime whose primary form is a rhomboid may assume 8,388,664 distinct secondary forms and the number of these actually found is very great.

The theory which accounts for the production of…

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…the secondary form from the primary form is very ingenious. Before I proceed to explain that theory I will give you one of the easiest examples of the mode in which a secondary crystal may be cleaved to produce the primary form.

From a cube cut out of an apple or potato cleave in such a manner as to produce an octahedron. (Fluate of lime crystallizes in this manner and has an octahedron for the primary form)

Now for the production of secondary forms. If we suppose successive laminae of integrated particles to be applied to the faces of the primary form the effect we are contemplating will be produced. It is necessary however to suppose that each succeeding layer of particles is less in extent than the preceding that is that one or more rows of particles are abstracted either on the edges or the angles of each layer so that the successive layers to form a regularly decreasing series. This abstraction of particles is called decrements or decriments. There are several kinds. When ranges of particles are abstracted from the edges of the laminae parallel to the edges of the nucleus or primary form they are called decrements on the edges. Decrements on the angles are when the same abstraction of particles takes place on the angles of the laminae parallel to the diagonal on the faces of the nucleus. Intermediate decrements are those made parallel to lines and intermediate between the diagonals and edges of the nucleus. Mixed decrements take place when the number of ranges subtracted is greater than unity. Thus the decrement is said to take place by two ranges in breadth and one in height or vice versa.

Exhibit a model illustrating this mixed these mixed decrements.

Exhibit the models that illustrate this subject.

1. That in which a dodecahedron is formed upon a cube by decrements on all the edges.
2. That in which a dodecahedron with pentagonal faces is produced by mixed decrements on the edges.
3. That which exhibits the production of a six sided prism with three rhombs at the summits from a rhomb.
4. That which exhibits the production of a dodecahedron composed of two six-sided pyramids applied base to base - from the rhomb by mixed decrements on the edges. This represents the hogtooth spar.

We are not able often to see this process of deposition of laminae and abstraction of particles actually going on. These particles are so small that when the…

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…secondary form is produced in this manner a smooth and even brilliant surface will still be presented. In some instances however we can catch a glance at the process.

Exhibit a crystal of rock salt that shows these decrements.

The most important use of crystallography is its application to the determination of the species of minerals from the forms of their crystals. To be able to do this requires a more minute knowledge of crystallography than can profitably be given in a public lecture. We can only state general principles. In the first place different mineral species may belong to the same class of primary forms. If the primary form be a cube, regular tetrahedron, regular octahedron, or rhombic dodecahedron, the angles and different species will be the same: but if any other solid be the primary form the species always differ from each other sometimes in the angles of which their primary planes incline to each other and sometimes in the relative lengths of their primary edges. In other words where there is a change in the ingredients of a mineral there is a change also in the angles or edges of its crystals. Even a slight change in the proportions of the component parts is sufficient material to affect the form of the crystal. The few apparent exceptions to this principle are gradually disappearing as a composition of minerals is more thoroughly understood and the angles of crystals more accurately measured.

To obtain then an accurate admeasurement on the angles and relative links of the sides of primary crystals is an important point in the determination of species. But the great difficulty in the case is that few minerals occur crystallized under their primary form. The inquiry then arises is there any mode of determining the primary form of a crystal from its secondary form without actual dissection? This has been attempted by Mr. Brook by giving us a table of the modifications of the different classes of primary forms with a systematic mode of description with the quantities of the constant angles and descriptions of anomalous cases: and it cannot be doubted but some degree of success has attended his efforts. All the crystals he describes which include no only those discovered in nature but also those that are possible according to the theory are arranged according to the number of planes under which they are contained in seven classes: 1. Those contained within four planes, 2. Those within six planes, 3. Within eight, 4. Within 12, 5. Within 16, 6. Within 24…

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…and 7. within 48. But to go into a detail of his tables of modifications would be tedious and without numerous models unintelligible.

Exhibit models illustrating modifications of the cube.

<u>Hemitrope and intersected crystals</u>

[Greek words]

Hemitrope crystals are an anomalous variety of secondary forms. They are turned macles by Haüy. They are called hemitrope from their resemblance to certain crystals slit in a certain direction and the sections turned half round an axis passing through the center of the planes perpendicularly.

Exhibit a model of an octahedron half turned around.

Hemitropes are known by the entering angle formed by some of their planes. For example feldspar - second example titanium and sphene.

Intersected crystals are similar to hemitropes and are formed by the same general laws.

Exhibit staurotide.

<u>Epigene and Pseudomorphous crystals</u>

In epigene crystals a chemical change has taken place in the substance of the crystals subsequent to its formation. For example blue carbon and red oxide copper are converted in green carbonate. Notice the black carbonate lead from New Haven cabinet.

Pseudomorphous crystals have been formed either within cavities from which crystals of some other substance have been previously removed or by some natural causes upon crystals of some other substance that have subsequently disappeared.

Exhibit both sorts of pseudomorphous crystals.

Goniometers

1. Describe the common one
2. Describe the reflecting goniometer of the Dr. Wollaston.
See plate of this instrument in Brooke pg. 30.

[Possible Reference: Brooke, Henry J. 1823. *A familiar introduction to crystallography*.]

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Description of crystals

To enter into all the details of the mode of describing crystals would I fear be thought too prolix and not profitable in this place. To become an acute mineralogist however a knowledge of this mode is indispensable. But it will be learned more thoroughly from the treatises on the subject such as Cleaveland and Brooke. There are some terms of such universal and frequent use mineral descriptions that I feel called upon to notice them.

Among mineralogical writers we find two methods of describing crystals having the secondary form. By some certain forms are assumed and called the predominant form in other words the geometrical forms to which the given crystals most approximate is thus denominated. These are reduced to six: 1. a prism 2. hexahedron 3. A pyramid 4. a dodecahedron with pentagonal faces 5. A dodecahedron with rhombic faces 6. An icosahedron having 20 triangular faces. Some add a trapezoidion or solid with 24 faces. The variations of crystals from these predominant forms is regarded as their modification.

[Note the previous paragraph is marked "Obsolete" in the margin.]

Mr. Brooke however has given us tables and figures of the different classes of modifications that take place in his fifteen primary forms: and by using the same letters throughout to designate correspondent parts he hopes to enable the student to determine what is the primary form from the secondary and to describe any secondary crystal whose primary form is known. In both these methods similar terms are employed to designate the modifications of crystals.

When the faces of planes of crystals are very small they are sometimes called facets.

When an angle or an edge of a crystal is cut off the edge is said to be truncated - and to be replaced by the new face.

Exhibit sulfuret of iron truncated on the angles. Also remark upon the terms as not strictly correct.

When two contiguous segments are removed from the edges or angles or terminal faces of the crystal so as to form two new faces it is called a <u>bevelment</u>.

Exhibit specimens or models in illustration.

When a pyramid stands one or both ends of a prism that prism is said to be terminated or acuminated by a pyramid. Sometimes also these terms are applied to a solid angle which is replaced by [????] new planes.

Exhibit specimens (for example quartz) or models in illustration.

When a secondary plane replaces an edge and is parallel to it and inclines equally on the two adjacent…

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…primary planes or when such a secondary plane replaces a solid angle and inclines equally on all the adjacent primary planes it is called a tangent plane and is a term much used by the latest writers on crystallography.

Illustrate a tangent plane by models.

I have already described the cleavage of a crystal as simply the splitting of it in the direction of its laminae. The direction in which the crystal can be split is called the direction of the cleavage or the natural joint. The integrant molecules may be so arranged that a crystal shall have a cleavage in two are more directions one parallel to the plane of the primary form and the other in a diagonal line. The first of these is called the primary set of cleavages and the second a supernumerary set or cleavage.

Few crystals are found possessing that perfection in all the parts which the theory supposes. Sometimes one or more of the sides are extended and the other left deficient and still oftener the edges and angles are blunted and rounded. These imperfections probably arise from some disturbing cause operating at the time of their formation. When the edges of a prism are much rounded it is denominated cylindrical - when the crystal is long and very minute and so imperfect that its faces cannot be distinguished it is said to be <u>acicular</u> or like a needle (Exhibit specimen) a <u>capillary</u> crystal is even more minute and a little curved - a <u>lenticular</u> one resembles a convex lens (show specimens).

<u>Groups of crystals</u>

<u>Fascicular</u> like a bundle of rods (hornblende)
<u>Scopiform</u> like a worm (hornblende)
<u>Manipular</u> like a sheaf (hornblende)
<u>Dendritic</u> like a tree
<u>Reticulated</u> net work

Although I have become tedious gentlemen in these details concerning crystals yet I assure you I have only touched the limits of the subject and only so much of it is deemed indispensable to any one who means to understand mineralogy. Those who have a mathematical taste will be gratified in pursuing the subject farther and entering into the somewhat intricate but curious calculations connected with it. And here I cannot but express the conviction that one of the principal reasons why among so many collectors of minerals there are so few thorough mineralogists is that they are unwilling to go through…

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…the labor of studying crystallography.

[Much of the biographical information on Haüy appears to have been taken from Griscom, J. Biographical Notice of Haüy, AJS vol. 8, no. 1, 1823, pp. 362ff.]

I cannot close my remarks upon this part of mineralogy without adverting for a moment to the learned and amiable men to whom we are principally indebted for the science of crystallography. For it was the Abbé Haüy [Rene Just Haüy 1743-1822] who first disclosed the true structure of crystals and formed the beautiful theory of decrements. He was born in France more than 80 years ago and died in 1822. He was a son of a poor weaver and his precocity of talent excited the attention of some individuals who were able to assist him in obtaining an education. His proficiency was very rapid especially in the physical sciences and in natural history and these branches he pursued with zeal through a long life.

The manner in which he worked to make such discoveries in crystallography was remarkable. After having become a proficient in botany he attended the lectures of Dauberton on mineralogy and was led to inquire how it was that the some stones and salts should at one time assume crystal form so very different from their form at another time without the change of a single atom in their composition "while the rose has always the gland the same flexure the cedar the same height and development?" While occupied with such thoughts he one day awkwardly though luckily let fall a beautiful group of prismatic crystals of calcareous spar and observed that some of the broken fragments presented perfectly formed rhombs precisely similar to the Iceland spar. In a moment the fundamental principle of crystallography flashed upon his mind and he cried out, "the mystery is explained." This circumstance reminds us of the acorn which fell upon the head of Sir Isaac Newton as he lay in the shade of the oak and excited the fundamental idea of his noble system of gravitation: and still more nearly related to the case of Haüy was that of Archimedes when he discovered the motive determining specific gravity by bathing and excited by the discovery he rushed naked from the bath running through the streets of Syracuse and crying out Eureka! Eureka! [In Greek] You remember too how Archimedes when Syracuse was taken requested the Roman soldier who broke into the study to wait for him to leave and finish a particular problem and thereby lost his life: in a similar circumstance could well-nigh prove fatal to a Haüy. He lived unfortunately in those disastrous times when the fiery waves of revolution poured with such fury over France not sparing even the retired votaries of literature and science. Refusing to take the oath of allegiance to one of the new constitutions that were almost monthly imposed upon France he was stripped of all his perquisites and was reduced to extreme poverty. In his humble retreat…

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…however he still continued his favorite pursuits heedless of the storm that raged around him and when his retirement was invaded by soldiers who demanded whether he had any fire arms: "I have no other than this" said he drawing a spark from his electric machine. They dragged him however to prison along with other priests who were shortly to be immolated. Calm and unsuspicious however he only sent for his drawers of crystals that had been overturned by the soldiers that he might rearrange them. In his new cell he continued his studies not knowing the fate which was preparing for him by his bloodthirsty persecutors. By the active exertion of his friends without an order was at length obtained for his release and his friends hasten with it to the prison. But being late Haüy could not be persuaded to go that day - the next day he was taken out almost by force - and the day after that was the horrid 26th of September! [Massacres du Septembre, 2 September 1792]

Such a narrow escape from massacre did not however change the conduct of Haüy. He did not hesitate to perform his daily functions as a priest in the city when death was declared to be an eternal sleep and resistance of God publicly denied: and when Lavoisier was a arrested and Borda and Delambre deposed Haüy alone could write and did write in their favor, "At such an epoch," says his biographer, "his impunity was even more surprising than his courage."

It happened however that this amiable naturalist survived the fury of the revolution when so many men of science were buried in its waves. Honors thickened upon him and he was elevated to one office of distinction after another and became known and respected throughout Europe while from every quarter his cabinet of crystals was enriched until it became the finest in the world. Being in a measured dependent upon the French government however for support he not infrequently suffered from its unsettled character and in one instance the only answer his friends could attain to their solicitations in his behalf was that "there was no connection between the public contributions and crystallography." But neither adversity nor prosperity seemed to produce much change in his character for it is to be hoped that piety was the foundation of it. "It is his praise," says Col. Gibbs, "that he has preserved the meekness of religion amidst the most flattering success." "As pious as he was faithful to his studies," says Baron Cuvier, "the most sublime speculations could not divert him from any of the prescriptions of the ritual and upon all worldly objects he placed just a value which they might be expected to hold in the eyes of a man penetrated with such sentiments. From the course of his pursuits the most beautiful gems which nature produced…

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…came under his observation, and he published a treatise especially upon them but without regarding them in any other light than as crystalline forms. A single degree more or less in the angle of a <u>schorl</u> or a <u>spath</u> would undoubtably have interested him more than all the treasures of the two Indies."

<u>External or physical characters of minerals</u>

The characters of minerals are usually divided into two kinds physical and chemical having reference to the branches of science on which they are dependent. The physical characters are also called external characters because they are obvious to mere inspection combined sometimes with a simple experiment.

1. External Characters

An accurate notion of the terms employed in this branch of mineralogy is indispensable to a right apprehension of the description of minerals. Still more important are they to one who would himself attempt such a description.

1. Colours

One of the most striking but least valuable characteristics. Mention the two sources of most colours viz. different proportions and degree of oxidization of metallic oxides and reflection of light.

Eight colours are assumed as fundamental in the description of minerals and all others are regarded as varieties of these.

1. White

Varieties

1. Snow white - example incense – Genoa marble
2. Reddish white - porcelain Earth – Brown spar

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3. Yellowish white - zeolite
4. Silver white – native silver - mica
5. Greyish white - common quartz - granular limestone
6. Greenish white – Amaranth - talc
7. Milk white - common opal
8. Tin white - white cobalt or native antimony

2. Grey

varieties
1. Lead grey - Galena - graphite
2. Bluish grey – hornstone – clay slate
3. Pearl grey – Flour silver - common quartz - porcelain - jasper
4. Smoke grey - Flint - Horn Stone
5. Greenish grey - clay slate common Jasper maker

6. Yellowish grey - Indurated Marl - Clay Ironstone
7. Steel grey - grey copper or radiated grey manganese
8. Ash grey - Basalt Wake close Lite

3 Black

1. Greyish black basalt - limestone - basaltic hornblende
2. Iron black - magnetic iron sand micaceous iron
3. Greenish or Raven Black - serpentine hornblende pitchstone
4. Brownish or pitch black - black blend - tinstone – bituminous slate
5. Dark or velvet black - obsidian - Lydian Stone
6. Bluish Black - black lead ore

4 Blue

1. Indigo blue - blue iron Earth - sapphire - tourmaline
2. Russian blue - sapphire - warm copper
3. Azure blue - blue Lapis lazuli
4. Violet blue - fluorspar amethyst apatite
5. Plum blue - spiral arsenite
6. Lavender blue - porcelain - jasper
7. Smalt blue - Blue iron Earth - arsine copper
8. Sky blue - feldspar turquoise

5 Green

1. Verdigris green - copper green fluorspar
2. Seladon green - green earth beryl
3. Mountain Green - Moonstone actinolite
4. Emerald Green - Emerald fluor
5. Black green - nephrite prase augite
6. Apple green - chrysoprase
7. Grass green – Uran mica malachite
8. Blackish green - serpentine hornblende
9. Pistachio green - chrysotile Garnet
10. Asparagus green - chrysoberyl - asparagus stone
11. Olive green - Olivine Garnet
12. Oil green - barrel pitchstone Fullers earth
13. Siskin green - Uran – mica - green iron earth

6. Yellow

1. Sulfur yellow - native sulfur
2. Brass yellow - copper pyrites

3. Straw yellow - calamine Mika
4. Brown or bellmetal yellow – Iron pyrites
5. Wax yellow - opal yellow lead ore
6. Honey yellow - honey stone Amber
7. Lemon yellow - orpimint

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8. Gold yellow - native gold copper pyrites
9. Ochre yellow - yellow earth brown Ironstone
10. Wine yellow - topaz fluorspar
11. Isabel or cream yellow - calamine - mountain cork
12. Orange yellow - chromate lead

7. <u>Red</u>

1. Aurora red – sealgar blend
2. Hyacinth red - hyacinth garnet
3. File red - common clay - jasper
4. Scarlet red – red cinnabar
5. Blood red - garnet - camellia - jasper

6. Copper red - Native copper
7. Carmine red - red copper or cinnabar
8. Flesh red - feldspar
9. Crimson red - noble garnet - amethyst
10. Rose red - rose quartz red manganese
11. Peach blossom red - cobalt bloom lepidolite
12. Columbine red - noble garnet - red cobalt
13. Cherry red - red antimony - red iron froth
14. Brownish red - jasper clay ironstone

8. <u>Brown</u>

1. Reddish brown - brown tin-stone - blende
2. Clove brown brown Ironstone rock crystal
3. Hair Brown – wood tin wood opal
4. Broccoli brown - zircon
5. Chestnut brown - Egyptian jasper opal jasper
6. Yellowish - brown – ironstone – cats eye
7. Pinchback brown - magnetic pyrites mica
8. Wood brown - bituminous wood brown coal

9. Liver brown - brown earthy cobalt semi opal
10. Blackish brown - mica - brown coal

Colours are often arranged in stripes veins clouds or dots - Exhibit examples .

Minerals that have been partially acted upon by air and moisture sometimes exhibit a colour at the surface very different from the interior called tarnished colours - such as iris pavonine etc.

Chatoyment or Play of Colours

Different colours appear and disappear as the position of mineral changes - examples cat's eye – Labrador feldspar - this property sometimes called opalescence. Different parts of the mineral seem to possess the property of reflecting different rays of light modified too by refraction.

2. Lustre

This varies exceedingly in different minerals. When spoken of reference is always had to the internal not the external lustre unless otherwise mentioned. It is described by comparison with some well-known substance. Thus when the lustre resembles broken glass it is said to be vitreous - adamantine when like the diamond pearly one like the pearl…

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…Metallic one like pure metals etc. etc.

3. Transparency

An obvious property. Minerals are semitransparent when objects are seen through them indistinctly - translucent when light passes but objects cannot be seen through them - transparent on the edges when light passes through the edges only - opaque when no light passes – hydrophanous when they become more or less transparent on being plunged into water.

4. Refraction

That transparent crystals should possess the property of refracting light is what we might expect from the same power in other transparent media. In certain minerals however a peculiarity already is observable in their refraction. It was first noticed in the Iceland spar a variety of carbonate lime. Objects seen through a crystal of this spar appeared double in other words they have the power of producing double refraction. Mention how to observe this property by laying the mineral upon a black sight line or circle or by viewing a pin held up before a window. Many other minerals have been found possessing the same property - few of them so decidedly however as the Iceland spar. In many instances it is necessary to view the line through two faces of the mineral either natural faces or artificial ones. Makis, Arago, Biot and Brewster have recently brought to light many interesting facts and principles on this subject and one connecting with it viz. polarization of light. Indeed the subject may be regarded as growing up into a distinct and profound science. The best account of it may be found in the Edinburgh Encyclopedia article Optics.

Exhibit specimens illustrating double refraction. The crystal must not be viewed through two continuous facets at the same time for that would be ordinary refraction. Place the object in one plane and look at it through another inclined to its equator.

5. Forms

Regular forms have already been sufficiently considered under the crystallography of minerals.

Minerals are said to be a imitative form when they resemble some other body in figure. They are the results of a confused crystallization and hence they possess a lamellar or fibrous structure though sometimes they are mere concretions.

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Cylindrical structure - more or less hollow
Dentiform – like a tooth
Filiform - like a thread asbestos
Capillary - like a hair asbestos
Dendritic and arborescent - like a tree
Coralloidal - like coral
Ramous - having branches
Reticulated - like a net
Pectinated - like a comb
Stalatical - like an icicle
Botryoidal - like a bunch of grapes
Mammillary - when smaller segments of larger spheres are presented through the botryoidal form
Reniform - like the kidney
Specular like a mirror

Encrustations - deposits in the forms of a crust on other minerals or vegetables.

Geode - a spherical cavity lined with crystals.

Amorphous forms. Such as are neither singular nor imitative - indeterminate irregular (Greek word)

6. Surface

The external surface of minerals (to which this term usually applies) is said to be granulated when covered with minute roundish grains: dusky when covered with minute crystals; striated when marked with small striae or channels.

7. Touch

A characteristic of some importance. Some minerals are smooth to the touch: others rough especially in powder: others in powder are said to feel dry or meagre: others feel soft or greasy and are said to be unctuous.

8. Coldness

Some minerals are better conductors of heat than others and therefore feel colder.

9. Odor

Few minerals have any odor. Some however are bituminous others sulphureous - others alliaceous or like a garlic - others empyreumatical - like burnt substances others earthy or argillaceous especially when breathed upon - others fetid when heated or struck with a hammer

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10. Taste

The few minerals which are so far soluble in the saliva as to produce taste are described by terms in common use and therefore it is not necessary to repeat them here.

11. Adhesion to the tongue

Argillaceous substances particularly possess this property which depends upon the power of absorbing moisture. In other cases the mineral seems to be in a state of partial decomposition. Example Potters Clay.

12. Soil or stain

This is the trace some minerals leave on paper or other white substances when rubbed upon them. The degree of this property may be denoted by comparative terms. It should be noted also whether the colour of the trace be the same as that of the mineral or unlike it - example Plumbago Black wad.

13. Streak and powder

The colour of the powder in some minerals is very different from that of the mineral itself. Even a mineral exhibiting several colours may in the state of powder present in uniform colour. Hence the colour of the powder becomes a property of considerable importance.

It is the powder that is exhibited in the streak of a mineral that is when a scratch is made upon it with a substance harder than itself. Examples micaceous oxide of iron.

14. Distinct Concretions

In some instances minerals are made up of somewhat distinct layers united by a seam through which they will separate more easily than any other direction. These layers and seams form what are called distinct concretions. The form of these concretions is said to be granular when they are more or less round, lamellar when straight or curved and columnar when they have a tendency to a column in our figure. Example agate.

15. Flexibility and elasticity

These two properties need no definition and they are not often found in minerals though some may be rendered flexible by the application of moderate heat. It should always be noticed whether a flexible mineral is also elastic that is whether it returns to its original position when bent – a property by no means common. Examples mica and talc.

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16. Sound

Not a remarkably good character. Different minerals however possess different degrees of sonorousness, and this property varies as the form is more or less tabular.

17. Cohesion

Minerals with strong cohesion are called solid when easily crumbled down – friable or earthy - when liquid - fluid.

18. Hardness

The relative hardness of minerals is an important character although the same species is libel to a slight variation in this respect through partial decomposition or the presence of some accidental ingredient. A mineral may be very hard and yet easily crumble to pieces that is its grains may be hard while the mass is friable.

One mode of describing the hardness of a mineral is by noticing the effects of a knife or file upon it. When these make no impression it is extremely hard: when a file produces a little effect very hard: when but little very little by a knife hard: semihard when it yields without much difficulty to the knife but does not give fire with steel: soft when easily cut with a knife but receives no impression from the fingernail: very soft when the fingernail impresses it.

A better method of describing this hardness is to observe in what order minerals scratch each other. For example diamond sapphire chooses chrysoberyl garnet quartz feldspar phosphate lime carbonate lime and sulfate lime in this order each mineral scratches all those that follow it.

The angles and edges of the primary forms of crystals are considerably harder than those of the secondary forms.

Danger of the suction in scratching one mineral with another unless the surface attempted to be scratched be washed. See Shepard's Mineralogy page 116.

19. Structure

The most perfect instances of the structure of minerals has been already considered in describing the crystals. The term however is usually employed to divide the internal natural appearance of minerals which is fractured. This will depend upon the shapes…

…and arrangement of the minute parts of which the mineral is composed. The following are the most common structures exhibited by fracture.

<u>Fibrous structure</u>. This is best exhibited when the fracture is in the direction of the fibers: and these may be coarse or fine broad or narrow straight or curved parallel or diverging.

Exhibit specimens <u>fascicular</u>, <u>scopiform</u>, <u>radiated</u> and <u>promiscuous</u> fibers in the fasciculite and cummingtonite.

<u>Foliated laminated or lamellar structure</u>. This is exhibited in minerals composed of thin plates or laminae. These terms are all employed indiscriminately to denote this structure. Foliated however is the most general turn indicating nothing in regard to the size of the foliar laminae. Laminated is usually applied to minerals whose laminae are large. Lamellar to those whose laminae are small.

Sometimes the plates are long and narrow and very thin at one edge which is called a bladed structure.

<u>Slaty structure</u>. In this structure the layers are somewhat thick and extensive and either staggered combed or undulated .

<u>Granular structure</u>. When the grains of a mineral are large enough to be seen by the eye or even with the glasses structure is said to be granular. When these grains cannot be distinguished for example jasper the mineral is said to have a compact texture.

20. <u>Fracture</u>

In some instances when we fracture a mineral the surface of the fragments exhibit a particular structure which did not exist naturally in the mineral that was produced by the fracture (for example splintery fracture). In such cases the term fracture is used rather than structure to denote the appearance of the surface of the fragments. The principal kinds of fracture exhibited on breaking minerals are these:

<u>Splintery fractures</u> - surface nearly even but small splinters or scales exhibited. Example serpentine.

<u>Even fracture</u> - surface nearly plain - grey quartz

<u>Conchoidal fracture</u> - surface exhibiting concavities and convexities as if impressed by a shell - example jasper.

<u>Uneven fracture</u> - numerous inequalities elevations usually sharpen angular

<u>Earthy fracture</u> - surface rough grains very minute Example chalk

<u>Mackeley fracture</u> - Peculiar to metals - surface presenting numerous sharp points perceptible in passing the finger over it.

Fragments of regular crystals will usually present prismatic rhombic cubic or trapezoidal forms. Fragments may also be <u>cuneiform</u> like a wedge <u>splintery</u> - tabular etc.

21. <u>Tenacity</u>

This property depends upon the strength of the cohesion between the particles . Minerals possessing it in a high degree for example many of the metals are ductile and malleable. If they can be cut with a knife and the particles not fly away they are said to be tactile.

22. <u>Magnetism</u>

Iron nickel and cobalt are the only simple substances that can be made permanently to affect the magnet. Iron is the only one that operates in nine cases out of ten. Even some of its oxides possess the property.

Magnetism if strong may be detected in a mineral by holding it near a magnetic needle. But in many instances the power is so weak it is necessary to employ what is called double magnetism. Explain what is meant by this term.

23. Electricity

Electricity of minerals may be observed in a variety ways. We may make use of silk threads suspended or we may take a common magnetic needle when we are sure that mineral is not magnetic and hold it near the poles where it will be moved if electricity be excited. Or a still better mode is to prepare an electrometer almost exactly like a magnetic needle except using copper instead of iron and terminating the ends of the needles with balls. (See Cleaveland also Comstock).

Minerals do not exhibit electric properties until an effort be made to excite the electric power. Some for example Iceland spar will become electric by merely pressing them between the fingers. Others exhibit electricity by friction. Others require to be heated either before the fire or by plunging them in hot water. In this latter case they acquire both positive and negative…

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…electricity. And in such a manner too that on whatever part of the specimen negative electricity appears the positive will be exhibited on the side directly opposite. It is a curious circumstance too that the two opposite portions of the crystal that exhibits these opposite electricities are almost always different from each other in their configuration or number of sides and when a crystal does not become electric by heat it is usually found that the opposite sides are similar.

In order to determine whether a mineral possesses electric polarity we have only to present the different sides of it to an electrometer and if the property exists it may well be perceived by the attraction on the one side and the repulsion on the other. In order to determine whether the electricity be positive or negative we must communicate either the one or the other of these electricities to some substance and then by observing the attractions and repulsions between them and the mineral we can determine the character of electricity: always bearing in mind that similar electricities repel and opposite electricities attract each other.

24. <u>Phosphorescence</u>

When a body shines with a feeble light but emits no sensible heat it is said to phosphoresce. Some minerals are so easily made phosphorescent that they will exhibit this property by being brushed with a feather. Others need to be rubbed against each other. But the best method is to reduce the mineral to coarse powder and then project it upon a hot shovel heated a little below redness.

This property is in general more clearly exhibited in minerals that have colour: it is not essential to the species some varieties which exhibit it while other varieties of the same species are destitute of it. The colour of the light is variable and may even change during the experiment.

25. <u>Specific gravity</u>

The relative weight of minerals is an important property particularly in those that occur under a crystalline form. For though the presence of…

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…accidental ingredients may slightly modify the weight still by taking the means of a number of specimens we can obtain a good degree of accuracy.

In all cases when the specific gravity of a mineral is spoken of water is assumed as 1 in the standard of comparison. Now it is evident that any body that will sink in water will displace a quantity of water equal in bulk to itself and as water presses equally in all directions the body will weigh as much less when immersed in it as the weight of the water displaced. Hence the difference between the weight of a body in water and the air will be just equal to the volume water equal in bulk to the body itself. The weight of the body in the air then divided by what it loses in water will show how much heavier it is than water - that is the specific gravity. If the mineral be lighter than air and the weight that is necessary to make it sink in water to its weight in the air: then say as they sum is to its weight in the air so is one to the specific gravity.

Take the specific gravity of a mineral before the class.

Notice Nicholson's Portable Balance.

<u>Chemical characters</u>

These are so called because it is the business of chemistry alone to determine them. A complete analysis of the mineral though often exceedingly important in settling its place among other minerals is not included in what are called chemical characters. In general the experiments for determining these characters are simple and easy requiring that little apparatus and few ingredients.

1. <u>Fusiblity</u>

When a mineral can in any way be melted or fused by the use of atmospheric air…

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…it is said to be fusible. If a stream of oxygen and hydrogen be employed for the purpose as in the compound blowpipe the circumstance must be mentioned.

The instrument commonly employed in examining the fusibility of minerals is the common mouth blowpipe. Describe the instrument – the mode of using it - a new method by employing a gazometer to supply air. Some minerals melt into scoria others into glass others into enamel. When infusible bits of some other mineral are diffused through the melted mass a <u>frit</u> is produced.

Notice <u>fluxes</u>. Borax - white and black flux.

Notice the Compound Blowpipe. No mineral now remains I believe which has not been fused by this instrument.

2. <u>Action of acids and other tests</u>

Sulfuric muriatic and nitric acids are those most usually employed being diluted with two or three parts of water. Describe the manner of applying this test and the effects.

Other chemical tests are sometimes employed in examining minerals: but it will be better to mention them under the particular minerals in whose examination they are needed.

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<u>Arrangement of minerals</u>

Peculiar difficulties present themselves in attempting a systematic classification of minerals. In the organic departments of nature the differences as well as resemblances between different objects are usually strongly indicated. By reproduction and the exclusion of nonessential ingredients and properties in animals and plants the identity of the species is preserved and exhibited. But in minerals which are incapable of reproduction and which admit ingredients into their composition foreign to their nature and unessential to the species this identity is often much observed and often entirely lost.

The grand point in classifying minerals is to determine what constitutes a species. In zoology and botany we observe those individual plants or animals which agree and their characters and put them together into species. Observing several species to agree in certain characters we can put the species together into a genus. In the same manner by neglecting the points in which the genera disagree with one another and turning the eye upon certain general points of resemblance we can collect these genera into orders and proceeding in the same way with the orders collect these into classes.

These same principles so far as they can be applied are to be employed in mineralogy. Hence the necessity of determining species. But what shall we assume is the essential characteristics of a species. Werner and his followers Jameson and Mohs tell us that the physical or external characters are to be exclusively employed in distinguishing species. “This,” says Jameson, "which may be called the Natural History Method I have always considered as the only one on which minerals could be scientifically arranged and the species accurately determined." This principle however which is carried to its fullest extent in the works of Jameson and Mohs often separate substances the most nearly related in their nature. For example different ores of the same metal are placed some in the class of metals and some in the class of earth and in one instance…

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…a variety of arsenate of copper is placed in one order while the other varieties are placed in another order.

By other mineralogist the crystallographical characters the minerals are used to distinguish the species though none have attempted to apply this principle to all minerals because some are not crystallized and therefore we can know nothing concerning the primary forms of these crystals. In such case resort is had to external or chemical characters. In many cases no doubt mineral species may be determined with great accuracy by measuring the angles of their crystals. It is not possible even with the reflective goniometer to ascertain the quantity of angles of crystals with that strict precision which would be indispensable to make the measurements the basis of classification. The most accurate crystallographer cannot be certain of his results so near as to minutes of a degree and sometimes not nearer even than two degrees. Now we cannot say but many very distinct species may have primary forms different from each other in their angles even less than one minute. We do know that some species do not differ more than a degree from each other in this respect, for example carbonate lime and carbonate iron. Although therefore the crystallographical characters of minerals be an important auxiliary in determining the species they are too imperfect in the present state of the science to admit of being made the basis of a systematic arrangement.

The optical characters of minerals has of late occupied the attention of several distinguished men and hopes were entertained by Dr. Brewster that these would furnish the means of accurately distinguishing one species from another. But here too we are likely to be disappointed. Dr. Brewster on examining specimens of apophyllite from different localities found the optical characters of one variety so decidedly different from the others that he proposed to erect it into a new species under the name of Tessellite. Brewster however analyzed this variety and found its chemical composition to agree exactly with the apophyllites from other localities and Brooke about the same time determined its crystallographical characters also to agree with their other apophyllites. No one surely would think of calling this specimen a new species in opposition to chemistry and crystallography…

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…merely because its optical characters were somewhat different from the other varieties. So that it is probable for this trial the optics will fail of affording the principle of classification we need.

Another method proposed for distinguishing the species of minerals is by their chemical composition. This at first few seems to be a proper and the only proper mode of arrangement and it is accordingly adopted by many of the most distinguished neurologists. We cannot depend upon the color, form, fracture, hardness, or refraction of minerals because these characters vary in individuals of the same species. But when we find minerals uniformly composed of the same ingredients there can be no doubt but they belong to the same species. In such cases although the external characters often vary the crystallography with one or two exceptions does not. And I hesitate not to say that chemical composition is the true basis of mineralogical arrangement so far as it can be adopted.

But this method is not without its difficulties. In cannot in all cases be adopted.

For in the first place we have no means of determining in all cases what ingredients are essential in the composition of a mineral and what are not so. The siliceous limestone of Fontainebleau for example consists of more than 50% of sand and yet its crystals have precisely the form of pure carbonate of lime: which shows that the sand is only an accidental ingredient and not chemically combined with the lime. And so in a multitude of other instances we meet with the same difficulty. Almost all the metallic ores however in some of the combustibles and the alkaline and earthly salts the composition is so well-settled as to afford a good criterion in distinguishing species. We may consider the arrangement of these classes of minerals therefore as settled. But in the extensive class of minerals composed chiefly of the different earth their essential composition is not yet sufficiently understood to be made the basis of specific and even generic arrangements. We can indeed obtain with a good degree of accuracy the composition of particular specimens but we know not in what manner the ingredients are combined nor which of these are essential nor whether some may well be accidentally present. And…

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…besides this different analysts give us different results. And how should we determine which of them is most accurate?

How then shall we dispose of the earthy class of minerals? We must resort to other characters until the further progress of chemistry shall enable us to analyze them according to their composition. And next to their composition their crystalline form unquestionably furnishes the best criterion of arrangement. It so happens too that many of these earthy minerals are so perfectly crystallized as one ablest to apply their crystallographical characters and assigning them their specific place. But when these characters cannot be ascertained as is the fact in quite a number of instances we must then resort to their physical or external characters and arrange them accordingly. Such an arrangement however must be regarded as provisional merely to be altered as soon as chemistry puts into our hands the means of more accurate discrimination.

We are now prepared to give a definition of what constitutes a mineral species, viz. "a collection of minerals which are composed of the same ingredients combined in the same proportions." Many who leaned very much to the use of characters derived from the crystalline form varies this definition, “a species is a collection of bodies whose integrant particles are alike and composed of the same principles united in the same proportions."

In grouping together species into genera chemistry seems to be our best guide. Those species may be classed in the same genus that contain some common predominant ingredient and resemble each other in chemical properties. For example lime and an acid.

An order is composed of those genera whose bases resemble each other in their nature. For example an earth united to the acids.

The relations by which classes are formed from Orders are more general. Thus in the first class we include all those minerals not metallic which are composed entirely or in part of an acid. In the second class we place the Earthy compounds. In the third class the combustibles. And in the fourth class the ores.

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This is the classification adopted by Professor Cleaveland and which I shall follow in the present course. Other arrangements may be found in the different mineralogical systems that are extant. Professor Mohs the successor of Werner at Freyberg divides minerals into…

[space was left here as if he intended to complete this thought later]

Mr. Phillips has a classification different from that of Mr. Cleaveland. His division is 1. Earthy minerals, 2. Alkaline earthy minerals, 3. Acidiferous earthy minerals, 4. Acidiferous alkaline minerals, 5. Acidiferous alkaline earthy minerals, 6. Native metals and metalliferous minerals, 7. Combustible minerals. Mr. Brooke has an ingenious arrangement of minerals according to their alphabetical order without losing sight altogether of their chemical and crystalline graphical affinities. Notice also the new arrangement proposed by Dr. Emmons.

Notice the synonyms (synonymia?) of minerals.

Also the geological relations.

[At the bottom of the page he has listed citations for various systems of classification]

See Jameson's Mineralogy Volume 1 page 17 Introduction (1820)
Mohs Mineralogy (1825) Vol. 1 page 391
Also Emmons Jr.
Also Harry's Mineralogy Vol. 1 introduction
Also Becidant's Mineralogy Vol. 1 page 520 and Vol. 2 page 735 (1830)
Also Shepherd's Mineralogy Vol. 1 page 148
Also Cleaveland Vol. 1 page 99

[The remainder of the notebook, pages 30 to 51, includes two classification systems for minerals and a few comments. I have transcribed only a few headings and comments. Pages 37-38 appear to have been inserted later.]

Class 1: Substances not metallic composed entirely or in part of an acid

Order 1: Acids not combined

Order 2: Alkaline salts
Order 3: Earthy salts

Pages 37-38

[A single sheet that may have been inserted later]

Ornamental stones: marbles, granite, syenite, prophyries, serpentine, agates, lapis lazuli, malachite, jasper.

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Class 2: Earthy Compounds or Stones (rest of page is blank)

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Classification of Minerals According to their Utility

Class 1: Minerals employed in the useful arts (acids, salts, earthy compounds, combustibles, metals and ores)

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Ornamental minerals:

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Cabinet minerals or minerals useful only to illustrate the science

SHELLS LECTURE NOTES

[Edward Hitchcock classroom lecture notes, "Shells", "Mineralogy", EOH, Box 10, Folder 11.]

[Parts of this lecture seem to be related to or perhaps even belong to the “Gentlemen Geology” lecture. See in particular the list of rock types that begins here with #12 Common Feldspar; that seems to be a continuation of the list in the other lecture.]

158 genera and many hundred species formed fossils — Edinburgh Encyclopedia Arts – Organic Remains

Shells are divided into

1. Univalves
2. Bivalves
3. Multivalves

A fourth division is necessary for those fossil shells which though externally appearing like bivalves contain numerous septa by which they are divided into many chambers.

Exhibit numerous shells in a fossil state

===

In 1824 fossil species of shells known 2529

	Genera species found fossils	Species	Number of species like those now living
Chambere	29	297	8
Univalves	81	1141	151
Multivalves & bivalves	111	1091	107
Total	221	2529	264

Philosophical Magazine Vol. 2 N. Series p. 103

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<u>Insects</u>

Very few of these exist in a fossil state.
Native insects in amber.
Also trilobites regarded by some as a crustaceous insect by others as a bivalve shelf — occurs in our

country.
In the Stonefield slate England occurs specimens pronounced by Dr. Leach a distinguished entomologist.

Crabs — Cancer

Number of species considerably great — in the Stonesfield Slate – Isle of Sheppey, etc.

Birds

Rarely found fossil
Cuvier has found five or six species in the plaster quarries near Paris
Plate of Ornithocephalus Cuvier's Theory Frontispiece

Fishes

In considerable quantities though not as many places. Sometimes they are nearly entire — sometimes with them harder parts in a natural situation with their skin and scales preserved. Sometimes the skeleton is almost gone and nothing remains but a thin plate of bituminous substance exhibiting the form of the scales from heads fins heads etc.

Notice the Ichthyolites from Sunderland, Middletown, Deerfield, West Springfield.

Nearly 100 species of fish occur at Monte Balsa near Verona Italy — several of which agree with recent species from the ocean.

Ceti — Whale Tribe

Some parts of these animals have been found in England

Amphibia

Numerous and important remains of this tribe occur — as the Turtle, Snake, Lizard, Crocodile

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The Testudo crocodile, seahorse etc. are arranged by Cuvier under the term sorry and animals

Quadrupeds Mammalia

Cuvier has discovered and describes 78 species of viviparous and oviparous quadrupeds existing in a fossil state 49 of which are new species not known to exist at present on the globe. Among these are the bear, the dog, the cat, the hyena, the weasel, the horse, the deer, the ox, the buffalo, the rhinoceros, the hippopotamus, the hog, the beaver, the elephant, and the mastodon.

<u>Mammoth or elephant</u> — two living species

A third in a fossil in Europe, Asia, and America North and South. More abundant in the Arctic.

Give an account of the fossil elephant with flesh and skin preserved found in Siberia — Cuvier p. 253.

Mastodon found in abundance in our country. Differs from the mammoth.

<u>Man</u>

Although several accounts of human skeletons found in a fossil state have been published Cuvier says "*it is quite undeniable that no human remains have been hitherto discovered among the extraneous fossils*." *Theory of the Earth*, p. 129

Homo diluvii testis or *Scheuchzeri* — a great salamander

Professor Plater's giant 17 feet high at Lucerne. See Cuvier. Theory of Earth p. 235.

Human bones found at Guadalupe by Sir Alexander Cookson. Same work p. 235, engraving p. 344.

Plate of the Megatherium, Cuvier, p. 344.

Monkeys have not been found in a fossil state.

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<u>Distribution of organic remains</u>

Those rocks already describe which contain no vegetable or animals in a fossil state are called primitive or primary. In no well—authenticated instance have any been found in these rocks — though some of the following rocks containing a few of them in a few cases alternate with these.

The rocks yet to be described lying above these are called secondary. In the oldest of these occur sparingly the zoophytes and a few shells. As we rise we meet with the coal formations whose organic remains are almost entirely vegetable; but like the zoophytes they are almost entirely different from any found on the globe in the living state not only in species but in general and even in orders.

Above the coal is a succession strata in which we find a lot of organic remains more numerous differing from those in the lower strata and also from those at present found on the globe but not so much as the lowest.

It is not till we have risen considerably above the coal strata that we find any remains of quadrupeds and mostly fine most are always of a marine origin and oviparous.

All remains below the chalk are properly petrified. Above this mainly preserved — differing from recent shells in the ocean only in their dullness and brittleness.

Spread over all other strata we find every where a mantle of loose sand and gravel called diluvium. In this only are found land animals and quadrupeds — many of them of unknown gender and species. *[in pencil]* Saurian animals found low as the New Red Sandstone. Remarkable instance in East Windsor, Connecticut.

As we approach the surface we find the shells agreeing nearer and nearer with those found in present in the ocean until in the highest strata we notice a perfect identity. *[in pencil]* All the shells in the transition and secondary rocks are of genera and species not now found living. Bakerfield, p. 28.

The lowest strata contain the most imperfect animals generally with some exceptions however.

These remains are not scattered through different strata in an indiscriminate and confused manner; but they are disposed as it were in families so that each kind of…

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…rock contains petrifaction is peculiar to itself. Sometimes in two rocks considerably distant (for example chalk and carboniferous limestone) not a single instance of specific agreement occurs. The nearest rocks to each other the nearer the agreement.

Hence results an important rule for identifying the same formation in different countries viz. to compare their fossil organic remains.

Not absolutely true in all cases adjacent formations contain more remains that are common than the most remote. Refer to De La Beche's tabular view of rocks.

Vertebrated animals extremely rare in the transition rocks — fish only. Saurian animals in the Lias first. Furnished with paddles instead of feet and differing from all known genera. For example the Ichthyosaurs, Plesiosaurus, Iguanodon, the latter exceeding 70 feet and the size of its body exceeding that of the elephant. [In pencil] Tracks of an animal in sandstone in Scotland, ???? Journal Vol. 18, p. 84.

Marine freshwater and terrestrial remains exceed one another in irregular order – rarely if ever mixed in the same formation. Refer to De la Beche's table.

Most remains found in the rocks agree more nearly with the vegetables and animals in the torrid zone than with those in higher latitudes. The natural conclusion is that the climate was warmer in earlier times than at present.

Two thirds of our continents so far as they have been explored are covered with rocks containing organic remains. Our current continents therefore must have been formally and for a long time covered by the ocean.

Embedded or rolled pebbles or fragments

State the facts about their occurrence. Notice the inferences

1. That these rolled masses must have been broken off from another rock and rounded before the existence of the one containing them.

2. Hence the rock from which they were broken is the oldest.

3. If found in highly inclined strata those strata must have been elevated subsequently to their formation since loose pebbles cannot sustain themselves on highly inclined planes.

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[There appears to be a gap here; this may be a continuation from Geology Gentlemen, p. 24, which concludes with 11 - Serpentine]

12 Compact Feldspar

A rock of very limited extent. It occurs in two connections very different from each other like several of the rocks hereafter to be described. 1 Associated with gneiss. 2. In veins and masses connecting with rocks of the overlying class.

Contains both potash and soda – whereas common feldspar contains potash only. Hence probably they are different species.

13 Argillaceous schist (Macculloch) [John MacCulloch (1773-1835), Scottish geologist]

This rock comprehends several rocks long distinguished in books of geology and the source of much confusion. All these varieties however agree in containing stony or indurated clay either constituting the entire rock or forming the cement of sand or fragments of other rocks. Varieties mostly schistose.

Distinguished from certain rocks of the overlying family by their schistose structure — stratified form or geological connections. From some varieties of shale they are distinguished alone by geological position.

Varieties

1. Argillite - Argillaceous Slate

Indurated schistose Clay - Extremely fissile — stratified — beds not always parallel to the schistose structure.

Colors gray light and dark red etc. The most perfect variety occurs along with primitive rocks as mica slate gneiss etc. Course granite sometimes and in Ireland alternates with it. Generally the latest of the primary rocks.

Uses of Argillite.

It occurs what are called transition rocks and these contain organic remains sparingly.

Novaculite — compact imperfectly fissile
Aluminous slate
Graphic slate
Passes into one variety of siliceous slate
It passes into

2. Gray Wacke Slate. This consists of indurated clay and minute scales of mica — structure apparently homogeneous. Impossible to distinguish this in many cases from the transition argillite of some geologists.

Contains vegetable and animal remains.

Page 7

3. Gray Wacke. This consists of fragments of quartz feldspar, siliceous slate, argillite etc. united by an argillaceous cement. Some writers say that the cement may be the same materials minutely comminuted. But this destroys the distinction between this rock and the sandstones.

Sometimes the embedded nodules are very large.

Remark upon the indefiniteness of the term gray wacke. Dr. MacCulloch proposes for these rocks the term argillaceous conglomerates.

This rock is stratified though sometimes indistinctly. Abundant in this country. Traversed by veins of quartz: which may tend to distinguish it in some cases from sandstones.

Contains vegetable and animal remains not very abundantly.

Minerals found in argillaceous schist. See MacCulloch p. 362.

14. Limestone

An interesting and widely diffused rock.

The base in all cases consists of carbonate of lime. More or less united with other substances forming numerous varieties.

Distinguished in almost every case by their effervescence with acids. The magnesium and argillaceous varieties effervesce slightly.

Those limestones that are of a highly crystalline texture and are destitute of organic remains may be classed among the primary rocks. Indeed they alternate with them as mica slate and gneiss and in some cases this is the only satisfactory evidence of a primary character as the secondary limestones are sometimes crystalline in their structure and the primary in one instance at least contains organic remains (MacCulloch p. 364).

The varieties are numerous and often important especially in an economical point of view.

1 Primary Limestone

A. Crystalline – Carrera and Parian Marble. Most of the marbles in New England.

B. Compact splintery

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C. Limestone with mica interspersed — micaceous limestone — in beds in mica - slate Conway, Deerfield, etc. etc.

D. Conglomerated limestone — fragments of limestone alone or of quartz or argillaceous schist or of various primary rocks

Minerals embedded MacCulloch p. 373.

Primary limestone is stratified

2. Secondary limestone

A. Crystalline more or less perfect
B. Compact   MacCulloch
C. Fibrous
D. Carboniferous or mountain limestone
Phillips and Conybeare Geology of England and Wales, Vol. 1, p. 352.
Called also metalliferous – entrochal and encrinal limestone —

Imperfectly crystalline
Used for marbles
Contains nodules of chert
Full of caverns
Principal depository of the English Lead Mines - other metals found in it.
Organic remains abundant
It reposes on the Old Red Sandstone sometimes separated from it by thick shale called limestone shale.

E. Newer Magnesian or Conglomerate Limestone   Conybeare and Phillips

First Floetz limestone Werner

Distinguished from the mountain limestone by its geographical and geological position, by its organic remains, by the frequent occurrence of beds of calcareous conglomerate found in it and by the greater quantity of magnesia it contains - about 20%.

Structure granular and sandy colour yellow
Organic remains rarely found in this rock
Lies immediately beneath the New Red Sandstone or saliferous sandstone

F. Lias - An argillaceous limestone varying in the proportion of aluminum it contains and alternating with beds of blue marl.

Contains numerous organic remains particularly of the more perfect (vertebral) animals - as lacerta, Ichthyosaurus, etc.

Used for water cement. Also for lithographic purposes in England.

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It constitutes the lower part of the Oolitic series of rocks in England.

G. Oolitic limestone or oolite Conybeare and Phillips

Extensive strata of this rock in England.
Consists of a series of beds of limestones oolitic in its character alternating with argillaceous beds.
Organic remains abundant
Furnishes the finest stone for architectural purposes in England — comprehending the Penbeck and Portland stone – the Conrbrach Forest Marble Coral etc.

H. Chalk Marl — Conybeare and Phillips

Consists of Cretaceous and argillaceous matter and sand and lies immediately beneath the chalk.
Organic remains resembling those of the chalk

I. Chalk

Occurrence of flints one of its most remarkable characters.
It is nearly a pure carbonate of lime.
Organic remains numerous and sui generis.
Average thickness of the stratum in England from 600 to 1000 feet.
Abundant in England France and Holland — also occurs in Ireland Italy? Spain etc. No certain locality of chalk beyond Europe - perhaps in Persia -

J. Above the chalk there are found occasionally marly or calcareous beds alternating with beds of clay sand and gravel for example in the Paris basin -

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15. Secondary Sandstones

Sandstone consists of grains and fragments of the rocks chiefly of quartz sometimes of feldspar mica flint and siliceous slate united by a cement usually composed of siliceous and argillaceous matter. Sometimes it is marly or calcareous simply argillaceous or argillo-ferrigenous or silicious. The embedded fragments are usually derived from the primary rocks granite gneiss and mica slate. When these fragments are large this rock is called a conglomerate when angular a breccia.

Structure of the rock is entirely mechanical — that is it is entirely destitute of a crystalline structure.

Varieties of sandstone are extremely numerous. Often they cannot be distinguished by the eye though very remote in their geological situation.

1. Old Red Sandstone Conybeare and Phillips. Lowest red sandstone MacCulloch.

The colour is usually iron red — sometimes gray. It reposes upon graywacke and passes into that rock by insensible shades.
Its superior consolidation distinguishes it from certain red sandstones higher up in the series.
Very few organic remains occur in it - a few annonia and incrinites in its lower beds.
It sometimes forms a course conglomerate or puddingstone.
Abundant along the Connecticut and along the whole extent of the Atlantic states.

2. Millstone Grit. Conybeare and Phillips

Consists of a coarse — grained sandstone of quartzes particles united by an argillaceous cement.
It alternates with beds of shale.
Sometimes contains beds of limestone and coal.
Lies between the sandstones of the coal measures in the old red sandstone. Much harder than the sandstones above it — not so easy to be distinguished from the old red sandstone.
Vegetable and animal remains occur sparingly in the shale and limestone associated with this rock.

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3. Sandstones of the coal measures. These are mostly gritty and micaceous — schistose and splitting into thin layers and easily broken.
They alternate with beds of coal in shale or slate clay.
Used extensively for flagging roofing building whetstones grindstones etc. Called in England Plate Post and Pennant.

Abound in vegetable remains and a few shells.

4. Red Marl or New Red Sandstone Conybeare. Called also red rock or red ground — saliferous rock etc. variegated sandstone

Sometimes it appears as a reddish marl or clay sometimes as a sandstone and sometimes these are interstratified or passing into one another. Contains beds of a conglomerate containing fragments of different rocks cemented by marl or sand.
Remarkable for containing beds of gypsum and rock salt.
Exists in New York Sir Eaton Canal rocks
Entirely destitute of organic remains.

5. In addition to the above varieties of secondary sandstone we occasionally meet with beds of sand and pebbles partially consolidated almost without a cement and those alternating bands of gravel sand and clay that live below the chalk formations and particularly in those above forming what geologists have named the tertiary formation.

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16. Shale

Slate clay of some geologists
(Were I to rewrite these lectures I should place shale as a variety of argillaceous schist)
Consists of indurated clay of a schistose structure.
More fragile than the argillaceous schists.
Colors gray or blackish occasionally brighter
Schistose structure less continuous than in argillite. Often however the two almost exactly resemble each other and pass into each other.
Occurs in thin strata or lamina alternating with other rocks — in all the sandstones upwards commencing with the old red sandstone and the secondary limestones. Also with coal and among the clays.
Sometimes containing bitumen constituting bituminous shale .
Dr. MacCulloch enumerates among it varieties aluminous schist adhesive slate and polishing slate.
Abounds in vegetable and animal remains.
Passes into siliceous schist when in contact with trap.

17. Overlying rocks. MacCulloch

In this term is comprehended a numerous anomalous and perplexing series of rocks that have been usually denominated trap rocks.

Term derived from the Swedish word Trappe signifying a stair.

Professor Cleaveland defines trap rocks to be those in which hornblende predominates. Some of these I have already described under the head of hornblende schists. The geological position however of hornblende schist and the overlying rocks is so different as seems to justify the separation. Under the term overlying rocks also are included several aggregates in which no hornblende is found. Yet all the rocks of this class agree together in so many respects that it seemed the most convenient mode of describing them to write them under this general name.

The predominant substance in these rocks is a simple rock. It is either indurated clay or wacke claystone, clickstone, or hornblende, or feldspar the common or the compactor augite or hypersthene. Some species or varieties this simple mineral constitutes the…

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…whole rock. In other cases it is composed of two of them combined in various proportions producing often great diversities of her aspect without much change in the fundamental character of the rock.

Overlying rocks rarely occupy very extensive tracks: yet in some countries they constitute the prevailing lock and there are a few countries where some of the members of the series are not found.

They exist in three modes

1. In irregular unstratified overlying masses rising into high ridges or mountains
2. In veins often connecting to stratified beds and irregular masses. These are more usually called dykes.
3. In beds interstratified and alternating with the other strata.

Found in contact with every rock from granite upward to some of the most recent of the secondary strata. It is not been proved however that any of these rocks are later than the latest of the secondary.

They are however of different ages as is proved by the fact that in some of the lowest sandstone conglomerates are found fragments of these rocks while subsequent sandstones are penetrated by their dykes.

In granite they occur only in veins. Among the stratified rocks they occur in intruding masses which appear to be beds — Dr. MacCulloch doubts whether these masses are strictly beds.

In one case they form regular strata alternating with jasper siliceous slate and ferruginous clay. In Isle of Skye - MacCulloch classification p. 469.

The structure of these rocks has some peculiarities

1. The prismatic — this includes the common prismatic type, when the large lamella are divided by joints so as to form cuboidal masses. Also the columnar. These are often extremely irregular varying from 3 to 12 sided. Always aggregated that is more than one column. Sometimes curved (Mount Holyoke) sometimes radiated. Usually rarely at right angles to the plane of the bed but not always. Lie at all angles with the horizon. This structure vanishes often in the same continuous mass.

Breadth of these columns from an inch to 9 feet. Length from a foot to 300 or more.

Example Cave of Fingal - Giants Causeway etc. In this country along the Connecticut River and the Hudson.

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Overlying rocks often have a cavernous structure. That is they are full of small cavities more or less rounded rarely exceeding half an inch in diameter. Rocks of this structure among the traps bear a great resemblance to certain varieties of lava.

When these cavities are filled with some embedded mineral of a different nature from the rock their structure it is said to be amygdaloidal. This structure exists in several varieties of the overlying rock so that the term amygdaloid does not indicate any particular rock but only the structure of several.

The porphyritic structure is common in these rocks. Strictly speaking of porphyry implies that crystals of one mineral are embedded in a compact homogeneous base. But the term is used with rather more latitude. Two or more minerals are sometimes embedded in this manner and still the rock is said to be porphyritic. And even if the base have a crystalline form with crystals imbedded the rock is still called porphyritic .

<u>Varieties of Species of Overlying Rocks</u>

1. Wacke. Resembles indurated clay — often amygdaloidal.

2. Indurated clay. Dr. MacCulloch says this is much more common in Scotland than wacke.

3. Claystone. Difference from the one or two varieties by its superior hardness . Occurs in mountain masses most frequently

4. Indurated claystone. Harder than No. 3. Common in Scotland.

This variety has been called basalt by some writers.

5. Clingstone. Still harder than the last and not easily scratched by a knife.
The dark varieties have also been ranked among basalts.

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6. Compact Feldspar including the hornstone of some mineralogists. This passes easily into porphyry. Indeed this and Nos. 3, 4, and 5 are occasionally porphyritic and amygdaloidal.

7. "Hornblende compacted into a solid mass apparently consisting of minute crystalline particles." (MacCulloch) This is one of the principal varieties of basalt.

Remarkable for the number and regularity of its columns. It has been doubted whether basalt exists in this country. But according to this definition there can be no doubt of its existence.

8. Greenstone. Composed of hornblende and compact feldspar in nearly equal proportions and the two minerals distinctly visible.

Variety of porphyritic greenstone consists of feldspar crystals and a base of greenstone.

This rock greenstone abundant along the Connecticut and Hudson Rivers.

Columnar at Holyoke, Deerfield, etc.

Often cavernous and amygdaloidal.

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9. Compact Feldspar and Hornblende — The feldspar predominant. This constituted one of the varieties of syenite and forms mountain masses.

10. Hornblende and Common Feldspar. Some place this rock among the greenstones others among the syenites. Sometimes the feldspar predominates - which constitutes a syenite.

11. Augite Rock. Augite and feldspar

1 . Augite and compact feldspar - the augite in superior or equal proportions
2. Augite and common feldspar — the feldspar predominating. Dr. MacCulloch says that this has not been observed in Europe. But it exists at the Cold Springs on Hudson River and in Belchertown.

12. Hypersthene Rocket. Hypersthene and compact or glassy or common feldspar - in the Isle of Skye.

13. Claystone common or indurated with scales of mica in the Western Isles of Scotland

14. Grains are imperfect crystals of quartz embedded in a simple base – ???.

15. Crystals of feldspar embedded in a simple base. This constitutes porphyry. The base may be

1 Claystone
2 Indurated claystone
3 Clinkstone
4 Compact feldspar
5 Basalt

Feldspar common or glassy

Occurs in veins and mountain masses

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16 Feldspar Hornblende and ????

When the feldspar is compact it constitutes the true syenite. When the feldspar is the common it forms a variety of granite already described as sienitic granite.
Porphyritic sienite — Feldspar crystals in a base of syenite.

17. Feldspar quartz hornblende and mica — This occurs in Skye incumbent on conchiferous limestone and therefore cannot be referred to granite but must be ranked among the members of the overlying rocks.

For several other similar varieties see MacCulloch p. 514, etc.

For minerals found in the amygdaloid of the overlying rocks see MacCulloch p. 521

18. Conglomerates.

1 Fragments of different trap rocks of various sizes angular and reunited trap tufa
2. Trap and sandstone in fragments united by the same materials. Northampton East Sunderland Mount Tom. See *American Journal of Science* Vol. 7. Also in Hadley, east side of Mount Holyoke.

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18. Pitchstone

Resembles in many respects the rocking of the overlying family and occurs only in the districts where these are found.

Invariably in the form of veins — which are not connected with large masses but seem to be independent.

Imperfectly prismatic on a large scale
Occasionally porphyritic — pitchstone porphyry
Convectionary spheroidal - Peastone
Amygdaloidal

Occasional rocks MacCulloch

19 Jasper

Of limited extent
Occurring in primary and secondary strata

20. <u>Siliceous schist siliceous slate</u>

Of limited extent
In primary and secondary strata

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21. <u>Chert</u>

Occurs in similar situations of Jasper and siliceous slate.

22. <u>Gypsum</u>

It exists in connection with the red marl and in the newer fresh and salt water formations of the tertiary class — doubtful whether it is found among the primary strata

23. <u>Coal</u>

Give an account of its relative position etc.

24. <u>Rock salt</u>

Occurs in connection with the red marl and no where else.
Why should it not be classed among the rocks?

25. <u>Tertiary Strata</u>

These embrace all that series of beds of sand and gravel and clay with occasional layers of limestone marl and sandstone which are found above the chalk. They have been more accurately examined in England and France than in any other country and I shall make these countries the basis of my description

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1. <u>Plastic Clay Formation</u>

Consists of an indefinite number of your irregularly alternating beds of sand and clay and pebble beds. The clay of almost every variety of colour.

Organic remains are shells teeth of fish imperfect coal and even branches and bases of plants.

Exists in this country at Martha's Vineyard, Long Island, New Jersey - Philadelphia Cape Sable Florida Chickasaw Bluffs and Natchez

2. <u>London Clay</u>

Consists chiefly of consist chiefly of bluish and blackish clays
Occasionally contains beds of sandstone and limestone.
Organic remains of great interest
Banks of James River Virginia at Washington, etc. (?)

3. <u>Lower Fresh Water Formations</u>

Consists of a series of beds of sandy calcareous and argillaceous marls. Some of them consist almost entirely of fresh water shells as Lymnaea, Placorbis, Cyclostoma, Helix, etc.

In Paris and in the Isle of Wight

4. <u>Upper Marine Formations</u>

Beds of clay and marl with numberless marine petrifactions
In England and France
At Cape Henry Virginia and Staten Island ? (Finch)

5. <u>Upper Fresh Water Formation</u>

Consists of a thick bed of a yellowish white marl full of freshwater shells seeds and coleopterous insects.

26. <u>Diluvium</u>

Rounded fragments of various rocks mixed with sand and clay without order

27. <u>Alluvium</u>

1. Mud
2. Loam
3. Sand and gravel
4. Sandstone
5. Limestone or calcareous tufa

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6. Various substances cemented by nest of iron
7. Compact limestone deposits from lakes etc.
8. Siliceous deposits from hot springs

28. <u>Volcanic Rocks</u>

Give an account of volcanoes in general, varieties of volcanic rocks

1. Obsidian - massive and porphyritic
2. Pumice
3. Volcanic porphyries base compact feldspar
4. Base of basalt or some analogous substance.
Dark scoriform compact porous prismatic and convectionary lava
5. Volcanic Amygdaloid
6. With a base of greenstone and some analogous substances — simple porphyritic and amygdaloid
7. Basic common feldspar indurated granite

8. Ejected substances more or less altered by fire
a. conglomerate of fragments of different rocks. Ditto chiefly of clay ejected in the state of mud
b. Tufa volcanic
c. Prozzolana ashes dust

<u>Sketch of certain branches of geology not fully entered upon in the lecture of 1827.</u>

1. <u>Associations and transitions between different families or species of rocks.</u>

1. Granite graduating into gneiss
    Mica slate
    Quartz rock
    Hornblende shifts
    Argillaceous late
    Porphyria Greenstone basalt
    Syenite etc.

2. Gneiss passing into hornblende schist
    Mica slate
    Quartz rock
    Primary sandstone
    Chlorite schist
    Argillaceous schist

3. Mica slate passing into quartz rock
    Calico slate
    Chlorites slate
    Argillaceous slate
    Hornblende slate

4. Quartz rock passes into primary sandstone
Argillaceous schist as well as those rocks already named

5. Hornblende schist — Gray slate
    Chlorite slate

6. Argillaceous schist passes into chlorite schist, primary sandstone

7. Serpentine passes into hornblende schist, basalts or greenstone

8. Sandstone pass into the shales

9. Limestone passes into the shales.

10. The overlying rocks pass into one another by the most imperceptible gradations.

2. <u>Arrangement of Rocks or Their Classification</u>

1. Werner Hypothetical Arrangement
1 Primitive 2 Transition 3 Secondary 4 Alluvial 5 Volcanic

2. Brongniart's Mineralogical Arrangement
See Journal des Mines No. 199. Juillet 1873.

3. Geological classifications of Dr. MacCulloch
1 Primary 2 Secondary 3 Occasional rocks 4 Appendix

4. Arrangement founded merely on superposition by Rev. W. D. Coneybeare.

1 Superior order 2 Supermedial order 3 Medial order 4 Submedial order 5 Inferior order

See Geology of England and Wales p. 7, Introduction

5. Humboldt arrangement 1 Primitive formations 2 Transition formations 3 Secondary formations 4 Tertiary formations 5 Formations (exclusively) volcanic

3. <u>Order of Succession Among Rocks</u>

See MacCulloch classification of rocks, p. 90.
Also Humboldt on the superposition of rocks
Also Phillips and Coneybeare Geology of England and Wales

4. <u>Geological Hypotheses</u>

1. Former geological hypotheses or theories of the earth – L. Cuvier's theory – Coneybeare and Phillips Geology of England and Wales - Edinburgh Review No. 57 p. 311. Edinburgh and Rees Cyclopedia; also *American Journal of Science* Vol. 2, p. 151.
See also Lyell’s Geology, p. 22 etc.

2. Whether causes now in action are sufficient to account for the formation of rock strata?

1. Slips or the falling down of mountains
2. Alluvium
3. Downs
4. Cliffs are steep shores
5. Depositions formed in water
6. Stalactites

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7. Incrustations
8. Lithophytes
9. Volcanoes
10. Motion of the pole of the earth round the pole of the ecliptic as affecting geological changes.

3. <u>Wernerian or Neptunian Theory</u>

1. All the rocks deposited from water

2. Waters gradually diminished and left mountains bare which were abraded by the current and the transition rocks deposited

3. As the waters diminished still more the same effect taking place the secondary rocks would be deposited.

4. Trap rocks were deposited by a second more sudden rise of the waters

5. These deposits are supposed to have been originally universal: but subsequently were worn away by various subsequent revolutions and changes

6. Veins were filled by matter from above deposited from water

4. Huttonian or Vulcanian Theory

1. Caloric is the grand agent in this theory.

2. The present continents resulted from the destruction of former ones: the rocks being gradually disintegrated and abraded by the atmosphere and the waters and by the latter the materials were carried to the bottom of the seas.

3. The layers of sand and gravel dust deposited on the bottom of the ocean were subsequently consolidated by the action of subterranean pressure.

4. Granite and other overlying rocks were by this agent completely fused and forced up through the higher strata giving strata various degrees of inclination and different degrees of consolidation and crystallization according to their distance from the source of heat.

5. Veins were filled from beneath.

6. This theory supposes the same process of deposition is going on at present at the bottom of the ocean and after a period this bottom is said to be raised and the present continents sunk and this alteration is to take place an infinite number of times. As Hutton says, "*We find no vestige of a beginning no prospect of an end.*"

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Objections to the Neptunian Theory

1. The materials of the rocks are few of them at all soluble in water.

2. The inclination of the strata which ought to be horizontal on this theory.

3. The change of inclination of the layers of the same stratum within a short distance.

4 . Many veins have forced the edges of the strata upward while no instance of the contrary occurs.

5. Substances through which trap veins have passed are often indurated.

6. Trap rocks that occur in the form of veins buds and overlying masses could not have been all deposited by water after the other rocks were consolidated.

7. The relative height of the basset edges of different strata does does not correspond with the Wenerian hypothesis. Conybeare Geology England and Wales, p. 18. Introduction

8. Not enough water on the globe to dissolve the rocks. The water weighs only the 50,000th part of the whole globe and the volume of water is only about one 6000th part that of the solid parts.

Werner was mistaken as to the position of the unstratified rocks in Saxony. Lyell, p. 57.

<u>Objections to the Vulcanian Theory</u>

1. The distinctly crystalline structure of most of the primitive rocks.

2. The distinct and sudden transition often seen from one rock to another.

3. Beds of clay sand and gravel are often formed beneath stratified rocks that are consolidated.

4. Our present rivers convey but a small quantity of abraded materials to the ocean.

5. The same solvent could not contain the materials of so many entirely different rocks as we find. This objection lies also in a measure against the Wernerian hypothesis.

6. The existence of organic remains in trap rocks.

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Geologists at the present day seem to be disposed to neglect both these theories and content themselves with stating facts. If I do not mistake however they generally admit that some things are true and some false in both these theories. The fact is the science is not yet advanced enough to form any hypothesis that shall be unexceptionable. If I were to state the conclusions of my own mind on this subject they might be contained in the following propositions :

1. <u>All the stratified rocks were deposited from water.</u>

1. Those of a crystalline structure were in a state of chemical solution and may hyence be called chemical deposits.

2. Those whose structure is mechanical were merely diffused in the water and were deposited merely by the force of gravity. These are mechanical deposits.

3. Those partly crystallized and partly mechanical existed in the water in a state of solution and diffusion in the same ratio.

2. <u>Great and often sudden changes must have repeatedly taken place in the nature of materials held in solution and diffusion</u>.

No other way to account for the juxtaposition of rocks of such different characters and the sudden passage from one to another we often witness.

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GEOLOGY OF THE DELUGE

[Edward Hitchcock classroom lecture notes, "Geology of the Deluge: A Lecture", EOH, Box 10, Folder 14.]

A LECTURE

[This lecture was probably delivered after 1830 (see comment on Brewster); perhaps given to students, but more likely to the Boston Society for Natural History (see comments about that on the last page) and maybe also in Portland, ME]

My object Gentlemen at this time is to present before you what may technically be called the Geology of the Deluge. In other words to exhibit the evidences which the science of Geology furnishes of a Universal Deluge. That science contains abundant proof of numerous deluges more or less extensive in the earlier periods of our world's history and before it became the residence of man: but I shall confine myself to the last of these catastrophes and enquire whether there is any evidence from the record of geology of such an event since the globe assumed a habitable state.

Before entering directly upon this subject it seems desirable to spend a few moments in elucidating the subject of organic remains since this is so intimately connected with the geology of the deluge.

A large proportion of the rocks found on the exterior part of the globe is arranged in layers one above the other. In the upper series of these are found imbedded numerous examples of shells and other animals and vegetables of various kinds concerted or partially converted into stone and hence said to be petrified. Those found in the loose soil above the rocks are frequently no more changed than bones must be by lying for thousands…

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…of years in the earth.

Those organic remains found the lowest down in the rocks are totally unlike any now existing on the globe. As we ascend the resemblance becomes closer and closer until in alluvial soil we find animals existing at the present day.

(Refer here to drawings of some of these ancient animals and exhibit specimens of petrifications.)

Most of these organic remains are of marine origin especially the animal remains.

Most of them are of a tropical character.

They must have lived and died on or near the spot where they were found.

Almost every distinct rock has its peculiar fossils.

In this lecture I shall speak chiefly of the loose soil that overspreads the solid rocks. This is of three kinds:

1. When clay sand and gravel are arranged in regular and successive layers the series is called a Tertiary Formation

2. When these materials are mixed confusedly together and could not have resulted from streams and other causes now operating the formation is called Diluvium: that is an effect of a deluge. Such a coating is found almost everywhere overspreading nearly every other rock.

   The term Diluvium always refers to a deluge.

3. Those accumulations of loam, sand and gravel that result from causes operating as existing rivers are called <u>alluvium</u>.

These preliminaries seemed necessary before entering directly upon the subject of the deluge. And it is a subject I would here remark that has been greatly abused both by the friends and enemies of Revelation. The former assuming the hurtful and unfounded dogmas that the principles of natural philosophy are all to be found in the bible and that every important change in the crust of the globe must be accounted for by the last deluge had in earlier times so distorted all the evidence of that catastrophe and had so disgusted all reasonably intelligent men by their self confident manner and intolerant spirit that multitudes rushed into the opposite extreme and maintained that there were not to be found in nature any marks of a deluge. It was in this spirit that Voltaire maintained that the petrified shells found in the rocks of the European mountains were dropped there from the hats of the crusaders who it is well known wore the scallop as a distinctive badge. But ridiculous as such an opinion now seems it is scarcely less absurd in the view of the practical geologist than the opinion extensively prevalent at the present day that the fossil sea shells found in the rocks of high mountains are decisive evidence of Noah's deluge.

It is indeed an imposing argument to those not conversant with the details of geology to say that on high mountains in every quarter of the glove is found a great abundance of sea shells in a petrified state. For the min is apt to leap at once from this fact to the conclusion that the sea must once have covered the places where these shells occur and that probably they were left there by the deluge. The fact does indeed prove beyond all reasonable doubt that our continents once constituted the bottom of the ocean. But in order to determine whether these fossil shells were deposited by the deluge of Noah we…

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…must compare the Mosaic history of that event with the history of these fossils. Such a comparison I maintain shows conclusively that Noah's deluge had nothing to do with their deposition: in other words that the supposed cause is totally inadequate to the known effects.

For in the first place a deluge which was the result of forty days rain and the breaking up of the fountains of the great deep must have been tumultuous and violent in its action on the globe wearing away its solid parts instead of making additions thereto. During the 150 days in which the waters prevailed or increased they must have surged over the land in strong currents and while they were diminishing the remainder of the year similar currents must have produced especially as Moses tells us that <u>God made a wind to pass over the earth</u> to assuage the waters. These waters therefore could have deposited only such materials as violent streams and floods now deposit viz. a heterogeneous mixture of whatever they sweep away whether of minerals vegetables or animal substances. But the petrified shells under consideration are embedded in the solid rocks of ten thousands of feet in thickness and there is the most decisive evidence that these rocks for the most part were deposited from still waters and the shells were gradually and slowly enveloped in them very near the spot where they lived and died. The most delicate parts of the shell are generally preserved showing that they could not have been exposed to the action of strong diluvium currents which must have worn them away as we now find shells worn and broken on the sea shore. These remarks apply chiefly to the petrification found in the solid rocks. Those occurring in the loose sand and gravel overspreading the surface of the globe are frequently worn and broken and these might have been drifted to their present situations by the Noachian deluge. It is only the marine fossils in solid rocks (and the common idea of organic remains includes only these) which I maintain afford no evidence of that catastrophe.

In the second place of the petrifications of the solid strata were left in their present situations by the last deluge we ought to find them mingled confusedly together: since they must have been drifted thither by the ocean rushing over the land. But there is in fact as much order among the petrified animals as there is among living animals. We find many species of animals living together in different countries and so we find many species entombed in the same rock: But as we find in most countries particular animals that occur in no other so in the rocks we find species of animals peculiar to each and occurring but rarely in any other formation. In many of the rocks lowest in the series not a single species is found identical with those high up in the series. Four footed land animals occur only in the highest beds of sand and gravel. In short there is conclusive evidence that successive and different races of plants and animals lived and died near the place where we now find them petrified. But had the deluge accumulated these remains where we now find them they must have been promiscuously mingled together: a decisive evidence that the deluge was not concerned in their deposition.

In the third place most of the organic remains under consideration are real petrifications: that is they are actually converted into stone. And in some places mountains several hundred feet high are in a great measure composed of these petrifications. But wherever the process of petrification is now going on it is slow in its progress and occurs in still waters. It is absurd therefore to impute such a process and on so immense a scale to the agitated…

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…and transient waters of the Noachian deluge.

In the fourth place we meet with conclusive proof every where that the rocks were more or less worn away by the last deluge. Now can we impute their previous formation to the same agent? What evidence is there in the Mosaic history that the effects thus diametrically opposed could have resulted from the diluvium waters?

In the fifth place the great diversity in composition and other characters exhibited by many of the rocks containing petrifications is opposed to the idea of their production by the Noachian deluge. Sometimes we meet in these rocks with a gradation of one into the other by almost imperceptible degrees. But at other times the change in composition is sudden so that those rocks the most unlike in composition are placed in contact. It appears too that in some cases after one kind of rock had been deposited in still waters a violent current rushed over it and partially tore it away. Then again succeeded a calm and the fragments thus worn off were reconsolidated into rock: then another change took place in the materials held in solution or diffusion by the waters of a third kind of rock was produced: then another took place resulting in a fourth rock, another in a fifth and so on to the end of a numerous series. Resides all this it is obvious that between the deposition of these different rocks were intervals of many centuries. Now how can these facts be reconciled with the facts stated by Moses respecting the flood of Noah which he represents as a rapid rising and falling of tumultuous waters? Who can believe that all these changes took place in the short period of a year?

(Here illustrate this statement by a section of the rocks at the north end of Mount Tom.)

Finally, it has been fairly shown that several caverns occurring in rocks which themselves abound in marine relics were the dense of carnivorous animals during a long period previous to the last deluge. How then could these rocks have been produced by the deluge as they must have been if the sea shells which they contain (were) deposited by that event?

These arguments (and more might be added) seem to me to prove incontestably that the immense masses of marine petrifications found in the solid rock are no proof of Noah's deluge. Indeed they prove that the evidence of that event is not to be expected in the solid strata. Where then shall we look for such evidence? <u>I reply, upon the surface of the globe.</u>

In the first place we find evidences of a universal deluge in the scratches and grooves which many rocks exhibit and in the phenomena of certain vallies called vallies of denudation. Every one is acquainted with the appearance of rocks which are exposed to the action of existing streams: and when the same appearances are exhibited where no stream now flows it is natural to impute them to the action of former rivers. But when we come to examine these phenomena over a large extent of country we shall find such an explanation to be inadequate. We find for instance these grooves and furrows to have nearly the same direction over an extent of hundreds of miles. In New England they rarely deviate much from a north and south direction and there is reason to suppose that this is their general course over nearly all the American continent. And in Europe and Asia the current seems to have been the same way in general. No river therefore could have produced these grooves and furrows. They must certainly have resulted from the wide and mighty currents of an extensive if not an universal deluge.

Again these grooves and furrows occur on the summits of many of the highest mountains which are…

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…elevated thousands of feet above the beds of any existing streams. I could refer to numerous examples of this kind in New England (for example)…

[space]

…and in other countries the same fact has been noticed. To suppose that existing streams could ever have flowed over such spots is perfectly absurd unless we suppose the mountains to have been subsequently elevated by volcanic power. And even admitting this to have occurred yet the uniform direction of these grooves over a wide extent of territory as already mentioned forbids our imputing them to the action of rivers and compels us to call in the aid of a marine deluge.

Many of these grooves on the surfaces of rocks are too deep and extensive to be produced by any ordinary rivers. The rock is "so furrowed as to resemble a wet road, along which a number of heavy and irregular bodies have been dragged": and these bodies must have been of great weight to have made so deep an impression as is sometimes exhibited even after the lapse of so many centuries during which most rocks are liable to (be) disintegrated to a considerable depth. Multitudinous as are the examples of this diluvial action upon the rocks of this country it seems to me a little singular that they should hitherto have excited so little attention.

Sometimes we find vallies of considerable depth scooped out in the midst of a particular formation of rocks or deep enough to cut through several rocks on the opposite sides of such vallies the layers of rock exactly correspond so as to leave us no doubt but they were produced by moving water. And several circumstances connected with many of these vallies forbid the supposition that existing streams could have produced them. In regions not mountainous for instance it is found that rivers instead of wearing deeper are actually piling up their channels.

It is in general the softer strata and especially in those consisting of regular layers of sand, clay, and gravel called Tertiary Formations, that these vallies of diluvium origin occur. And even here we must not impute in but few cases the entire scooping out of the valley to the diluvium waters; since existing streams have sometimes accomplished a part of the work. Both causes united nearly swept away extensive formations leaving only here and there are a few conical or ovoid hills as wrecks of the devastation. And I cannot here repair from expressing the opinion that the celebrated mounds or tumuli in our Western states which have so long been regarded as the stupendous works of some ancient and comparatively civilized race of man are nothing but the insulated hills which remain after powerful diluvium and fluviatile currents have swept over tertiary formations. The immense number and size of these tumuli will satisfy anyone who takes the trouble to calculate the labor requisite for their erection that the Chinese Wall and the Egyptian Pyramids were mere pygmy efforts compared to these. And the facts stated by a writer in the Illinois Magazine that he "had never examined one that was not composed of different strata of earth, invariably lying horizontally to the very edge of the mountain," proves beyond all question that they are insulated portions of a one continuous tertiary formation. If this opinion be correct we have in the Eastern states hundreds and thousands of tumuli of precisely the same character and as much entitled to the examination and veneration of the antiquary as those at the west.

In the second place we find evidence of a universal deluge in the occurrence of that coating of sand clay and gravel called alluvium in every country hitherto examined. This consists of the ruins of the rocks and soils of different districts in different countries mixed promiscuously together and piled up irregularly over a great part of the earth's surface in just such a manner as powerful amounts of water operate upon such a loose and heterogeneous mixture. Although this diluvium occurs on almost…

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…every square mile of the dry surface of the globe it so much resembles accumulations of sand and pebbles that are constantly produced by rivers that nothing but a careful examination leads to the conclusion that this diluvium could not have been produced by any present or former rivers or their inundations: or any other cause indeed but a mighty and universal deluge. For in the first place this diluvium occurs in situations where no rivers or landslides could ever have conveyed. It is found indeed wherever it could find a lodgment on the highest mountains and is so spread over almost every portion of the surface as nothing but a wide and mighty deluge could have spread it. In the second place it occurs generally in quantities immensely too great and is sometimes piled up vastly too high and at other times scooped out in cavities vastly too deep to be the result of rivers even in the mightiest inundations. Even the waters of the Amazon pouring down a mountain gorge or Lake Erie bursting its eastern barrier could not produce effects even on a single district to be compared with those which diluvium exhibits. In the third place the fact already mention that the current that piled up and scooped out this diluvium then rushed over both the Eastern and Western continents from the north is decisive proof that it could not be the result of fluviatile action even if we suppose the elevated lands now covered with diluvium to have been formally at a low level. For to have produced such effects these rivers must have been as wide as the two continents.

Were it in my power to conduct my hearers to the southeast part of New England all of these phenomena of diluvium would arrest their attention and make a much more vivid impression than any description. In the whole of Cape Cod and in the counties of Dukes and Nantucket and Plymouth they would find diluvium covering almost every ledge of rocks (refer here to the rocks in Brewster). In this diluvium however they would see a countless number of rounded masses of rock called bowlders from the diameter of a few inches to 10 and even 20 feet obviously torn up from their bed and drifted to the places they now occupy by some terrific rush of waters from the north. For in every case not only in the eastern but in every part of the state we always find the parent rock one two five ten and even twenty miles north of its bowlders. Looking at these huge masses we are no longer at a loss for the origin of those remarkable grooves and scratches in the faces of the solid rocks already mentioned. Nay some of these were left by the mighty inundation upon the very ledges in which they were plowing their way: and there poised upon a narrow base they constitute rocking stones which although many tons of weight may sometimes be moved by a single individual. The rock on which our Pilgrim fathers first stepped at Plymouth is only a huge bowlder of granite: and when we ascend the hill a little to the west of this rock which was chosen by the Pilgrims for their landing place we find that we stand upon one of those hillocks of diluvium so common along that coast and especially within the range of our vision as we stand upon that holy spot. And if we pass northward especially a little beyond the capital of New England we shall see from whence this immense accumulation of sand gravel and bowlders was torn. For there especially on Cape Ann we shall see little else but the naked rocks which notwithstanding its…

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…extreme hardness is often worn to entire smoothness by former diluvial agency. In short the eastern part of Massachusetts exhibits the traces of a former diluvial catastrophe of prodigious power. In the forms and aspects of the hills and vallies there we can almost see the sweeping and the gyration of the mighty current.

Nor are other lands destitute of similar diluvium and similar bowlders. These latter are even perched upon the Alps and other mountain peaks of Europe and to allude to a spot of holier associations Mount Horab itself is nothing but an immense red granite bowlder torn probably by diluvial action from the precipices of Mount Sinai. Now the universal diffusion of this diluvium with bowlders and grooves and scourings upon the rocks proves that every part of the earth has been subject to the action of a devastating deluge. And there is one important fact rendering it probable that it was the same deluge that covered every country simultaneously. The bones of numerous and peculiar pieces of land animals such as the mastodon, the mammoth, and extinct species of the rhinoceros, hyena, and bear are found in the diluvium of distant countries and there is no evidence that these animals have existed on earth since the deluge produced this diluvium. That event seems to have annihilated several species. But had the diluvium of different countries resulted from different deluges we should expect that some individuals would have escaped by passing from one region to another in the intervals: or that some part of the globe would have escaped the inundation. At any rate a single deluge accounts satisfactorily for the present coat of diluvium that envelops the whole earth and therefore it is unphilosophical to assign a plurality of causes. Indeed I do not see how the waters of the ocean could have rushed furiously over one continent without drowning every other in the mighty flux and reflux.

I am aware of a very recent ingenious attempt by some European geologists to account for the diluvial action which the earth exhibits by imputing it to the returning waters of the ocean as our present continents were uplifted at different epochs from the bottom of the ocean. That they once constituted the bottom of the ocean and that they were raised by volcanic agency beneath and at different periods I fully admit because it seems to me that facts afford little short of demonstration on these points. Marine organic remains in the secondary rocks could have been deposited only at the bottom of an ocean and the inclined position of all the older rock strata could have resulted alone from such an elevation of the surface since originally there position must have been horizontal. And that a violent current of water would attend such volcanic catastrophes and produce alluvium I also admit. But I maintain that subsequent to the last occurrence of this kind this time a mighty deluge has swept all over our present continents missing together and modifying the diluvium of other epochs and producing new grooves and furrows in the rocks. Let us examine the diluvium of New England to see whether the elevation of the strata could have produced. With local exceptions the direction of the strata here is nearly north and south and their dip to the east at various angles. In other words their elevation was produced by a force acting beneath our…

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…continent along a line farther west from New England so that the western edge of the strata have been raised. It is obvious then that the waters of the ocean which once stood over this continent must have run easterly at least in New England as its bottom was raised so as to become dry land. But we find that in fact the last deluge that swept over this land rushed from the north: and therefore it could not have resulted from the original elevation of the strata.

In the eastern part of New England there is a rock formation of considerable extent whose strata run nearly east and west. But the dip is north and hence their elevation must have produced a current from south to north the reverse of the actual direction of the waters of the last deluge.

There is another fact conclusive against the opinion that the ecisting stratum of diluvium was brought into its present situation by the retiring waters when this continent was raised from the deep. We have in New England at least two distinct tertiary formations whose strata are horizontal and which therefore were deposited since the older strata were elevated, since such an event would have given the strata an inclined position. But the last deluge happened since these tertiary formations were deposited as is obvious from their having been worn away by it and covered by diluvium. This deluge therefore must have happened a long time since the elevation of the solid strata instead of having been produced by that event.

Whether facts similar to the above exist in other countries I know not. But it seems to me that the general fact that the waters of the last deluge took a southerly course over the eastern as well as western continents is inconsistent with the idea that the elevation of the strata produced it since the direction and depth of the strata follow no general law but are as various as possible and therefore the diluvial current must have taken directions equally various.

The third geological evidence of the universal deluge results from an examination of the contents of certain caves and fissures in rocks. This is indeed but a particular branch of the last argument. Yet its novel and peculiar character entitles it to a separate examination.

A few years since in exploring a limestone quarry in England the workmen laid open the narrow mouth of a cave which had been closed by diluvial gravel ever since the last deluge. Here were found large number of the bones of more than 20 species of such animals as the elephant, rhinoceros, hippopotamus, horse, ox, deer, bear, hyena, etc., mixed confusedly together, very much broken and splintered and enveloped in mud or loam overspreading the bottom of the cave and in the calcareous deposits of stalagmites beneath the mud that had accumulated in the lapse of ages from the infiltration of water.(Here refer to a drawing of the Kirkdale Cavern and explain its structure and contents). It is impossible to go further into details respecting this remarkable charnel house at this time. But the inferences which were legitimately deduced from a careful examination of all its phenomena are too important to be passed over in silence. These inferences have been abundantly confirmed by the subsequent examination of many other similar caverns in England and other countries stored with relics of ancient animals. The <u>Reliquiae Diluvianae</u> of Dr. Buckland contains a full development of this entire argument.

1. He infers that these caverns were mostly the abodes of hyenas or bears for a long period previous to

the last deluge and that the hyenas were in the habit of dragging in thither the bones of other animals for food. These bones could not have been drifted by a flood. Nor could the animals have entered of their own accord. That it was an abode of the hyenas (i.e. the Kirkdale cave) is evident. From the habits of the animals, marks of teeth on the bones.

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Large quantities of their excrement (album graecum) found in the cave.
Comparative experiment with the living hyena.
Wear of the bones on one side.
Stalactites broken off at the entrance.

2. That therefore all the animals found in this den inhabited England and other countries where similar caves exist anterior to the deluge although nearly all the species are now extinct.

3. That they became extinct by a general deluge. No partial inundation will account for the facts.

4. That only one general deluge has occurred in those countries since the earth assumed a habitable state or since existing continents were raised above the waters of the ocean. Only a single deposit of Diluvia mud was found in the caves.

5. That the period since this deluge has been longer than that anterior to it since the present order of things commenced on the globe.

The stalagmite over the mud was more abundant than beneath it.

6. That man scarcely existed if it all in Europe previous to the deluge.

In only two of three instances in the south part of Europe have human bones been found associated with those of the antediluvian animals so as to make it certain that they were of contemporaneous origin. In America too no human bones have been found in diluvium.

7. That the sea and land did not change places at the deluge in those countries where these caves occur. For their inhabited by quadrupeds before that time.

8. That the climate of Europe was probably warmer before the deluge than it has been since. The animals above-mentioned are now found only in the torrid zone - that is their congeners.

What a singular development is here presented to us! And how providential that this storehouse of antediluvian history should not have been unsealed till the 19th century!

Such are the most striking and decisive evidences of a universal deluge. And so decisive are they that few geologists would think of doubting the occurrence of such a catastrophe even if the inspired record were silent concerning it. "*If there be any facts well-established geology*," says one of the most experienced and able naturalists of the present day, "*it is this, that the surface of our globe has suffered a great and sudden revolution the period of which cannot be dated farther back than five or six thousand years.*" This conclusion of Baron Cuvier is strengthened by the uninspired records and traditions of all nations. Permit me in this place to present the summary of these to complete the argument for a deluge leaving the bible out of the account. Profane history and tradition coincide with the Mosaic account in the following particulars.

1. That a general deluge occurred in early times. This opinion is found incorporated into the written and unwritten histories and mythologies of almost every nation and tribe under heaven.

2. That this catastrophe was a penal infliction upon the race.

3. That one man on account of his piety was warned of the approaching destruction.

4. That he was of the 10th generation from the first man.

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5. That he was directed to build an ark.

6. And to take with him into it his sons and sons' wives.

7. That all all animals came into the ark by pairs.

8. That seven days before the flood commenced this man was warned of its approach.

9. That he entered it on Sunday, November 30th.

10. That he was directed to lay in a store of provisions for himself and the animals.

11. That the deluge was produced by torrents of rain and the bursting forth of waters from the earth.

12. At the end of 40 days a raven was sent out of the ark.

13. Also another bird was sent out and returned.

14. A third bird was sent out which brought back the branch of a tree.

15. And finally the holy man preserved in the ark (who is expressly called Noah in the Persian histories) disembarked, built an altar and offered sacrifice.

These numerous coincidences between the inspired and uninspired records can be explained only by supposing them to have a common origin. But the facts just enumerated borne down to us as they have been on the current of tradition and false religion are mingled with a thousand fables and absurdities whereas all of the Mosaic account is simple and consistent with itself and free from fable. Can there be any doubt then that this is the history among all others to be relied on?Can these scattered traditions be regarded in any other light than as mementos of the faithfulness of Moses? And when to the testimony of Moses and from other historians and traditions we join the geological proofs of a universal deluge have we not here "*a three fold cord of evidence which is not quickly broken?"*

It is not long since infidelity seizing with avidity upon certain natural phenomena and historical records pronounced with confident triumph that human society had existed a far longer period than the sacred record allows. The zodiac of Denderah and the famous astronomical tables of the Hindoos were arrayed against the Mosaic chronology with all the confidence of demonstration but within a few years the hoary aspect of these vaunted relics has disappeared before the counterdemonstrations of infidelity itself. Who now speaks of the alternating layers of lava and soil around Mount Etna or the rubbish of the iron mines of Elba or of the retrocession of the Falls of Niagara as evidential of the erroneous chronology of Moses? A few years since these were fruitful themes for declamation but now they are regarded as only interesting geological facts not difficult to explain. On the other hand how does almost every crumbling precipice of rock many a peat morass and every alluvial delta attest in the comparatively recent period at which the several processes began that the time when the present order things commenced on the globe cannot be very remote. Just so soon as geological facts have been accurately understood every apparent discrepancy between them and the Mosaic history has vanished.

Not long since it was urged against the Mosaic account of the deluge that the climate in the vicinity of Mount Ararat where the ark rested was far too cold to allow the olive to grow a branch of which the sacred writer declares was plucked by the dove sent out of the ark. The study of organic remains has demonstrated that the temperature of the earth in early times was much higher than at present; and therefore the olive might have flourished at the time of the deluge where now is perpetual frost.

Even at this day some learned commentators on the bible regard the difficulty of identifying the…

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…site of Eden as decisive proof of geographical ignorance in the sacred writer and of the fabulous character of his whole narrative. But who that understands the nature and effects of diluvial and volcanic actions in modifying the surface of our globe is not prepared to expect that the river which went out of Eden and from thence was parted and became into four heads should have had its channel greatly altered by the deluge and perhaps by subsequent volcanic agency? And when he learns that from four great rivers do in fact arise in the vicinity of Mount Ararat two of which the Euphrates and the Tigris are the same as those mentioned by Moses and that their heads are only some 30 or 40 miles apart will he not recognize the rivers of Eden as changed in its beds by one or both of these causes? Indeed had Moses described this river so as to correspond exactly with existing rivers it would have excited the suspicion that his narrative was an invention of his own imagination adapted to the state of things after the deluge making no allowance for changes by diluvial and volcanic action.

Philosophers in former days objected to a universal deluge from the difficulty of finding water enough on the globe to cover its whole surface simultaneously. But in the present aspect of geological facts and theories it is not necessary even to suppose a miracle (which might reasonably be supposed) to accomplish the entire submersion of of existing continents. For since the phenomena of volcanoes and earthquakes have been accurately studied it has been ascertained that the force by which they are produced often acts beneath the ocean sometimes elevating and alternately depressing its bottom after an interval of weeks or months. Suppose then at the period of the deluge a powerful force of this kind to have been acting beneath some one of the great oceans on the globe, say the Arctic Ocean. The consequence would have been a gradual uplifting of its bed and a rise of the waters whereby the whole globe might have been inundated by mighty rushing waters from the north the course of which it seems was actually taken by the last diluvial current: (although perhaps the effects which we witness were produced by the retiring and not the overflowing waters) at the end of six months suppose the confined gas or lava vent and began to escape. The effect would be a gradual sinking back of the bed of the ocean to its original level and a subsidence of the waters to their former situation. I do not maintain that this was in fact the mode in which the deluge was produced and I make this a position just to show how easy it is on acknowledged geological principles to account for its production.

We might even carry this explanation farther, and suggest a probable reason for the forty days of rain that preceded and accompanied the deluge. For only supposed the eruption of steam to have commenced early and this being condensed will return to the earth in torrents of rain: a phenomenon not uncommon in volcanic eruptions.

Here then I terminate my comparison between the Mosaic and the geological records of the deluge. I am aware of the danger of hasty generalizations and inferences from scientific facts. By making the most extensive allowance which can reasonably be demanded for possible mistakes can any philosophical mind take a full view of the testimony which geology compares to the faithfulness of the divine record and not feel a firmer assurance that the record is indeed the word of God especially when tradition and inspired history speak the same language. Formerly it was supposed by the sceptical that many a fact in natural science and especially in geology stood in irreconcilable opposition to the Mosaic record. But as these facts have been more accurately understood their apparent discrepancy with inspiration has vanished and almost every step in the progress of…

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…discovery in modern times has brought science and revelation into closer union and coincidence. It is reasonable then to predict that as the last cloud of ignorance passes away there will be seen painted upon its retiring darkness the bow of science blending its colors with the bow of Christianity – a happy prelude of the millennial day.

But I will not further enlarge. I cannot however conclude this short course in geology without an expression of my earnest wishes that the society before before which I have had the honour to lecture may continue to go on as it has been with a firm and a rapid step. I am not a member of the society and here had no connection with it except this short one which now terminates and therefore I speak briefly.

I cannot but believe that the citizens of Boston – no - I will say the citizens of Massachusetts - will feel that interest and a pride in patronizing and fostering such a society. Other nations have found it for their interest to patronize natural history because the naturalist holds in his hands a part of the keys by which alone some of the national resources can be unlocked. Shall it any longer be said that New England in advance as she is of most nations in the diffusion of knowledge is yet behind most others in attention to natural history. Now in order that the community should be interested in these subjects and derive benefit from them there must be some nucleus - some Central Point from whence an influence shall radiate - and to which specimens and naturalists shall be attracted. And what more proper place for such a center then the metropolis of New England - the city known everywhere as the munificent patron of benevolent literary and scientific institutions!

Nor can I conclude without returning my thanks to this audience for the patience with which they have listened to my imperfect attempt to elucidate the principles of geology and the kindness which which they have borne and overlooked my deficiencies. Should any be induced by the effort to look with more interest upon our rocks as they traversed the land I shall be gratified and especially should any be lead when the season for recreation and travel come to sally forth hammer in hand among our mountains how happy should I be to meet them among the Alpine scenery of our state and point out to them on the great map of nature what I have here exhibited on the contracted walls in the lecture room!

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<u>Geology of Portland and Vicinity</u>

Rocks all primary

Stratified - dip and direction of the strata

Gneiss - called often granite - precious stones found in it. Beryls at school in North Yarmouth - precious garnets hill of gneiss back of the cove for building stone.

Talcose slate – mica slate and quartz rock

Steatite - at Harpswell injected by actynolite

Gold in talcose slate

Novaculite on the beach

Plumbaginous mica slate - Charged with calcareous matter apparently plumbago - also color dark with decomposing pyrites - plumbago may probably be found in this rock in beds - possibly some of the oldest varieties of anthracite as at Worcester.

Give an account of the usual manner in which coal occurs in other parts of the world.

Now it can be ascertained whether anthracite or plumbago exist in these rocks.

Pyritiferous mica slate on Jewel Island - three strips of it - a fine spot for the manufacture of copperas and probably of alum

Limestone should be further examined

Dykes – of greenstone

Tertiary – Notice the slide on Presumpscot river and the shells and crabs found there

Alluvium - show the drawings of the lighthouse and on Jewell’s Island.

NATURAL HISTORY LECTURE NOTES

[Edward Hitchcock classroom lecture notes, "Natural History", EOH, Box 10, Folder 9.]

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Natural History

Gentlemen,

The subjects in which I am called to instruct in this institution are comprehended in two general and well marked divisions the first Chemistry and the second Natural History.

Both these branches have reference to all the natural objects to be found on and within the globe. Chemistry investigates their composition and the changes that take place in their constitution through their action upon one another. After the chemist has pushed his analysis to the utmost, these objects as they exist in nature still remain undescribed although analysis…

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…is an important item in their description. To make out this description is the business of Natural History.

The term Natural Science or the Natural Sciences is often used as synonymous with Natural History. But their meaning is not the same or rather the one includes the other. Natural Science embraces the results of all the investigations men have ever made upon the work of God. Hence Astronomy is one of the branches of Natural Science and Physics or Natural Philosophy another: chemistry or a third and Natural History a fourth.

So vast is the variety of objects creation presents and so limited the human faculties that the mind of the natural historian immediately attempts to classify - that is to assemble these various objects into distinct groups agreeing in some common characters. And it is the principle of classification that divests Natural History of that chaotic appearance it exhibits to those who only look at it from a distance. They perceive an immense variety of objects in the creation of God and when told that Natural History takes cognizance of them all they feel that the task of naming and treasuring up the names of so many things would be altogether intolerable and hence give over the attempt. But classification in a great measure relieves this apprehended difficulty and enables a man to learn very much of Natural History without any remarkable tax upon his memory.

Illustrate the principle of classification by supposing a person approach…

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…ing a thick forest - the first view is bewildering: but soon he would learn to group together the different sorts of trees and soon learn all of the forest contained.

One of the most striking divisions running through natural objects is that which separates them into organic and unorganized - or those which have life and those destitute of it. In inorganic beings the different parts have an independent existence for example taking away a joint of basalt or cleaving a crystal. But organic body is injured if not destroyed by division - for example plucking a limb from a tree or an animal. Inorganic bodies are also vastly more permanent than organic: for example a stone which continues the same unless acted upon chemically or mechanically. But a plant or animal is always in increasing or decaying. Organic bodies are also distinguished from unorganized by integument or covering to defend them from injury. Nourishment is necessary to organic but not to inorganic bodies.

If we proceed still farther in this grouping together of bodies agreeing in some respects we shall come next to those general divisions of Natural History which are usually regarded as distinct sciences. These are zoology, botany, and mineralogy, which embrace the whole circle of Natural History.

1. Zoology includes all animals beginning with man and terminating with the zoophytes. Cuvier, the most distinguished modern writer on the subject, divides all animals into vertebral and invertebral, that is such as have vertebrae and such as have none. The invertebral are again separated…

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…into three divisions: 1. Molluscous Animals or such as have no bones but have the muscles attached to the skin which in many species becomes a stony shell; 2. Articulated Animals or those having jointed bodies and limbs with an external crust; 3. Radiated Animals or Zoophytes in which the organs of sense and motion are disposed circularly around a center - whereas in all other animals these organs are disposed along an axis.

Hence then the whole animal kingdom is divided into four important branches: 1. Vertebral Animals 2. Molluscous 3. Articulated 4. Radiated. The vertebral animals he divides into four classes the first of which includes man and the quadrupeds the second birds the third reptiles and the fourth fish. The Natural History of birds is usually denominated Ornithology and forms one of the most elegant and enchanting branches of Natural History. The description of reptiles is sometimes called Herpetology and of fishes Ichthyology. Of the Molluscous animals Cuvier makes six classes: one of which comprehending shells is usually denominated conchology or testaseology. He makes four classes of the articulated animals one of which embraces the insect tribe called entomology. The radiated animals of which corals and sponges are examples form five classes. But a more particular account of these divisions must be deferred to another opportunity.

The radiated animals in several respects approach very near to plants and in regards to some of them it is even yet disputed whether they belong to the animal and vegetable kingdoms.

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The history of the vegetable world, a history various and beautiful, is all included in the science of botany. Here also are numerous subdivisions of classes and orders: but these are too complicated in their characters to render it proper to give them in these preliminary remarks.

The history of the unorganic part of the creation around us is embraced in the science of mineralogy. In a more limited sense mineralogy comprehends a description of those minerals only which are simple or homogeneous while the history of those that are composed of two or more simple simple minerals constitutes the science of geology.

Such are the outlines of Natural History in its present state. In other words these are the grand divisions of the subject. In all these branches we find several other subdivisions which it is important to notice. Classes are the first and largest division consisting of a collection of genera possessing some common peculiar and striking character by which they may be distinguished from all other genera. Classes are next divided into sections called orders which are groups agreeing in certain characters different from those that distinguish the classes. Proceeding still father in the subdivision we come next to genera which consist of groups having certain common and peculiar characters which do not belong to the whole order. One step farther carries us to species which are composed of groups agreeing together in all their characters. Each species differs from every other and there can be no farther divisions except the occasional varieties that are…

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…sometimes found among individuals of a species but are not permanent.

The branches of Natural History to which more particular attention is given in the colleges of this country are botany, mineralogy, and geology. But it seems to me of very great importance that every student should get a correct general view of what is embraced in the whole science. To promote this object I have given an outline of the several branches composing it. With the same intention I shall add a numerical view of the various yet connected groups of organic and inorganic objects found upon our globe.

(Here introduce pages 6 and 7 of the Discourse on Utility of Natural History.)

There is a method of acquiring a more distinct view then mere words can give of the various classes of objects embraced in Natural History which I shall here mention. It consists simply in examining the plates on Natural History amounted to between 200 and 300 given in Reese's Cyclopedia and in the order there given.

Natural history must have been cultivated in some degree from the beginning of the world. For men would soon begin to learn the uses and of course some of the properties of animals vegetables and minerals. Thousands of years however passed before any effort was made to analyze and classify the facts which must have been collected. Indeed the works of all the ancient naturalists are little more than a vague and unarranged mass of facts - many truths blended with not a few errors. The most distinguished naturalists of ancient times were Aristotle Aelian Pliny Solinus and Theophrastus. Some of these have left us treatises of some value and very voluminous particularly Pliny. In modern times before the days of Linnaeus little…

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…was done for Natural History except to accumulate facts. So numerous had these become at the beginning of the last century the works of Aldrovandus [Ulisse Aldrovandi, 1522 – 1605] an Italian naturalist of great industry and perseverance who wrote upon nearly every department of this science - his works amount to 13 volumes folio. This is the largest work upon Natural History that has ever been published and drew forth from Pope Urban VIII the following panegyric:

The various forms that swim the watery plains
Whate’er the earth’s capacious womb contains
The trees and herbs that on her face appear
And all the wing’d inhabitants of air
In thy stupendous work collected lie
To feast the soul and strike the astonish’d eye
Her own productions industry no more
Does own but wonder at the first she bore
And fruitful nature at thy deeds amaz’d
Wishes her own those works thy art has raised.

But after all Linnaeus who was born about 100 years ago must be regarded as the father of Natural History. Although botany was the branch in which he particularly excelled yet his vigorous mind glanced upon every department of nature and reduced to order the heterogeneous mass of materials the industry of ages had accumulated. From that time to the present the sciences have most rapidly advanced while almost every succeeding naturalist has rendered the homage due to this great man and followed in the tracks he marked out.

To enumerate the names and the works of the distinguished naturalists who have flourished in Europe since the days of Linnaeus would occupy volumes. It may not be irrelevant to advert for a moment to the naturalists of our own country where until recently only a few insulated individuals gave their attention to these pursuits.

And here it must be confessed that no small part of the Natural History of our country has been elucidated by foreigners. The able and splendid works of the Michaux, the father and the son, and of the eccentric Pursh upon our botany are examples of this kind. They are not alone in this department. The labours of…

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…the Rev. Henry Muhlenberg exhibited in his valuable collection of plants and in his Catalogue of our plants and work on the grasses will always be remembered in the history of American Botany. The works of Mr. Elliott on the plants of South Carolina and Georgia is a splendid monument of industry and botanical skill. In the recent unfinished work of Doctor Torrey, the present professor of chemistry and mineralogy at West Point in N. Y. illustrative of the plants north of Virginia is of a similar character and must be regarded as a national and a standard work. In the cryptogamic department of our botany the Rev. Lewis de Schweinitz stands preeminent as his late work on the Fungi of North Carolina and another worker on the Hepaticae testify. Of the same high character is the works of Mr. Nuttall on the genera of North American plants. Among the smaller works illustrative of this department may be named Barton's Flora of Philadelphia and Bigelow's Florula of Boston. Tories Compendium of his Flora, Beck’s Botany, Eaton’s Manual and the Introduction to Botany by Skinner and Locke. The splendid Medical Botanies of professors Bigelow and Barton and the flora of North America by the latter exhibit not merely the skill of our botanists but also the ingenuity of our artists.

In American mineralogy the work of Professor Cleaveland stands unrivaled: in geology the works of Mr. McClure exhibiting the results of his Herculean labours in surveying the rock strata of our country. The very numerous smaller works on these sciences and papers and the scientific journals by gentlemen in every part of our country show with how much ardor and success these branches are now cultivated. *[In pencil]* Fossil Geology by Conrad, Lea, and Morton.

The zoology of our country has received no small share of attention. The labours of the venerable Heckwelder in illustrating the history of our own species will long be remembered. The quadrupeds of our country have recently been described by D. Harlan in his Farina Americana and by Dr. Godin in his. The great and magnificent work of Alexander Wilson upon our birds with a continuation by Charles Lucian Bonaparte will bear a comparison with any work ever published. Notice the work of Anderson. The like may be said of the work of Mr. Say presenting descriptions…

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…and most elegant drawings of our insects. Our fishes have been described with ability by Raphinesque and D. Mitchell our reptiles by Harlan Le Conte Leveur and Barnes and our shells by Say, Conrad, Lea and Barnes.

Although this rapid sketch shows us that the Natural History of our country has received no small degree of attention yet the whole field is by no means occupied and in no civilize country on earth perhaps may young naturalist hope to make more brilliant and useful discoveries. Indeed so inviting is the prospect that multitudes of zealous cultivators of the sciences of both sexes are starting up on every side and almost every village has its collections at least of botany and mineralogy. So that now instead of being regarded as an evidence of mental derangement as it was a few years ago to be seen collecting specimens of rocks and plants he can hardly maintain his claims to the character of a learned man who exhibits an entire ignorance of these pursuits. Especially is it expected in the instructors of youth if they be able to give their pupils some scientific knowledge of the plants and minerals they tread under their feet. These sciences are forcing their way into all classes of society and though individuals may decry them and attempt to throw ridicule upon them it is too late to arrest their progress or conceal their value.

But what is their value is a natural and not infrequent inquiry? To this inquiry I invite your attention. And here I shall make no apology for making free use of the language of an address on the subject which I had occasion to prepare several years ago presuming that as its circulation was limited it has fallen into the hands of few if any of you of the class - and being sensible that more care was bestowed upon it than my health and time would permit me to give it now. At any rate the alternative was before me either to adopt this course…

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…or to abandon altogether the attempt to bring the subject before you.

Here introduced the language of the Address.

BOTANY LECTURE NOTES

Botany

[Edward Hitchcock classroom lecture notes, "Botany", EOH, Box 10, Folder 2.]

[The paintings referred to were likely all by his wife, Orra White Hitchcock.]

Gentlemen

The science in whose investigation I invite you this morning to engage embraces one of the grand divisions of natural history, and in extent and variety it far exceeds the two other departments. While not more than 30,000 species of animals have been described, and only a few hundred minerals, 50,000 plants have been already registered in the calendar of the botanist.

In thus dividing the dominions of natural history into three distinct kingdoms, the animal, vegetable, and mineral, I follow a distinction which a very slight acquaintance with the subject suggests, and which has been recognized by every naturalist in every age. And although the characteristics of these classes may at their nearest limits be so blended as to perplex the most acute discriminant, yet in their grand outlines they bear a peculiar distinctive impress that cannot be mistaken.

To define the limits between the mineral kingdom…

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…and the animal and vegetable kingdoms is not so difficult a task since the two latter are endowed with a principle of life of which the former is destitute. For although to define the nature of the vital principle be something beyond the reach of physiology, yet are its effects so manifest that its presence or absence essentially changes the constitution of the individual.

But when we attempt to mark off vegetable from animal nature - both possessed of life - the task is not so easily executed. Animals are organized beings and supported by air and food, and so are vegetables. Animals have spontaneous motions, so have vegetables, of which the sensitive plant is a striking example. However disturbed may be the leaves of plants, they will uniformly turn the same side towards the sun, and the flowers of many species close at evening and expand in the morning while others are open at night and closed during the day. Is it said that animals are distinguished from vegetables by their locomotive power? But many species of corals and kindred animals are fixed as immovably to the bottom of the ocean as vegetables to the earth; while many a plant is floating around them. Is it said that animals are possessed of sensation and plants are destitute of it? This may indeed be true, yet it would be difficult if not impossible to prove that vegetables are wanting in this character. Upon the whole, the only distinction that will hold throughout, seems to be, as a French writer has expressed it, "that plants alone have a power of deriving nourishment, though not indeed exclusively, from inorganic matter, such as mere earths, salts, or airs; substances certainly incapable of serving as food for any animals, the latter only feeding on what is or has been organized matter, either of a vegetable or animal nature. So that it should seem to be the office of vegetable life alone to transform dead matter into organized living bodies."

The lowest tribes of animals come nearest to the lowest orders of plants. This destroys the idea of a regular chain.

In practice, however, we are not much perplexed with this difficulty of definition: first, because in most instances the characters of the plant or animal under examination are very decided, and it is only in the lowest classes of animals that we meet with difficulties; and secondly, because we can very readily distinguish an animal from a vegetable substance, by the peculiar odor that exhales from the former when thrown into the fire. The only cases in which burnt vegetables emit…

[Written in pencil on the margins of the pg.]

The most imperfect animals also come nearest the most imperfect plants, for example, Polypodia and flowerless plants.

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…a similar effusive, are those of caoutchouc *[rubber]* - gluten of wheat and the juice of the pawpaw *[?]* tree.

In the place of a better definition then plants are living organized beings springing from seeds and deriving their nourishment from inorganic substances. It belongs to chemistry to ascertain the simple principles that enter into their composition and medicine develops their salutary efficacy upon the animal system. But botany distinguishes their external forms - arranges them into distinct groups or families - exhibits their internal structures - their histories their habits their geography and natural affinities.

I have no time to enter into a detail of the utilities of this science. The noble and ingenious mind, which is fired with whatever is grand and beautiful does not need a logical array of arguments to induce it to the study of the works of God. Such a mind - being itself an emanation from heaven - knows that whatever bears the impress of Jehovah's workmanship, must be profitable and interesting to contemplate; and especially when called to look with a more scrutinizing eye upon those flowering beauties that arrested its attention when first in its infant days it looked abroad upon the material world it will feel as if called only to examine and admire new wonders that escaped the superficial observations of childhood. I know, indeed, that there are those whose taste is so perverted that they can admire nothing which is not artificial - who can see no beauty in the landscape unless splendid mansions or monuments meet their eye - who never felt a thrill of emotion in view of unsophisticated nature. There are others whose curiosity seems limited by their animal wants and it were as difficult to excite in their bosoms any generous admiration of natural beauties as to make the palm and the olive spring up and flourish amid the icebergs of the frozen ocean.

To awaken in such minds any interest in botany cannot be done by exhibiting before them its utilities any more than casting pearls before swine will cause them to estimate their value. But we want not such to attempt to acquire a knowledge of natural history. We rather exclaim upon this approach, “*procul o procul este, profani*!” [Translation: Keep away, o keep far away, ye profane ones!]

There is however one point of view in which the study of botany may be contemplated which I am unwilling to pass unnoticed. For it is a view that may otherwise be forgotten and one which is in my opinion particularly important to the members…

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…members of an institution like this. I would recommend the study of botany because it affords an opportunity and an inducement to that kind and degree of bodily exercise which is indispensable to the health and success of the student. It is a mistaken idea that to effect these important objects nothing more is necessary than to give the limbs and the chest a certain quantity of motion: and I am persuaded that there is not so great a deficiency among sedentary men in the quantity of their exercise as in the manner in which they take it. It is of very little service, so far as the health is concerned, for a man to give exercise to his body unless he also give relaxation to his mind. No matter if the student takes his regular morning or evening walk, if he is meanwhile solving a mathematical problem or discussing a metaphysical subtlety, his health will be but little promoted. It needs something to direct his mind likewise from an accustomed routine and then he will return to his investigations with renovated strength. Now botany not merely furnishes an inducement to give exercise to the body, but it gives also that diversion of mind which is wanted. It exercises the student's faculties in his rambles just enough to turn them off from severe studies but not enough to fatigue.

In order however that should be the effect of botany upon the student it is indispensable that he acquire a relish for science. And in order to become attached to it he must be acquainted with its principles and begin to make collections. If he engage in botanical pursuits merely from a conviction that they will promote his health he will be apt very soon to become wary of it, and he might as well day by day collect and throw away pebbles up on the beach as to pluck flowers from the fields.

It is this application of botanical pursuits to the promotion of health that I wish to urge gentlemen upon your attention. In this day of premature decay among literary men I feel it to be a most important object to devise some means of arresting the evil in the beginning. Depend upon it that if you once suffer those hundred headed diseases to get firmly seated in your constitution which are now making such dreadful ravages in the learned world - if you get once firmly locked in their grasp they will never let you go. I do believe the study of natural history may be employed as a powerful means of saving you from such a catastrophe: and I would urge botany upon your attention chiefly for this reason. Its pursuit need interfere but very little with your regular studies and may be confined chiefly to the hours of relaxation and leisure.

I will not pursue this subject of the students health any farther at present. But it is one…

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…of vast importance and which demands the serious attention of every friend to humanity. From every college hall - from all the learned professions there issues a voice calling upon every one who has any connection with students to exert himself to save them from those insidious and rapidly increasing diseases that have cast down so many strong men wounded and so often blasted the hopes of church and state. I shall feel it to be my duty therefore often to call your attention to the subject so long as Providence shall permit me to act in my present situation. When remarks of this kind flow naturally from the subject under consideration I shall not fail to improve the opportunity: and if no opportunity present I shall not hesitate to trample on the rules of rhetorick to secure an object of such importance.

After these preliminary remarks we are prepared to proceed with an examination of the principles of botany. The first part of the science that demands attention is the physiology of plants: our knowledge of the structure and functions of the different parts. Some writers describe the structural plans under the term anatomy of vegetables and confine physiology to the function of the different parts. I shall comprehend the whole under the term physiology. I begin with the external covering of plants.

[*Two pages of additional introductory material have been inserted between pgs. 5 and 7. They are transcribed following pg. 59 below.]

Of the Cuticle or Epidermis

Over every part of plants we find spread *[See * above]* a skin or membrane generally thin and tough called the cuticle or epidermis. It corresponds to the scarf skin that covers the animal body. As it varies from the animal from the covering of the finest texture to the toughest thickest membrane covering the ox or rhinoceros so does it in vegetables.

Exhibit the epidermis of the birch - the buttonwood - the currant - the mullein - the nettle - the plum - the cork tree (Quercus suber) - the maple and locust?

The grand object of the cuticle in vegetables and animals is protection of the tender parts beneath. Hence it is composed of more durable materials than even the wood. For example the white birch. It is porous in plants as well as animals - admitting in the latter the passage of the insensible perspiration and of fluids and air from within and without in the former.

Some suppose the cuticle gives the form to the vegetable body: but it will conform itself only to the natural growth of plants - excrescences or monstrosities as they are called bursting it asunder and if the cuticle in any part of the tree be removed no swelling follows as would be the case if it came from the plant.

The extension of the cuticle is astonishing as it does not seem to have any connection with the living part of the plant. The cuticle however seems to…

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…be formed of the cellular parts of the plants dilated and multiplied and changed by their new situation. Hence we find in some trees scales of bark which having performed their functions become dead matter and are cast off. For example Platanus occidentalis.

Decandolle supposes the epidermis to be formed by the deposition of sap hardening under the influence of the ingredients of the air pg. 185. [Augustin Pyramus de Candolle, 1778-1841, Swiss botanist; possible Reference: De Candolle, 1812, Elements of the Philosophy of Plants.]

Cellular integument

This is a succulent cellular substance in immediately under the epidermis generally green and is the seat of colour - the cuticle being usually transparent. This is analogous to the rete mucosum of animals. Leaves consist almost entirely of this substance covered by the cuticle and in their economy it acts a most important part.

Exhibit specimens of plants containing the cellular integument. For example birch and basswood.

Bark or Fibre

This lies between the cellular integument and the wood and consists of a single layer in plants one year old. Every succeeding year adds a new layer that of the preceding year being pushed outward. It is in the fibre only that the essential vital functions are carried on, the outer layers being wholly or greatly dead. They are pushed out along with the cellular integument and becoming lifeless, something most remarkably exhibited in the pine the oak and the locust.

The bark consists of a large number of woody fibres mostly running longitudinally. These fibres give it tenacity and distinguish it from the parts already described. The layers of bark in some trees are so firmly connected and so pliable that they may be separated and form cloth of considerable durability. Of this kind is the lacebark from the West Indies: and specimens of a like kind are very frequently brought from the South Sea Islands. Prepared by maceration. See summary pg. 61. (Charles II had a cravat made of lace bark presented by the government of Jamaica and ladies have used it in their dresses on many occasions.)

The peculiar qualities of plants are found most marked in the bark especially in the inner coat or fibre although these are to be distinguished in almost every part of the plant. Here we find the resin of the pine tribe - the tannins of the oak and hemlock the bitter of the Peruvian bark and the fine flavor of the cinnamon.

There is one power possessed by the bark that shows what care Providence has provided for the preservation of the vegetable kingdom. When a portion of bark is removed from a tree it has the power of extending itself laterally till the wound is entirely closed. If the wood beneath has…

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…been injured this healing process goes on more slowly as the tree has no power to remove the decayed part. But if this be carefully cut away and the wound covered with a cement to protect it from the atmosphere the process will go on rapidly until the part is completely restored. This property has been applied successfully to the restoration of shade and fruit trees that had become much decayed.

Wood

This constitutes the principal and most solid parts of vegetables comprehending all that is contained within the bark except the pith. By cutting across the wood it will be seen to consist of numerous concentric layers each of which is hardest externally. Sometimes they are broadest on one side of the tree bringing their centre at a distance from that of the tree. These concentric layers consist of innumerable woody fibres running longitudinally or lengthwise of the tree. They are intersected by thin plates extending in all directions from the centre of the tree to its circumference. These are called the silver grain.

Exhibit specimens of wood and refer to the drawings

It is asserted by Linnaeus and is now generally admitted that every year adds one to the concentric layers of a vegetable and that consequently we can determine the age of a tree by counting these rings.

In most trees in northern latitudes they are quite distinct: but in many instances of tropical trees they are much more confused.

In many trees a number of the outer most rings differ in colour and solidity from the inner ones. The outer part is called the sap or alburnum and the inner part the heart. They are essentially the same except that the sap has not yet acquired that solidity which is possessed by the heart and in the latter too the vital functions have almost ceased though very active in the former. Some wood is entirely composed of sap. Example, bass wood tree.

It is a question of interest in what part of the vegetable trunk the new wood that is annually added has its origin whether the wood adds a new layer to itself or is secreted from the pith or is produced from the bark. The latter supposition is undoubtedly the true one. For on introducing a plate of tinfoil between the bark and the wood and closing the wound it was found on opening the spot one or two years afterwards that new layers of wood had formed over the tinfoil.

Describe also Dr. Hope's Experiment – Smith p. 44.

In some instances however it is found that the alburnum will produce bark: as when a tree is entirely…

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…stripped of its bark. A gelatinous matter soon exudes from the surface of the treaty called the <u>cambium</u> and erelong is converted into bark under which a new layer of wood is formed. Hence it is supposed that the alburnum does in fact first give rise to the new layer of wood by the production of the cambium which seems to need the vessels of the bark to convert it into wood.

Exhibit specimens of wood cut transversely.

<u>Medulla or Pith</u>

This occupies the centre of the vegetable being somewhat juicy in young plants but dry and cellular in those fully grown. Linneaus supposed it to be the seat of life and source of vegetation while other physiologists regard it as exercising no important function in the vegetable economy. It seems however to hold somewhat the same relation to the plant as the nerves do to the animal giving life and energy though not the source of nourishment.

Exhibits some specimens of plants with pith. Elder. Also some that are hollow.

<u>Sap vessels and Course of the Sap</u>

That plants contain fluids of different consistence and properties and that this fluid passes from one part of the plant to another must have been noticed by the most careless observer. But the physiologist attempts to explain the manner in which this sap is propelled through the appropriate vessels the plants so as to effect the object of its circulation - that is to nourish the plant. In different parts of the same vegetable we find different fluids such as gum sugar acids and oils - and as these are very different from the substances taken up by the roots from the soil or absorbed from the atmosphere by the leaves it is obvious there must be in the plant appropriate vessels not merely to contain these various substances but others adapted to produce those chemical changes that are necessary to their formation. This system of vessels is too complicated and too much removed from any but microscopic observation to be understood by us. We can however discover some of the tubes and cells and membranes that compose this system and see a part of the process that is going on. The whole vegetable body without excepting any part is a continued mass of tubes and cells - the tubes extending indefinitely…

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…but the cells frequently interrupted by transverse partitions producing in general hexagonal figures.

Illustrate these tubes and cells by magnified figures.

[The following is written in pencil.] *Introduce the opposite pg. here.

The sides of the tubes and cells often porous perforated or torn. Some of the tubes are laterally perforated others pierced with holes ranged in a close spiral line. In some those holes run together into spiral clefts and sometimes these clefts are so contrived as to cut the whole tube I into a spiral line.

Exhibit figures magnified of these various vessels.

Such is the general structure of vegetables. To come directly to the point under consideration viz. the circulation of the sap: If we cut a vegetable across its body we shall find a vast number of tubes ranged on concentric circles running longitudinally or lengthwise of the plant through its whole length.

Exhibit a block which shows these tubes.

[*The text may continue below. The following is to be inserted above.]*

*Decandolle says that every organizing fluid in passing from the fluid to the solid state exhibits small spheres or vesicles and spicules or needle shaped bodies of diminutive size. From these are evolved the primitive forms of the vegetable world. These forms may be reduced to three: 1. The cell form 2. The tube form 3. The spiral form.

1. <u>Cell form</u> - Similar to the cells of bees but less regular - refer to the drawings several of which exhibit the cells perforate and imperforate. “The function of the cellular texture is simply to prepare and contain the sap," but not to conduct it upwards or downwards.

2. <u>Tube form</u> - <u>sap tubes</u>. Appear to the naked eye like straight lined fibres: but are hollow. Constitutes the basis of trees and are very tough. Their use is to conduct the sap upwards. Show several of these tubes on the magnified drawings.

3. <u>Spiral form</u>. <u>Spiral vessels</u>. These are composed to canals whose sides consist of spiral fibres of extreme fineness. Refer to some of them upon the drawings.

There are one or two varieties of the spiral vessels that deserve notice. One of them is the <u>vasa scalaria</u> or ladder like vessels which appear to consist of original spiral vessels meeting with others running perpendicularly and forming a sort of plexus or network. The "Cortical Plexus" and "Plexus of Cellular

Integument" appear…

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…to be examples of this description.

Another variety is found in which the spiral vessels are porous punctured or surrounded by a reticulated covering. Probably the lace bark of the drawings and some of the tubes in the large figure are of this description.

The spiral vessels are uniformly found empty of fluids - they constantly appear where a strong shoot is sent out and in company with the sap vessels and they run diagonally. From all these and other circumstances some (Decandolle pg. 181) conclude that their object is to produce an excitement in the sap tubes whereby these shall be able to propel the sap upwards.

[Images 12 and 13 are identical except for flap along gutter.]

[This may be a continuation from above before the asterisk.]

These tubes are contained in the bark as well as wood. Now it is found that the sap which is absorbed from the soil by the roots ascends to these tubes which exist in the wood part of the plant principally in those of the alburnum. These tubes ramify so is to go to the extremity of the branches and by them the sap is conveyed into the leaves. Here it is exposed to the action of light air and moisture three important chemical agents by which it is prepared to form those various secretions such as sugar gum etc. we find in vegetables. These secretions descend from leaves by another set of vessels into the bark or rather between the bark and the wood and this thus a new bark is produced and at the same time other important secretions are perfected and lodged in the bark or exuded upon its surface. By what means the sap is made to ascend through the tubes of the alburnum is not easily explained. Undoubtedly heat is one of the agents employed but this alone is not sufficient to account for the ascent. It is necessary also to call in the aid of the vital principle: but in what way this exerts its agency is alike unknown in plants and animals. That there is such a circulation of the sap as I have described that it ascends along the central tubes and descends through the other ones is a fact established almost beyond controversy.

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And we cannot but see in this arrangement a striking resemblance to that system of vessels in the animal system by which the blood is carried in the arteries and to the extremities of the body and returned in the veins being exposed to the lungs also as the sap in the leaves to the action of heat and air. The reason why this sap is most abundant in the springtime and flows on in such quantities if the alburnum be wounded is that the vegetable has no leaves to absorb it.

If the sap descend in the bark of trees it is evident that by removing this its descent may be stopped. The consequence will be that some nourishment will be imparted to that part of the tree above the place where the bark is removed that that more nourishment will be imparted. On this principle those fruit trees have ever been made to bear much more abundantly and several weeks earlier by cutting out a narrow ring of bark in the trunk of the tree. But it must be remembered that this increase of fruit is at the expense of the roots which are thereby deprived of the nourishment intended for them and cannot therefore be in so good a state for absorbing sap the succeeding year.

After the leaves of plants are expanded in spring if some of them not detached from the living plant being closed in a jar it will be found by the condensation of vapour on the sides of the jar that a large quantity of moisture has escaped from them. This is called insensible perspiration and is precisely similar to the same process in animals. The quantity of matter thrown off by insensible perspiration from the body of a man in health by insensible perspiration during 24 hours amounts to three or 4 pounds: and in some plants the quantity is found to be much greater. The common sunflower (Helianthus annuus) perspires 17 times faster than the human skin and the Cornelian cherry evaporates from its leaves nearly twice the weight of the plant in 24 hours.

From these facts it is obvious how important an agency is exerted by the leaves of plants upon their growth and healthiness. Strip the vegetable of its leaves and you put a stop to its advancement. I shall hereafter mention some other curious and important effects that are produced by the wonderful powers inherent in the leaves.

This is the proper place to introduce a notice of the various substances that are secreted from the sap of plants, some of which are extremely useful and made articles of commerce. But a particular examination of these secretions…

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…belongs more properly to chemistry and there you have already learned their nature. In this place therefore I shall do little more than make an enumeration.

From the plum cherry peach and different species of sensitive plants exudes gum or mucilage. Gum Arabic and gum Senegal are from two species of Mimosa or sensitive plants.

Resins and gum resins are obtained from a variety of plants - as the various species of pine - the fig - milkweed – spurge and celandine.

The essential oils which are of a resinous nature are found in a great variety of plants and indeed they give most of the odours that are pleasant and unpleasant that are exhaled from leaves and flowers. That obtained from the cinnamon bark is one of the most agreeable known. Also obtained from the rose lavender various mints the partridgeberry and indeed from almost every plant that can be named which possesses an aromatic or resinous odor. These are found abundantly in every perfumers shop and in almost every family such is the zeal and perseverance of modern essence peddlars.

The bitter principle called tannin so useful in the arts is found mostly in the barks of various plants as the oak and hemlock and also in the wood of the chestnuts.

From the Myrica cerifera is obtained a species of wax called bayberry tallow.

The vegetable kingdom is the source of a great variety of alkalis two of which, potash and soda, are of the utmost importance in the arts.

No less than 15 acids are enumerated as occurring in vegetables and their number is rapidly multiplying.

Nearly all the colours that in the hands of the dyer and calico printer give such variety and beauty to the different articles of clothing are found among the secretions of plants.

[Asterisk]

*I cannot but remark here what a most bountiful provision of the Creator is exhibited in clothing the earth with green rather than any other colour - none other being so agreeable to human vision. Had a crimson red for instance spread over the face of nature the consequence must have been the destruction of the organs of sight.

Sugar is a vegetable secretion too important in domestic economy to be passed unnoticed.

It will serve to show us the intricacy as well as admirable structure of the vegetable economy to observe what very different and apparently discordant substances are secreted in some instances from the same plant. The peach is a familiar example. The gum that exudes from its bark is mild and mucilaginous. But the bark leaves and flowers abound with prussic acid - a bitter acrid and poisonous substance. The fruit contains not only acid mucilage …

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…and sugar but that peculiar and aromatic and volatile secretion which gives it its fine flavor. A perfect a chemical laboratory then must be a peach tree which can form separate and preserve so many curious products!

There is one other secretion now generally allowed to be found in plants which I shall notice on account of its peculiarity. It is silex or flint and is found in the hollow stem of the bamboo - an East India plant - where extraordinary virtues are attributed to it merely because it is difficult to be obtained. Silex occurs also in the cuticle of several kinds of grasses a familiar example of which occurs in the common scouring rush. It is the silex that converts this into a natural file capable of wearing away many of the metals. “How great is the contrast,” says an eminent botanist, “between this production, if it be a secretion of the tender vegetable frame, and those exhalations which constitute the perfume of flowers! One is among the most permanent substances in nature, an ingredient in the primeval mountains of the globe; the other the invisible intangible breath of a moment!" (Smith p. 74)

The constancy and regularity of the secretions of vegetables is manifest from the process of grafting now so common. The most important point be attended to in this act is to cause the fiber of the bud or branch to coincide exactly with the fiber of the tree into which it is inserted. The circulation may then go on uninterruptedly and the same kind of sap is made by the vessels of one branch of a tree to produce one kind of fruit is converted into another sort of fruit by the vessels of another branch. Trees very different in their nature however cannot be thus engrafted with success.

Mention a sort of engrafting practice in England and not in this country viz. uniting the branches of separate trees so as to cause them to form one combined tree. Example the willows around one of the colleges at Oxford.

The heat of plants alone not a secretion yet may with propriety be adverted to in this place. Like that of animals the temperature of vegetables is uniformly higher than that of the atmosphere. This heat probably results from the chemical changes that are going on the vessels of the plant so intimately connected with their vital principle. Vegetable heat however is is much below animal heat as the living principle in plants is inferior to that of animals. In some instances however plants for a short time emit a great degree of heat. Species of the arum at a certain period of its growth was so hot as to seem to be burning for several hours.

Like animals plants too by a similar provision of the Creator are capable of resisting great degrees of heat. In the vicinity of volcanoes the ground has sometimes been seen covered with flowers when the temperature was only 2° below the boiling point of water and plants were seen thriving on the…

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…margin of a rivulet so hot that swallows dropped motionless into it when flying 7 feet above its surface.

Describe the Banigar tree – Dick's Christian Philosopher pg. 144. Also Library of Entertaining Knowledge, vol. 2 part 2, p. 249.

The size to which vegetables sometimes attain is so remarkable as to deserve to be recollected. Among trees the buttonwood (Platanus occidentalis) are distinguished. One of these is mentioned by Pliny as having a hollow within it 75 feet in circumference in which the consul Licinius rested for the night with 18 followers. In Ohio a few years since were two of these trees one of which was 40 the other 47 feet in circumference. And one of equal size existed in Genesee now in the American museum. But the most enormous vegetable production of which we have any credible account is the Adansonii I digitate, a native of Africa. Its diameter is said to be 30 feet and its circumference 90 feet. Its branches are from 30 to 60 feet long and in its hollow trunk reside many Negro families (Ed. Energ. Art. Bot., pg. 51)

The flower of the Raflesia is a yard in diameter (Amer. ??? Rev. p. 466). (The Amherstia nobilis the most handsome of all trees - Lindley's Nat. Sys. Bot., p. 89)

In respect to the duration of plants those are denominated annual would live only one year, biennial when they live only two years and produce flowers and fruit but one those. Those are called perennial which produce flowers and fruits several years in succession. If a perennial plant dies yearly to the ground it is said to be herbaceous; if the stem be woody and much branched it is called shrubby. If its texture be cellular and filled with juices it is succulent; if growing only in the water aquatic; from the sea maritime; if in the seawater marine. Those plants which have not been introduced into one place yet have grown there since the memory of man are called native or indigenous and when a foreign plant extends itself without culture is said to be naturalized.

Little is known concerning the age of which some plants under favorable circumstances will attain. By counting the concentric layers of the olive tree it is sometimes found to be 300 years old, in the oak 600. Is said that in one instance 2500 layers is found on a tree but the observation wants confirmation. Grew, a vegetable physiologist, cut his name upon a tree in 1400 and it was seen there in 1749, 350 years afterwards and the tree had increased only 7 feet in circumference.

Adansonia digitata supposed to be 5150 years old by Adanson. Taxodium of Mexico (Cypressus distichum) 117 circumference still older according to Decandolle, 4000 to 5000 years. (Lyell's Geology Vol. 3, pg. 99; Scripture and Geology 2nd ed., pg. 442.)

Germination and Vegetation of Plants

In the remarks already made I have supposed vegetables to be in a state of flourishing vegetation. Let us now for a few moments go back to the first commencement of their germination. The seed as is well known contains the embryo of the future plant. Take for a good illustration of the common bean.

Open it and show the two lobes of cotyledons with the embryo or conculum (little heart) between them.

The bean and similar seeds are called dicotyledonous but there are others as the grasses and palm tribe that have but one cotyledon and hence are called monocotyledonous...

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…or rather they are destitute of a cotyledon. Others have more than two: but the germination of these differs in no respect from the dicotyledons.

When a seed is covered in the soil it soon begins to expand by the moisture it imbibes. The access of atmospherical air and a certain degree of heat are necessary also that it may be made to spring up. Hence certain seeds if buried too deep in the ground will continue a great length of time uninjured and afterwards on being placed in favorable circumstances will germinate. The farmer is often surprised on clearing away a grove of pines to find a dense grove of shrub oak succeeding where no oak ever before existed. The fire weed a species of Senecio is always found to spring up as if by magic where a forest has been cleared and the ground burned over. In these and the like cases the seeds of the plants have no doubt lain dormant in the soil perhaps thousands of years until some favorable circumstances caused them to germinate. So fertile is nature in resources to preserve from extermination the various species of plants originally created.

Germination commences is already remarked by the swelling of the cotyledons. The root is the first part of the plant that makes its appearance and by a fine law of nature which philosophy finds it difficult to explain uniformly tends downwards. It thus achieves the double purpose of absorbing nourishment from the soil and fixing the future plant in its place. When the root has made some progress downward the two lobes swell and carry it upwards by the ascending stem which as uniformly seeks the zenith as the root the centre. The expanding embryo called the <u>plumula</u> which resembles a feather soon becomes a tuft of young leaves. Till these expand the elevated and expanded cotyledons assuming a greenish colour perform the office of leaves: but when no longer needed they usually wither and disappear.

(Strikingly exhibited in the garden bean, lupine, radish etc.)

And now the plant advances to maturity in the manner I have heretofore describes.

The monocotyledonous plants germinate in a similar manner: but the cotyledon does not rise to the surface yet consisting chiefly of alburnum it gives support to the ascending plumula until it has become large enough to supply itself with sustenance from other sources. Thus has Divine wisdom provided for the support of the young vegetable as well as animal until its expanded energies no longer need foreign assistance.

It is and is already hinted a curious question among physiologists why the root of every plant tends downward and its stem upwards? Perhaps the most ingenious mechanical solution is that of Dr. Darwin who ascribes these phenomena to the fact that the root was sustained by moisture and the stock by air and that they are drawn towards the sources of their sustenance. But this does not explain why the stock still continues to ascend rather than bend in an horizontal direction…

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…after it is once fairly raised above the soil. Indeed no hypothesis will satisfactorily explain these different tendencies of the opposite parts of plants. But if we grant to plants a principle of life why should we be any more surprised to find in them such tendencies than to find in animals so many instincts as peculiar and as inexplicable on known principles? Concerning the nature of such a tendency we should know as much as we do concerning the instinct of animals. Perhaps however it would be wisest to call these tendencies of the roots downward and of the stem upwards facts for which as for gravity we can assign no other reason than the will of the Deity. Indeed one the most eminent English botanists of the present day closes his remarks upon the living principle of plants with the sentiment, "I humbly conceive therefore that if the human understanding can in any case flatter itself with obtaining in the natural world a glimpse of the immediate agency of the deity it is in the contemplation of this vital principle which seems independent of material organization and an impulse of his own divine energy." (Smith, pg. 26)

[Reference: James Edward Smith, 1833ed?), An Introduction to the Study of Botany.]

[In pencil] Define the Axis of a plant.

<u>Roots</u>

To give a formal definition of this part of a plant seems hardly necessary. It is more important however to describe as far as it may be possible different kinds of roots that occur with the specific designations botanists attache to each. A root is merely an elongation of the stem of the plant divided into numerous branches and terminating in minute radicals or absorbents. The following varieties are reckoned by most botanists.

1. <u>Fibrous root</u> - Example grasses
2. <u>Creeping root</u> - mint - ranunculus etc. - roots of this kind serviceable in binding down sand
3. <u>Spindle shaped or tapering</u> – carrot, parsnip, radish, etc.
4. <u>An abrupt root</u> – <u>Liatris</u> and <u>Scabiosa</u> or Devil’s bit. The origin of the singular name is thus described by Gerunde who wrote some hundreds of years ago, "The great part of the root,” says he, “seemeth to be bitten away: old fantastick charmens report that the devil did bite it energie because it is an herb that has so many good varieties and is so beneficial to mankind." Dr. Smith adds concerning the Scabiosa and we may say the same of the Liatris - "the malice of the devil has unhappily been so successful that no virtues…

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…can now be found in the remainder of the root or herb." Smith, pg. 98.

5. <u>A tuberous or knotted root</u> - of which there are several kinds for example potato, artichoke, paeony, and Viola pedata.
6. <u>A Bulbous Root</u> – as the onion and white lily
7. <u>A jointed or granulated root</u> – Example wood sorrel Oxalis acetosella.

The great use of roots besides fixing the plant in an erect position consists in their power of absorbing moisture from the soil. Their vessels also are capable of producing chemical changes in the sap thus taken up through the process and not completed until it reaches the leaves. The different varieties of roots I have described are calculated for different soils. Thus the <u>Phleum pretense</u> (show it) when it grows in a moist situation has a fibrous root but in dry or fluctuating soil requires a bulbous one: and thus is it guarded against too sudden deprivation of moisture. The same provision exists in some other plants.

Mention the parasitic plants - as the mistletoe viscus album and because Cute American a daughter.

Mention the parasitic plants as the mistletoe (Viscum album) and Cuscuta americana – dodder.

Mistletoe the sacred plant of the Druids and the golden bough with which Eneas obtained his passport to the infernal regions.

Different kinds of stems and stocks

The common application of these terms is to loose and indefinite for scientific language. Botanists accordingly have accurately defined them and pointed out their varieties. To go into minutiae on this point however in a public lecture would be tedious and unprofitable and without an extensive series of drawings almost intelligible. Knowledge of these definitions however is indispensable to one who would become proficient in botany and it is not possible to give a course of lectures on botany without using them frequently. The student therefore must acquire knowledge of such terms from his textbook or some other standard botanical work. And the like remarks will apply to many other parts of botany where numerous terms and definitions occur of the utmost importance to be understood: but whose recital in a public lecture would be about as profitable and interesting as if to read in alphabetical order a Greek or Latin dictionary.

It is necessary however to notice the general division botanist have made of trunk stems or stalks. Linnaeus reckons seven.

1. This stem properly so called or caulis is that which elevates leaves as well as flowers. Example the trunks and branches of all trees and shrubs. Exhibit one.

2. The culm is a peculiar stem of the grass rushes and similar plants. Exhibit one - term rather superfluous.

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3. The scape - this is the stalk that springs from the root and bears the flowers and fruits but not the leaves. Example Leontodon. Tusillago - several violae and Hieracia - Exhibit specimen. This term not indispensable.

4. Peduncle. This is the flower stock springing from the stem and bearing the flowers and fruits but not the leaves. Examples - Pea, ranunculus etc. Pedicel - partial footstock.

5. Petiole - this term applies exclusively to the stem of a leaf - either simple or compound - Example passion

6. Frond - In this are united the stem lead and fructification Example Ferns - applied to lichens - only in cryptogamia.

7. Stipe - The stem of a frond - applied also to mushrooms and to the thread culminating the hairy crown in plants of the class syngenesia.

Buds

Lest I should weary you with definitions I shall take some things for granted. I shall presume in this instance that you have a sufficiently correct idea of what is meant by a bud. I cannot doubt but every man would say at once that it contains the rudiments of a plant or parts of a plant - wrapped up in a latent state until a proper season and circumstances arise for its evolution. In some instances these buds are of slow growth and commence their expansion two or three years before they are finally unfolded. That is the buds of up to three years are enclosed within one another. Generally however in cold latitudes vegetation about mid summer seems to be checked: but it is only that its energies may be exerted in the formation of buds which we shall find to be now pushing out at the ends of the twigs just beyond the leaves. In the button wood tree however these buds form beneath the footstocks of leaves and as they expand push off the leaves.

A German physiologist (a nation whose laborious perseverance is not limited to philology) had the patience to examine a bud of the horse chestnut while yet no larger than a pea. He stripped off 20 scales or folds cemented together by resinous adhesive matter so common in buds and then he came to the embryo enveloped in down. Pressing the dissection still farther he distinctly perceived 28 leaves surrounding a spike of 60 flowers.

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The bud has been termed the winter cradle of northern plants and it is accordingly found in most northern plants but most tropical ones are destitute of it and this is one important reason why they will not survive a northern winter.

Three varieties of buds are noticed by botanists they are containing the embryo of the future flower - another enclosing the leaves and another including both. These varieties are convertible into one another. A rose for example was deprived of all its buds except those that enclose flowers and the next spring they put forth not flowers as was expected but branches and leaves.

In a similar way the number of flower buds on the plant may be increased. In general this is done by checking the luxury and production of leaf buds by surrounding the plant with a poor soil. Some plants however - especially those with bulbous roots which in their native situations produce abundant flowers had hitherto defied all the gardeners art to make them blossom when transplanted.

Mr. Tschudy has succeeded in inculcating the gourd with the melon - potatoes on tomatoes etc. Conversations on Vegetable Physiology pg. 194. *[Jane H. Marcet, 1830]*

Notes on Lindley's Introduction to Botany

[Reference: John Lindley, 1st ed. circa 1832?]

Plants are made of cavities surrounded by membrane. Each cavity is separable by maceration etc. These bodies constitute Vegetable Tissue.

<u>Organic Mucus</u> - the basis of all tissue

<u>Membrane</u> more or less transparent - always destitute of visible pores although permeable by fluids - supposed pores are mere pits.

<u>Elementary fibre</u> is like hair inconceivably fine for 1/3000 to 1/7250 of an inch in diameter - Direction very variable - has a tendency to anastomose .

The above constitute five kinds of Tissue.
1. Cellular tissue or parenchyma
2. Pitted tissue or bothrenchyma
3. Woody tissue or pleurenchyma
4. Vascular tissue or trachenchyma
5. Laticiferous tissue or Cinenchyma

All these are probably modifications of the simple cell.

1. <u>Cellular tissue</u> or <u>parenchyma</u>

Consists of little vesicles or bladders of various figures - generally the membranes are transparent and colourless - the colour flowers leaves etc. result from the colour of the fluid they contain.

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Not certain how the cells of this tissue are increased - sometimes by the addition of new cells to the outside of the old ones and sometimes by the division enlargement of the old ones. A fungus probably produced 47 billion cellules in 12 hours or 4 billion per hour.

The bladders vary in size from 1/30 of an inch in diameter to 1/1000.

Cellular tissue consists of two kinds.

1. Membranous cellular tissue – the sides nothing but membrane - Always present in plants and indispensable - some plants contain nothing else as Mosses Algae and Lichens etc. pg. 73.

(Wants Lindley's Woodcut Fig. 3, p. 9.)

Numerous varieties - see Lindley pg. 14 and 15.

Filio-Cellular Tissue is that in which the sides are composed of fibre only or of fibre and membrane together.

Only lately recognized: but found to be very common.

Granular material sometimes in the midst of the cellular tissue whose nature is unknown called Cytoblast.

2. Pitted tissue or Bothrencyma

Consists of tubes often of considerable size appearing as if riddled full of holes. But they are only pits in the lining.

Articulated Bothrencyma. Seen in the cross section of the oak the same etc. see enlarged drawings. It consists of truncated cylinders placed one upon the other to become a continuous tube when the partitions are absorbed.

Continuous Bothrencyma. Tubes long and slender, not tough nor collected into bundles.

3. Woody Tissue or Pleurenchyma

Consists of very slender tough transparent membranous tubes tapering acutely to each end lying in bundles. The tubes have no communication with each other except by invisible pores. Distinguished from other forms of tissue by its toughness and attenuated character. Example Flax hemp and cotton in cellular tissue hence weak. Often finer than the finest human hair – hemp six times smaller. See drawings.

Two kinds.

1. With no granules or glands sticking out of them.
2. The Glandular - In the conifer are chiefly - consists of circular spaces in the tube thinner than the rest of it and placed opposite to each other so as to transmit light.

Pleurenchyma forms a considerable part of all ligneous plants. It is abundant in fibre and forms the veins of leaves.

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4. Vascular Tissue or Trachenchyma

Consists of simple membranous tubes tapering to each end but often ending abruptly either having of a fibre generated spirally on the inside or having their walls marked by transverse bars arranged more or less in a spiral fashion.

Anatomists divided in opinion as to this tissue. See Lindley pg. 27.

Three kinds.

1. Spiraled vessels or tracheae.

A membranous tube with a fibre on the inside twisted spirally - looking like a wire twisted round a cylinder. See drawings. Size from 1/288 to 1/3000 of an inch in diameter.

Mostly absent from flowerless plants except for Ferns and Lycopodiaceae. Generally situated in the medullary sheath or that part of the stem surrounding the pith.

2. Ducts are membranous tubes with conical or rounded extremities - their sides marked with transverse lines and rings or bars and being incapable of unrolling. Between 1/400 and 1/800 of an inch.

5. Lacticiferous Tissue or Cinenchyma

Latex a viscid juice insoluble in water white red brown yellow and colourless. Upon exposure to the air it separates into a coagulum and serum like blood.

Laticiferous Tissue are vessels containing the fluid - or they are milk vessels. They consist of branched anastomosing tubes lying in no definite position with respect to the other tissue. Size 1/1400 of an inch - longest in plants with milk and juice.

Spurious Elementary Organs

1. Intercellular Passages

Spaces left between the elementary organs which are all modifications of the sphere and the cylinder.

2. Receptacles of Secretion

These are frequently intracellular passages enlarged by the accumulation of secreted matter.

3. Air Cells

Differ from receptacles of secretions in containing only air. So closed up as to prevent the introduction…

…of secretions.

3. Raphides

Apparently crystals of phosphate of lime and magnesia and oxalate of lime in four to six sided prisms, often acicular.

Epidermis

Epidermis is cellular tissue. Covered by a membrane of organic mucus.

Stomata are passages through the cuticle.

Stem

Consists of the pith, the wood, the bark and medullary rays.

Bark consists of

1. Epidermis continue with the leaves composed of cells.
2. The Epiphloem or Peridermis or several layers of thin sided tubular cells rarely coloured green.
3. The Mesiphloem or cellular integument composed of cells usually green and placed in a direction different from that of the epiphloem.
4. The Endophloem or fibre - in part cellular and in part woody fibres.

As long as the bark remains alive the parts give way to the expression of the wood within by adding new tissue: but when the bark dies it is torn into clefts and rents or rebands [?].

The cambium is a mucous viscid layer surrounded by the bark and the wood certainly by the latter and lying between them in the spring containing numerous minute transparent granules and traces of cellular organization.

Medullary rays are composed of muciform cellular tissue.

Age of trees by concentric rings. Reference Lindley, pg. 94.

Endogenous stems increased by the addition of woody plies to the inside pointing outwards such as were previously formed. They originate in the leaves proceed to the centre and thence downward.

Some endogenous stems are of essentially the same size in all stages of their growth. Others increase indefinitely. Generally they are cylindrical sometimes dichotomous. They have no bark separable from the wood but a cortical integument composed of epiphloem and something analogous to fibre.

<u>Appendages of the Axis</u>

Scales, leaves, bracts, flowers and fruit are all modifications of a common type by local and predisposing causes not on account of original…

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…structure.

The normal position of leaves is probably ultimate and their positions upon the stem an elongated spiral.

<u>Physiology of the Elementary Organs,</u> pg. 296
<u>Symmetry</u> pg. 302
<u>Physiology of the root</u> pg. 309
<u>Stem and origin of the wood</u> pg. 309
<u>Physiology of leaves</u> pg. 324
<u>Heat of plants</u> pg. 333
<u>Fertilization</u> pg. 337
<u>Food of plants</u> pg. 366
<u>Digestion respiration and secretion</u> pg. 372
<u>Circulation of sap</u> pg. 389

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<u>Leaves</u>

In no part of plants is there a greater variety of forms than in the leaves and no part sustains more important and interesting offices in the vegetable economy. It is the physiology of leaves however rather than their forms and modes of insertion that must now occupy our attention. But though this belongs to the botanical dictionary rather than the lecture yet I have laid upon the table a number of leaves labeled according to the books.

Leaves it is well known usually cover vegetables and it is these that spread such a richness over the summer landscape: while he who examines them minutely cannot but be struck with the beauty of their 10,000 fantastical forms. And although we discover but few uses for all this variety yet from what we know of Divine Wisdom we cannot doubt but it subserves other purposes than merely to feast the eye of botanical curiosity. We know for instance the plants which grow upon dry soil have thick succulent leaves as a security against drought while those growing upon trees situated in moist situations are very thin. Illustrated by the house leek (Sedum sempervivum) and maple. Some plants have no leaves (for example Salicornia).

The sap or alburnum of a tree is continued into the leaves and forms their skeleton which may often be seen in the spring in the leaves that fell the…

…preceding year all the fleshy parts having decayed. This fleshy part as remarked formally consists chiefly of cellular integument and is covered by a transparent cuticle or epidermis. The fleshy part is more commonly called the parenchyma.

The upper surface of the leaf is usually darker than the underside and infrequently is covered by a shining varnish. Show leave a grape vine.

The epidermis on the underside is thinner than on the upper side and full of cavities and as such is its construction that water will not wet yet but collects in drops and rolls off.

Either upon one or both surfaces of leaves are discoverable numerous pores seeming for the absorption of air among the internal vessels.

Leaves are the organs respiration perspiration and absorption to plants. By their pores oxygen is brought into contact with the fluids of the vegetable just as it has access to the blood in the lungs of animals. Concerning the perspiration of plants I have already spoken. The matter thrown off in this way does not usually differ from the sap. In some instances it is saccharin as in the orange tree: sometimes glutinous as in the gila or basswood tree sometimes resinous as in the poplar. Ovid represents the resinous exudation from the leaves of the Lombardy poplar as being the tears of Phaeton's sisters who according to the heathen mythology were transformed into these trees. The honey dew at least one kind of it consists of matter perspired from leaves of plants and it indicates in them an unhealthy state. In one instance this perspirant matter consists of a highly inflammable vapour.

The leaves of plants not merely give off moisture they also absorb it. In many instances this absorbing power is mostly confined to one side of the leaf and in others both sides are equally capable of it. These facts show us that it is important after transplanting a vegetable or in seasons of drought to wet not merely the roots but the leaves also.

But it is not merely moisture that is absorbed and perspired by the leaves of plants. In certain cases it is found that they give off oxygen gas and in other circumstances absorb carbonic acid. These operations have laid the foundations of one of the most beautiful hypotheses in the whole range of philosophy. Dr. Priestly made numerous experiments on this subject and came to the conclusion as a general fact that the leaves of vegetables during the day absorb from the atmosphere carbonic acid and give off oxygen and a small quantity of nitrogen. In the night it was suppose that this process was in part reversed and that carbonic acid is given off into the atmosphere and oxygen absorbed. Upon the whole however it was stated that the quantity of carbonic acid absorbed during the…

…24 hours was much greater than that thrown off: and the quantity of oxygen given off much greater than that absorbed. The final effect therefore would be to diminish the amount of carbonic acid and increase the oxygen in the atmosphere. Now it was also known that animals both by respiration and perspiration generate large quantities of carbonic acid by the former process take from the atmosphere a portion of its oxygen. The effect of these animal functions therefore would be to deteriorate the air and it was not seen why this corrupting process must not go on increasing without something to correct it until the whole atmosphere would become unfit for respiration. This counteracting influence Dr. Priestly supposed to exist in the functions of the leaves of plants. How natural then to suppose this to be one of those examples of compensation by which the Creator maintains the balance of the universe! No wonder philosophers should have adopted such a beautiful hypothesis even if it had the slightest evidence in its favour!

It is with reluctance gentlemen that I am constrained to enter a caveat against this theory. I do not say it is false: but the recent researches of Mr. Ellis a distinguished Scotch physiologist going directly to the total destruction of this fine fabric of philosophy cannot be passed in silence. From a most laborious course of experiments he comes to the conclusion that the oxygen gas in the atmosphere is converted into carbonic acid by the process of vegetation: and that the bulk of the latter gas nearly or exactly corresponds with that of the former and consequently they (the experiments) demonstrate that the air is deteriorated by the growth of plants in the same manner as by the germination of seeds, and that no part of the oxygenous portion of the atmosphere combines with the substance of the plant.

He explains more particularly the process of vegetable absorption and exhalation as follows:

See Edin. Encyclopedia Art. Botany pg. 59.

To those who urged the purification of the atmosphere as indispensable in the economy of nature and as illustration of the wisdom of Providence, Mr. Ellis replies: "It behooves us to employ no ordinary portion of delicacy and caution in pronouncing on the general plans and purposes of Providence, from the little and partial views of nature which at present we are permitted to take, less in the effervescence of our zeal we degrade the wisdom we pretend to exalt and prevent the designs of the goodness we profess to revere!"

With these remarks I leave this subject gentlemen and wish to leave every other controverted point to your own unbiased decision.

Remark on the dangers of putting large flowerpots in small rooms and sleeping there. Carbonic acid is generated at night on either of the theories broached above.

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The leaves of some plants exhibit a peculiar economy which although not well understood renders them objects of curiosity. The Nepenthes distillatoria is one of these – an East Indian plant growing in bogs. An appendage of the shape of a picture is attached to its upper extremity furnished with a lid to cover it over. This pitcher always contains a quantity of water which must be secreted from the plant itself. A similar plant we have growing among us is the Sarracenia purpurea.

Exhibit a drawing and explain the construction.

Insects venting into the hollow leaves of either of the Nepenthes or Sarracenia are entrapped unless they have wings and dying there they doubtless contribute to the growth of the plant. There is an insect also it is said which makes these cavities the receptacle of its food which consists of dead insects and by laying up a store of them here it contributes to the growth of the plant. Some have supposed this to be the principal use of this peculiar organization. Others regard the fact that a particular insect makes these plants it storehouse is rather an accidental occurrence as almost every species of plant has its peculiar insects and they suppose the use of the cup leaf to be to hold water against a season of drought.

This may be the most proper place to notice the irritability of plants which is usually most obvious in the leaves. The sensitive plant species of Mimosa exhibits is probably more remarkably than any other plant cultivated in this latitude. The Dionaea muscipula or Venus flytrap growing in North Carolina has a leaf so constructed that when an insect lights upon its upper inside where are several bristles immediately folds around its prisoner and confines him so long as he continues to struggle. A similar property is said to be possessed by that singular plant the Drosera rotundifolia common among us.

Exhibit specimens of this plant.

Mention the irritability of the stamens of the Berberis.

The most remarkable of all sensitive plants is the Hedysarum gyrans, a native of India. The leaves of this plants do not require the contact of any extraneous body to put them into motion. In a warm place secure from the wind they continue rising from a pendant to an erect position with tolerable rapidity and then falling back; and if their motion be checked for a time it is said that on being set at liberty there gyratory motion will be accelerated to make up as it were for the interruption.

The effect of light upon plant seems to be connected with their irritability or rather to result from it. Everyone must have noticed how imperfectly vegetation can be made to grow when excluded from light and how they will turn their branches towards…

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…any crevice through which light enters their dungeon. Plants raised in such situations are always sickly and feeble and produce no valuable fruit.

Notice the analogy in this respect between vegetables and animals.

Light however is beneficial only to the upper side of leaves: hence they always present that side to the sun and when the lower side is turned towards a source of light by art nature immediately exerts herself to bring them back into a more favorable situation - and this she effects usually in the course of a few hours. A few leaves seem to be indifferent which side is presented to the sun.

The sensibility to light is not confined to leaves but extends also to the flowers. Those of the 19th Linnaean class whose disc greatly resembles the sun exhibit this disposition to receive always his direct beams most remarkably. We notice it more particularly in the most magnificent of all northern annual plants the garden sunflower. This presents is broad disc to the rising sun and follows him in his daily course turning round at least 180°. By the elasticity of the stem it is during the night brought back so as to face the east prepared to welcome the returning light of the following day.

Many plants especially those with pinnate leaves as the Mimosa and the cassia either close their leaflets around the flowers at night or drop them into a perpendicular position along the petiole. This is called the sleep of plants and seems to be some analogy to the sleep of animals. Absence of light appears to be the principal cause of the phenomenon: perhaps also the increase of moisture may contribute to the effect.

Notice the Lotus tetragonolobus and exhibit it.

Where we to judge of the magnitude to which leaves sometimes attain by the largest found in this latitude our views would be much contracted. It is in the torrid zone that vegetation puts forth its most astonishing efforts. Here we find the Banana celebrated not alone for its rich fruit but for leaves often a foot broad and several feet long. In Ceylon grows the talipot whose leaf is large enough to shelter 20 men from the vicissitudes of the climate.

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Appendages

The number seven would seem to have been a favorite one with Linnaeus the great father of botany. We find him reckonings seven kinds of roots - seven sorts of stems - seven appendages - and as we shall afterwards see seven parts of fructification. And yet it does not appear that he made such a division from any predilection for this number or any superstitious notion concerning it - many of which have existed in the world. We find that succeeding botanist do not alter these subdivisions. In regard to the appendages of plants I shall barely enumerate them and present you with examples when it is in my power.

1 . Stipules – "a leafy appendage to the leaves or their foot stalks." Common pea, Pisum sativum.

2. Bracts - These are the "floral leaf or a leafy appendage to the flower or its stalk." Example Tilia americana.

3. Thorns. A conical spur proceeding from the wood and terminating in a point. Example Gleditsia triacanthos.

4. Prickles. (Acules) Similar to the thorn but confined to the bark alone. Examples Locust (Robinia) Rose - Raspberry etc.

Thorns often disappear by cultivation for example trees - but prickles do not.

5. Tendrils (Cirus) Cylindrical projections that coil around other bodies for supporting the plant here called feliza. Example pea, grape etc.

The flower stalks or peduncles of Aronia hexapetala formsa hook which grasps the neighboring branch and supports the heavy fruit. Notice the Clematis virginiana the petiole of whose leaf answers for its tendril.

6. Glands. Linnaeus calls these little term turmoses discharging a fluid. Abundant on the stalk and calyx of the moss rose – found also on Ribes floridum Viburnum opulum etc.

Exhibit one of these.

On 7. Hairs. (Pilus) These are excretory ducts of a bristle like form. Example nettle. Explain the nature of the hairs on its surface.

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Inflorescence

This term is employed by Linnaeus to indicate what the other authors have denominated the modus florendi or manner of flowering. As every thing relating to the flowers and fruits of plants is of great importance in understanding the artificial system of Linnaeus upon whose explanation I shall soon enter, you will I trust bear with me while I exhibit specimens and explanations of the most common forms in which flowers are arranged upon the plants that bear them.

1 . In a Whorl - surrounding the stem in a sort of ring. Example Mentha – Lycopus – Agrimonia, etc.

2. Raceme or cluster - flowers arranged at some time distance along the common stalk each on its own pedicel. Example currant, Phytolaca, etc.

3. Spike - Numerous flowers arranged along one common stalk without any partial stalks - sometimes short partial stalks. For example Plantago major - orchis – Antirrhinum canadense unilateral spike Paspalum secateum.

4. Corymb. The flower stalks of the corymb come from one common stalk and are arranged along it as in the spike but those coming out below have longer pedicels so that the flowers are brought upon nearly the same level. Examples Sorbus - mountain ash - yarrow - Achillea etc.

5. Fascicle. This is applied to flowers on such short stalks variously inserted and subdivided collected into a close bundle level at the top. Example Dianthus barbutus sweet William and other pinks.

6. A Head or Tuft. Flowers arranged in a globular form. For example globe amaranth - clover - Cephalanthus occidentalis.

7. Umbel. In this form the flower stalks proceed from a common centre and form a nearly level top. Example Cicuta maculata – Conium maculata - better still - Asclepias.

8. Cyme. Agrees with the last in having the flower stalk spring from a common centre but those stalks are variously and alternately subdivided. Example Elder and viburnum

9. Panicle. In this form the flowers are arranged in a loose subdivided bunch or cluster without any order. Example Contrada, Thalictrum, etc. Racemed panicle - Example Solidago Paniucled spike E. Spiraea

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10. Thyrse. This is nothing more than a dense panicle more or less ovate. Example Lilac - bunch of grapes - Linnaeus considered the latter to be a raceme.

Flowers and Fruits

We now come to a part of the organization of a plant not only the most delicate and beautiful but also the most important - essentially indeed they are to the preservation and continuation of the species and important in a botanical point of view as affording the foundation for those divisions of vegetables into classes orders and genera which have conferred immortality on the name of Linnaeus and which is the easiest method of obtaining the knowledge of plants. You will find it therefore for your interest gentleman if not already acquainted with these organs to make an effort to acquire a thorough acquaintance with them. Scarcely any individual is insensible to the most prominent beauties of flowers and fruits and they have always been a fruitful source of comparison and illustration in fine writing. But botany would lead us to the discovery of beauties that lie hidden from superficial observation: and display organs of utility where we see only elegance. I shall proceed to describe the several parts of the fructification of plants with as much brevity as possible. Linnaeus enumerates seven of these parts viz. the calyx - the corolla - the stamens - the pistils - the pericarp or seed vessel - the seed itself and the receptacle. Some of these are indispensably necessary to the existence of flowers or fruit and therefore are always present: others may be dispensed with in some cases and are occasionally wanting.

Take a plant that has all these seven parts of fructification and dissect it before the class. Example Convolvulus Sepium.

Calyx

The general general definition of calyx is the flower cup or external covering of the flower but of this there are seven varieties important to be noticed.

1. The Perianth. This is the calyx proper or where the external covering is contiguous to the flower and makes a part of it. Example rose – pink.

Double Perianth - Example Malva - triple Scabiosa. Refer to paintings illustrating Class Monodelphia. Forms numerous as inflated – prismatic (Mimulus) imbricate (Thistle) squamous – muriate – scariose – spinous (Thistle).

2. Involucre. This is remote from the flower and can scarcely be distinguished from a bract. It is a sort of general calyx common to many flowers. Usually comprises umbelliferous plants.

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Example Conium maculatum.

3. Ament or Cathim. This consists of a number of scales arranged along the stalk each scale protecting one or more stamens or pistils. Examples oaks - walnut - chestnut - birch - hazelnut etc. See paintings of willow and hazel.

4. Spathe. This is a sheath which bursts longitudinally and is more or less remote from the flower. Sometimes involving a spadix or elongated receptacle. Examples Iris – Arum – Refer to the English Arum in paintings.

5. Glume. The proper calyx of the grasses consisting of a husk. The separate pieces of them are called valves. Examples Phleum – Briza - Indian corn.

Notice the Arista or awn - the sensitive art

Unfortunately for the science
On the awn there's no reliance

6. Calypta - a hood covering the capsule of the mosses like the extinguisher of a candle. By some reckoned a corolla. Refer to the paintings of this organ.

Some botanists substitute the perichaetium, a scaly sheath inserting the base of the fruit stalk in some mosses and call this a calyx.

7. Volva - a wrapper or covering of many Fungi. It first invests the head of the fungus and is afterwards burst and appears as a ring on the stipe or disappears.

Refer to paintings of Agarices on magnified paintings also to “Fungi selecti picti” Nos. 39-78 and 79.

One use of the calyx of flowers is obvious upon slight inspection. It serves as a defense to the tender organs within. And it probably acts the same part in relation to the flower stalk as the leaves do the stalks and branches of plants viz. to afford them nourishment and strength. For in many instances the flower stalk is observed to swell just below the flower and become harder than the adjoining parts in order to obtain the burthen of the seed. And this effect is not observed to take place in those plants which are destitute of a calyx - for example Lilium, etc.

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<u>corolla</u>

This is the more deeply and forcefully coloured part of a plant that constitutes its chief beauty consisting of one or more delicate leaves always within the calyx when that is present and surrounding the stamens and pistils. It consists of two parts the petal and the nectary. The nectary is that part of the corolla that contains or secretes honey and is confined to no particular part of the flower indeed cannot in all cases be considered as a part of the flower.

Example Larkspur, trapaeolum, and Aquilegia.

The petal constitutes the principal part of the the corolla - the nectary being generally so small as to be unnoticed. Sometimes the corolla consists of a single petal and this is called monopetalous (for example Morning glory, convolvulus, etc.) sometimes of several petals and is called polypetalous. Examples Nos. 37, 42, 43, 46 etc. paintings.

There is great variety in the forms of the corolla: a few I shall mention because I am able to exhibit to you magnified drawings of them and a knowledge of these varieties is highly important.

1. Tangent - gaping No. 23 & 28 (upper part of the helmet, lower part the lip or beard)
2. Personate - irregular and closed by a palate – No. 25 & 30.
3. Cuneiform - regular and like a cross – No. 33 & 35.
4. Papilonaceous - irregular and spreading somewhat like a butterfly. Nos. 39 & 42.
5. Bell-shaped Eg.
6. Tunnel shaped for example Morning glory
7. Wheel-shaped Eg.
8. Rosaceous Eg.
9. Incomplete Eg.

The particular functions of the corolla are most of them unknown. In many instances for the protection of the parts within. Example Sarracenia purpurea - In other cases they doubtless attract insects in search of honey and these produce the important effect by agitating the flower of disseminating the pollen of the anthers. To attract insects seems to the chief if not the only object of the secretion of honey in the nectaries. Whatever therefore the poets may say about these elegant flowers that bloom in the wilderness unseen by human eye as if they "wasted there sweetness on the desert air," it is still true that many an eye more curious too than some placed in the human face are attracted by the beauties and rewarded by their sweets. We are hence taught that man is…

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…not the only living being in creation for whose admiration and pleasure nature puts on her rich attire and collects abundance in her storehouse.

While man exclaims ‘see all things for my use,’
See man from mine, replies the pampered goose
And just as short of reason he must fall,
Who thinks all made for one and not one for all.

[Source: Alexander Pope, An Essay on Man, 1735.]

A stamen consists usually of two parts - the filament and the anther. The anther is the only essential part, the filament seeming merely for support. The number of stamens varies exceedingly in flowers from one to several hundred.

The most common form of the stamens filaments and anthers, see paintings No. 11 to 13.

The anther is generally of a membranous texture containing two cells filled with a powder or dust called pollen. In warm and dry weather the code coat of the anther contracts and bursts and the pollen is thrown out and scattered over the flower and often carried to a distance through the air. Each grain of the pollen consist commonly of a membranous bag round or angular rough or smooth which when it meets with moisture bursts asunder with force discharging a subtle vapor whose nature has not been investigated.

Notice the change of stamens to petals in double flowers. Monsters are thus produced. Example Rose – peony or pinks - daffodil – snow balls.

[In faded pencil]

Hypogenous - when the stamens are not untied to the calyx
Perigynous – when united with calyx
Epigynous - united with the calyx and ovary

Pistil

This as well as the stamen is an essential part of a flower without which no food can be produced and the species would be destroyed. It consists of three parts - the germen or rudiment of the young fruit and seed the style answering to a filament in a stamen and the stigma placed like the a anther on the top of the style.

Exhibit the various kinds of pistils on the drawings No. 14-27, 51-57,79,80,77,82,84,88.

Pistils have sometimes changed into petals and once at least into a common leaf. It is an indispensable part of the plant. Between stamens and pistils the distinction is most decided an absolute one never changing into the other.

<u>Pericarp</u>

This is the seed vessel and is formed of the germen enlarged. Its use is to preserve the seed until ripe when it usually bursts by its elastic force or in some other way scatters the seed at the proper time.

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This usually happens in dry weather which is most favorable for their dispersion. But by a most wonderful provision of nature certain plants natives of the sandy deserts of Africa open their seed vessels in moist weather as that is the only time in which they could endure the parching heat or stand a chance of vegetating.

Notice the elasticity of the seed vessel of Impatiens nolitangere, etc.

The different varieties of seed vessels are named according to their form as follows:

1. <u>Capsule</u> - a dry seed vessel of a woody coriaceous or membranous texture generally splitting into several valves - sometimes emptying by ports as the poppy or falling off entire. Examples Datura and Iris

<u>Utriculus</u> Ex. Clematis
<u>Samara</u> Example maple, ash, etc.
Folliculus – Asclepias – Apocynum and Coecum.

2. <u>Silique</u> - a long dry solitary seed vessel all two valves separated by a linear receptacle along each side of whose edges the seeds are arranged alternately. In paintings No. 32 – Also cabbage radish and mustard.

<u>Silicle</u> - A pouch or pod or rounded figure, for example paintings No. 36 Thlapsis, etc.

3. Legume – A membranous seed vessel of two valves – seeds attached to one suture only. Examples Pea, bean
Loment - Carnia - Hedysamen

4. Drupe - pulpy coat enclosing a nut Ex. plum and cherry etc.

5. Pome - pulpy coat and a capsule with several seeds; Example apple and pear

6. Berry. Fleshy pericarp without valves - seeds enveloped by the pulp. Example currant gooseberry whortleberry. See drawings of the fig.

7. Strobile - a hardened and elongated ament or catkin; example pine Platanus and Magnolia. See Michaux and Sylva Americana third half volume.

I have already spoken of the internal construction of the seeds of plants: the great variety of their forms and the peculiar appendages attached to many of them to facilitate the removal from one place to another furnish a curious subject for the philosophical botanist and in no part of creation is design in the adaptation of means and ends more apparent.

One of the most remarkable of these appendages is the pappus or seed down - a light feathery substance attached to the end of the seed which is carried by…

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…the wind a great distance through the air.
Examples thistle, Canada thistle, dandelion (not a native).
Bidens - pappus formed of 2, 3, or 4 barbed bristles.
The Cauda or Tail is another appendage of the same use as the pappus for example Clematis.

Wings are often attached to seeds - these are wafted in by the winds.

Some seeds have an appendage so arranged as to serve for a sail to waft it over the water. Seeds sometimes in this way pass from continent to continent. Many more are transported by rivers. Some of the burr kind attach themselves to the shaggy skins of animals and are carried by them a great distance, others taken as food by animals pass through them undigested and capable of vegetation. Some have barbs pointing upwards by which they work themselves into the ground.

8. Receptacle. This is the base or point of connection of the other parts of fructification - most conspicuous in the class syngensia. Painting No. 51.

Such are the important parts of fructification a process whose perfection seems to be the grand object of the most delicate organization of plants. The indispensable organs in this process are the stamens and pistils and the numerous methods in which the pollen of the one is brought in contact with the stigma of the other is striking evidence of superhuman contrivance and design in the formation of plants. It is not generally known that every species of plants produce flowers much less is it known that all of them produce stamens and pistils and that without bees the species would soon become extinct. It is true that in some of the lower orders of plants such as ferns mushrooms no stamens and pistils have been discovered but in all of them pollen exists abundantly and hence we infer the existence of the organs which in phanerogamous plants produce it.

It has been known to botanists for a long time and is now universally admitted that in order to the production of fruit the pollen must be sprinkled over the stigma. In most cases we find the stamens and pistils situated in the most favourable manner for affecting this fertilization. But in some instances these organs are unfavourably situated for affecting the object - the stamens being upon one flower or one tree and the pistils upon another flower or tree. Yet in such cases the wind generally conveys the…

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…pollen from the barren to the fertile flower. And this is effected also by insects. The bee for example in search of honey among the stamens becomes loaded with pollen which he conveys to the pistillate flower or plant himself in search of new sweets and wholly unconscious of the important office he is executing.

But the most wonderful provision for affecting this distribution of the pollen is found in certain aquatic plants. The most curious of these is the Vailisneria spiralis (growing in the Connecticut River at Sunderland) (Refer to the painting). The stamens and pistils here grown on separate plants. The fertile or pistillate flower rises on a long spiral peduncle which expands and raises the flower to the surface of the water where it floats about. The staminate or barren flowers meanwhile are produced on short stalks from which they rise like separate white bubbles suddenly expanding when they reach the surface and floating about so as nearly to cover the water their pollen is scattered over the fertile flowers.

A variety of other facts of a similar kind are pointed out by writers on botany which I have not time to repeat. The subject will be found ably treated in Dr. Smith's Introduction to Physiological and Systematical Botany.

If the general principles that have been exhibited are well fixed in your minds you are now prepared with advantage to engage in the examination of the classification of plants. And if there be any science where arrangement is indispensable it is botany. If we could not group them together into distinct collections what memory would be able to retain any tolerable impression of 50,000 plants? Even when the number was vastly less botanists felt the necessity of arrangement and made efforts to discover some leading and common characters by which the vegetable world might be classified. It was reserved for the keen penetration of Linnaeus to seize upon the clue by by which this desirable object might be accomplished. I know it is the custom of some modern innovators in botany to speak lightly of what is called the artificial system of this great man. And I doubt not but men extensively acquainted with botany may discover among plants affinities more natural than the system of Linnaeus presents: but to attempt to leave the beginner to an acquaintance with plants by giving the characters of what are called natural orders would be to plunge them into a Cretan labyrinth indeed. It is the Linnaean arrangement that must be followed by everyone who would readily become acquainted…

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…with the names and characters of plants. After following this clue until he is familiar with numerous species in the 24 classes he will then be prepared advantageously to study their natural affinities.

To call the Linnaean classification an artificial one however as if it were in no respect natural conveys a wrong impression. For the very foundation of the system rests upon certain relations one plant barriers to another and a similarity of some of its parts. These organs are the stamens and pistils: and the only deficiency in this arrangement the only reason why it is called artificial is that it does not take into account all the parts of a plant in assigning its place among others. Hence by this rule we sometimes find plants the most unlike in their general appearance and medical properties grouped together. So far the arrangement is unnatural: but the same plants agree in the number and situation of their stamens and pistils and so far the arrangement is natural. And in a majority of instances it is probably true that plants agreeing as to those important organs do also possess a resemblance in their general character and properties.

The name of Linnaeus is familiar as household words to those at all conversant with natural history in any of its departments. For his labours are not confined to botany. The broad glance took in every object in nature and all her organized productions he attempted to reduce to a system. But botany was his favorite science and in this subsequent writers have found less to alter than any other department. It is more than 100 years now since this distinguished man was born and 80 years since he was in the zenith of his course. His father was a Swedish clergyman and destined him for the church. He had early however acquired a taste for the study of nature - especially of plants and philological and metaphysical studies so important to the theologian - were intolerably wearisome to his youthful mind. He was sent to several schools and devoted himself with success to mathematics and natural philosophy: but such was his deficiency in other branches that his instructors - as was the case in regard to Sir Isaac Newton - gave him up in despair and advised his father to put him out an apprentice to the shoemaker or tailor or some other handicraftsmen. A physician however observing his peculiar turn recommended that he should be put to the study of medicine and his advice was followed. So feeble however were his pecuniary resources that in passing through his studies at the University he was subject to the severest privations being obliged to trust to chance for a meal. A succession of trials of this sort continued to attend him even for many years after leaving university and wherever he went he met but little except rebuff and discouragement. In one of his herbanizing excursions he met with that accident whatever it was which he always asserted ascribed to the bite of an animal which he has called Trivia informalis.

Give some account of this doubtful wound and its effects.

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In Holland wither Linnaeus had gone for a degree his skills and honesty had for a time well nigh ruined him. One of the burgomasters there was possessed of that refuted wonder a Hydra with seven heads which inspired awe and admiration in all who beheld it and on which its owner had fixed an enormous value. But Linnaeus proved it to be artificial and thus swept away at once the golden dreams of its possessor. At length however the great merit of this naturalist began to meet its due reward and one honour after another continued to poured upon him even to the close of life. The man to whom he was first indebted for patronage that was valuable was that truly learned and eminently pious physician Dr. Boerheave who on his deathbed said to Linnaeus, "*I have lived all my time, I have done what I could; may God preserve them from whom the world expects much more. Farewell!*" Alas would there were as much evidence that Linnaeus inherited the piety as there is of his possessing the learning of this most worthy man.

Amid all his honours however Linnaeus was through life tormented with the same calamity that fell on Socrates viz. a parsimonious adulterous tyrannical wife. He found in natural history however a partial substitute for that domestic happiness of which he was deprived.

To enter into further detail concerning the life of this father of modern natural history cannot be expected in this place. Suffice it to say that he continued to the close of life of threescore and ten years to write and publish works of Natural History in which he laid the foundation for most that is grand and beautiful in those sciences. Colleges and universities - learned societies noblemen and kings vied with each other in bestowing on him their patronage. His own sovereign conferred on him the rank of nobility and after his death pronounced a eulogy upon him in a speech from the throne. Thus were his days ended in as bright a blaze of prosperity as their beginning had been dark and stormy and were I able to add that his was the death of the righteous it would put the finishing stroke to the picture of great learning and great worth.

From this brief biographical sketch which I think cannot be regarded as out of place I return to a consideration of the Linnaean arrangement of plants.

All plants are in this system divided into 24 classes and these classes into orders and these orders into genera and these genera into species. I shall begin with the classes. These are founded on the number, situation or proportion of the stamens.

A plant whose flower has one stamen belongs to the class Monandria.
2 stamens to Diandria
3 stamens to Triandria
4 stamens to Tetrandria
5 stamens to Pentandria
6 stamens to Hexandria

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7 stamens to Heptandria
8 stamens to Octandria

9 stamens to Enneandria
10 stamens to Decandria
12 to 29 stamens Dodecandria

Thus far the characters the classes are extremely simple. In the 12th class Icosandria the stamens are 20 or more inserted into the calyx. Here the situation of the stamens is taken into the account.

13th Polyandria - stamens commonly more numerous than the last and inserted into the receptacles
14 Didynamia - stamens 2 short and 2 long. Here the proportions of the stamens is taken into consideration
15 Tetradynamia - stamens four long and two short
16 Monadelphia - stamens united by their filaments into one tube
17 Diadelphia - stamens united into two sets both sometimes cohering at the base
18 Polyadelphia - stamens united into more than two sets. Small class rejected by some writers
19 Syngenesia – stamens united by their anthers into a tube rarely by their filaments also and the flowers compound.
20 Gynandria - stamens united with a growing out of the pistil either proceeding from the germen or the style
21 Monoecia - Stamens and pistils and separate flowers but on the same plant – name means growing in one house
22 Dioecia - stamens and pistils not only in separate flowers but in separate plants
23 Polygamia – "Stamens and pistils separate in some flowers united in others either on the same plant or on two or three distinct ones. Rejected by most botanists.
24 Cryptogamia - Stamens and pistils either not well ascertained or not numbered with certainty.

Orders

In the first 13th Classes the orders are easily determined depending upon the number of pistils. All of them have the termination gynia with the Greek numeral prefixed. Thus a plant having one pistil belongs to the order Monogynia, one with two pistils Digynia, with three Trigynia, with four Tetragynia and so on to Polygynia or having many pistils. The whole of these thirteen orders are not found in any one of the classes and rarely more than half of them. Thus in the class Monandria we find only monogynia and digynia - in Diandria we have three – monogynia, digynia, and trigynia – in Triandria the same, in Tetrandria first and Tetragynia – in Pentandria and Hexandria very large classes there are six orders, in Heptandria and Octandria four, Enneandria a small class…

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…only three – Decandria 5 – Dodecandria 6 – Isocandria 3 and Polyandria a very numerous class has 7. Of these orders Hexagynia is very rare – heptagynia still more unusual and although octogynia and enneagynia are put down by Dr. Smith and other botanists none of them as I can find offer us an example (Refer to the paintings of these Orders.) The truth is the pistils are by no means constant in many species and hence different observers will class newly discovered plants under different orders.

The orders of the 14th class Didymania are two quite natural and distinct. In Gymnospermia the first of these orders the seeds are marked and generally four. In the Angiospermia of the seeds are in a capsule and numerous.

Tetradynamia the 15th class is two orders also depending on the shape of the fruit. Siliquosa fruit in a pouch or roundish pod - Liliquosa fruit in a long pod.

In Monadelphia - Diadelphia and Polydelphia the 16th 17th and 18th classes - the orders are founded on the number of stamens - that is the same as the first 13 classes - and they have the same names as those classes.

The entire class Syngenesia has five orders - Linnaeus reckoned six - and they are more difficult to understand than any other class. They are marked by the united or separated barren fertile or abortive nature of the florets.

1. <u>Polygamia equalis</u> – florets all perfect or united that is each furnished with perfect stamens a pistil and one seed. Paintings No. 60.

2. <u>Polygamia superplura</u> – Stamens and pistils in the florets of the disc – those of the radius with pistils only but each kind producing perfect seeds. Paintings No. 54.

3. <u>Polygamia frustranea</u> – Florets of the disc having stamens and pistils or perfect. Those of the margin neuter or destitute of pistils as well as of stamens except in some cases the mere rudiments. This order might with advantage be abolished. Paintings No. 56 and 67.

4. <u>Polygamia necessaria</u> – Florets of the disc with stamens only: those of the ray with pistils only Painting No. 74.

5. <u>Polygamia segregata</u> – Several flowers either simple or compound but with united tubular anthers and with a partial calyx all included in one general calyx. Painting No. 65.

<u>6. Polygamia monogamia</u> – Simple flowers with united anthers. Paintings No. 61. Now generally rejected.

The 20th 21st and 22nd Classes, Gynandria, Monoecia, and Dioecia, have their orders distinguished by the characters of the classes that precede them and in most instances are distinguished by the number of stamens and are hence called monandria diandria etc. In the class Monoecia however we find the orders Monadelphia, Polydelphia, and Gynandria distinguished in the same manner as these classes are respective. The paintings exhibit in Gynandria – the orders monandria and polyandria (and now removed to monoecia). monoecia, polyandria and dioecia.

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The orders of the 23rd Class Polygamia are distinguished upon the principles of the classes immediately preceding. They are three: monoecia, dioecia, and trioecia. Paintings Nos. 80 & 89 – monoecia (pullitory), Nos. 85, 86, & 87 trioecia (Fig.)

The Edinburgh Encyclopedia reckons about 30 genera under this class although most botanists reject it.

The orders of the 24th Class Cryptogamia depend neither on the stamens nor pistils it being impossible to distinguish these with any certainty. These orders therefore are professedly natural resting upon the general habits and affinities of the species. It is a vast class and one which will well repay the student for an attention to it because he will discover the beauty and system and design where he least expects it.

Linnaeus reckoned but four orders in this class. Botanists now number six with several suborders as they are called and the distinction between these orders are most plainly marked. It is easier however to perceive that distinction than to state it in words just as we readily perceive a distinction among the different members of a family notwithstanding a general resemblance although to describe that distinction would be no easy task. Refer to Decandolle's divisions of this class, Philosophy of Plants, pg. 138.

Order 1. Filices or Ferns. A beautiful order bearing their fructification on the back summit or near the base of the frond. The parts of the flowers have never been distinctly traced: the capsules however are evident and there are abundantly prolific seeds. (Refer to the paintings, Nos. 95, 96, 97, 98.)

Another set of genera called Stachyopterides – Ditto A third called Schismtopterides –

Ditto. Refer to Decondolle's divisioins of this class, see Philosophy of Plants, p. 138.

Order 2. Musci. The mosses. These have distinct stalks and leaves of usually stems bearing a capsule.

Explain their construction from the paintings.

103 – Bryum unduslatum somewhat magnified
100 – Calypta operculum 2 capsules of same
101 – Showing the operculum and outer row of cilia or teeth
102 – Calyptum magnified greatly
108 – Capsule (Hypnum retabulum) showing the inner and outer rows of teeth – Always either 4 or 8 or 16 or 32 or 64.
109 – Front view of the teeth magnified greatly
110 – Inner fringe greatly magnified showing it to consist of reticulate membrane.

In many instances mosses are dioecious that is have stamens upon one plant and pistils on another. Those stalks having capsules are of course the pistillate or fertile ones. Paintings 112-113-114-115 exhibit several staminate flowers. Sometimes they are monoecious – both kinds growing on the same plant. Hedwig raised mosses from the seed and has given figures of the plant in its various stages of growth.

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See Smith's Introduction to Botany.

3. Hepaticae. This is a tribe of plants not greatly differing from mosses in many points. Thin capsules rise usually on stalks like the mosses and these open at their summit but they are not furnished with a lid or teeth. Not a numerous order.

Refer to paintings No. 104 & 105 also to brook liverwort Marchantia.

4. Algae. These are chiefly such cryptogamia plants as grow in the ocean: they are not however confined to salt water – found also in running water (as Lamaria fluvcutiles Ct. River Gill) and in stagnant water (frog's spittle, Conferra).

Refer to paintings No. 121.

5. Lichenes. Some botanists do not separate these from algae. They grow in rocks – trees – fences indeed almost e very where. They are generally destitute of a distinct root or stem and consist of an uniform receptacle or frond in which frequently appear some form spots called apothecia or partial receptacles.

Refer to paintings No. 118-119-120.

Notice – Cetraria islandica – Cenomuce rangiferina – Strica pulonaceae, etc.

6. Fungi. These form the last link in the vegetable kingdom and it is only the closest observation that enables us to state that they are really plants produced like the more perfect ones from seeds and that they have parts of fructification. Their number and variety is immense though as they usually grow in retired situations few of them are noticed. Persoon, one of the ablest writers on the subject, divides fungi into two kinds:

1. Angiocarpi – such as bear seeds internally as Lycopodon, Sphaeria, etc.
2. Gymnocarpi – such as bear seeds embedded in an appropriate dilated, exposed membrane – Eg. Bolites, etc.

Refer to paintings No. 116-117-122 also to “Fungi selecti picte.”

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Such are the orders of the Linnaean system. By the classes all known plants are divided into 24 parcels. The orders carry this division much farther amounting to 115; into so many parcels therefore we have all vegetables arranged. But so numerous are plants that unless we are able to very much to multiply these groups great confusion cannot be avoided. To effect this object a system of genera has been invented.

A genus consists of those plants of the same order that agree in their flowers and fruits or in their parts of fructification. For it is a Linnaean rule strictly adhered to by all able botanists that the generic characters shall be taken exclusively from the parts of fructification a rule from which Linnaeus deviated only in regard to umbelliferous plants and this deviation is said to be unnecessary.

More than 3000 genera of phenogamous plants are established by botanist and the number is constantly increasing. The cryptogram genera are likewise very numerous.

We have now come to the last division of plants viz. that of genera into species. Species are the individuals of which a genus is composed. The characters of species are taken from every part of the plant not appropriated to classes orders or genera. Specific descriptions therefore comprehend a description of the whole plant.

Accurately to define species the most difficult part of botany requiring the exercise of the keenest discrimination. Read from Smith's Grammar of Botany 63 to 69.

Species are permanent in all situations the liable to transitory deviations called varieties.

The class of plants may be compared to the division of mankind into kingdoms. The orders to the subdivisions of those kingdoms as states counties - the genera represent the towns - the species families in a town and the varieties the individuals of the family.

How to determine the name of a plant unknown.

Dissect Epilobium spicatum and have it through class order genus and species.

Likewise Lysimachia ciliata.

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Difficulties in the Linnaean system

I have already remarked that this system is artificial rather than natural and hence it sometimes separates plants which nature has allied and brings together those of most different properties. There are however other difficulties that stamp the system with imperfection. A principle one is that the number and situation of the stamens and pistils are not always constant and hence it is sometimes impossible to determine the name of a plant from the description or if it be a new species we cannot tell where to refer it. In some instances two species of a genus have uniformly a less or a greater number of stamens and pistils than the others and yet are so nearly related by natural affinities that they cannot be separated. Cases of this kind are very perplexing to the beginner but when an extensive acquaintance with plants has been obtained such anomalies do not seem too much in the way.

Eminent botanist have also regarded some of Linnaean classes as superfluous and hence they have rejected them. Persoon *[Christiaan Hendrik Persoon 1761 –1836, Dutch mycologist]* who is followed by nearly all American botanists rejects the class Polyadelphia and Polygamia and Dr. Smith proposes to unite Monoecia Dioecia and Polygamia into a single class of the name Didania which arrangement is adopted by Pursh. Some botanists in this country dispense with the class Dodecandria and some Europeans have done the same with Gynandria.

It is evident that these innovations must create considerable trouble and confusion in botanical science. But the multiplication of synonyms an evil from which no system can be free produces still greater confusion. It often happens that the same plant will be discovered by several botanists about the same time and published under different names and this is one source of synonyms. Another source is the attempt that is often made to remodel a genus - a labour sometimes necessary and sometimes undertaken by men who have an overwhelming conceit of their ability to correct the deficiencies of others.

<u>Natural Orders</u>

Linnaeus never published anything himself concerning natural orders: but the fragments of a natural method were made public by two of his pupils as he exhibited the subject in his lectures. No regular system however was published till the time of Bernard de Jussieu and his nephew Lamont de Jussieu who first formed a natural system upon scientific principles. But in the present state of botanical knowledge there is scarcely a principle of the Natural Classification that has not some exception. In the system of Jussieu – the most complete yet published - the structure of the embryo and cotyledons is of primary…

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…importance and Linnaeus thought this the basis of natural classification. Other circumstances however are taken into consideration. Among these the alburnum is of use in the discrimination of plants and Jussieu so makes use of the insertion of the parts of a flower or the situation of the germen whether inferior or superior with regard to the rest.

The Classes in Jussieu's system are 15 not having any particular application one is acotyledonous three monocotyledonous and eleven dicotyledonous.

There are 100 orders of definitions of which as well as of the classes is very prolix.

137 genera remain which Jussieu could not arrange in any of his orders – subsequent examination however has shown that some of these belong to his system.

Since the publication of Jussieu's system between 30 and 40 years ago the subject of natural classification has received great attention particularly from Mr. Brown an English botanist well known by his account of the plants of New Holland and Professor Decandolle of Geneva among the first of living botanists. In 1813 he published an account of Jussieu's system in which the natural orders are augmented to 145. In his Philosophy of Plants more recently published gives a catalogue of only 110. In that work the joint production of two of the most distinguished living botanists Deandolle and Sprengel will be found the best account of the principles on which the natural classification should be found which is to be found in the English language. After all that has been said in praise of Jussieu's system it is obvious that is not a strictly natural arrangement. The artificial system of Linnaeus arranges plants according to the number and situation of their stamens and pistils. Jussieu's system must be regarded as merely an extension of this method by comparing together a greater number of organs as the number cotyledons the situation of the germen etc. But a perfectly natural classification cannot be made unless we take into view the sum of the related characters- that is compare together all the characters of plants. This is a work of so much difficulty even Decandolle with all his…

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…acuteness and knowledge of plants has not been able wholly to free his system from everything that is artificial. For although he has succeeded in giving definitions of several orders that are strictly natural he is obliged to resort to an artificial distribution of the. In view of these difficulties Linnaeus was of the opinion that Dr. Smith is almost inclined to admit its truth that "*we are not competent to define technically any natural orders without so many and such paradoxical exceptions as to destroy all consistency*."

The fundamental principles of which should regulate us in forming a theory of natural classification are three:

1. We must be acquainted with the relative importance that belongs to organs compared with one another.

2. We must know the circumstances that might lead us to mistake the true nature of organs.

3. We must be able to estimate the importance which ought to be attached to each of the points of view under which an organ may be considered.

In the comparison of organs we find two principal functions which they directly or indirectly perform. 1. The nourishment of the individual, and 2. The propagation of the species. But as we find greater differences among the organs of propagation than of nourishment and the latter cannot be examined without dissection we must regard the organs of fructification as the chief basis of classification. The relative importance of these organs is according to the following order: 1. The embryon the ultimate object of the whole vegetation; 2. The parts of the seed; 3. The fruit; 4. The filaments and anthers; 5. The nectaries; 6. The interior cover the stamens and pistils or the corolla; 7. The calyx.

In regard to the second principle of classification viz. the means of avoiding mistakes respecting the true nature of organs it is well known fact that Linnaeus frequently made such mistakes particularly in regard to nectaries. The grand point to be determined in order to avoid such mistakes is to ascertain whether the organ actually performs those functions to which by its form and situation it seems destined. And yet in very many instances we find form similar to those connected with a…

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…definite function which do not serve that function but seem to be intended merely to give the plant an harmonious structure. A third method for determining the nature of an organ is by dissection aided by powerful glasses.

It is not here to be forgotten that in many cases the organs of plants are abortive sometimes in consequence of unfavorable weather for their evolution - sometimes in consequence of one organ being evolved at the expense of another. Nor are we to forget the change and degeneration that not infrequently take place in the organs of plants. It is a law of vegetable nature "that from every individual part of the plant every other may be evolved." (Give examples) Not infrequently too we find an union of organs e.g. two fruits two branches two trees are united with one another. Before we are prepared to assign a plant its appropriate place in the natural system we ought to be sure we are not deceived in respect to any of these particulars.

The different points of view under which an organ or system of organs may be considered are among the most important and most complicated principles to which the author of a natural system must pay attention. Among these points of view are the situation relative position proportional size and number of organs whose comparative value as characters can be learned only by the most extensive examination. In determining this comparative value botanists have taken it as a rule that "*the value of a character stands in a compound proportion to the importance of the organ and to the point of view in which we consider it.*"

From this slight and imperfect sketch of the principles of natural classification you perceive gentlemen that a field is here open wide enough to bring into action the most profound knowledge of science and to exercise talents and philosophy of the highest order. If any of you wish to study these principles more in detail I can put you in a way of gratify your wishes.

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<u>Geography of Plants</u>

That different countries and even different parts of the same country produce different plants is a fact of universal notoriety. In mountainous countries we observe this diversity strikingly exhibited within the space of a few miles. In ascending a few hundred feet we often find many plants common in the fields and meadows below to disappear and others unknown at the base of the mountain to be growing around us. If we change our latitude we shall find this change more rapid and greater then when we change our longitude because in the first case the change in climate is greater. It is a curious subject of inquiry to compare the plants of different regions to ascertain the distributions and such a comparison constitutes the geography of plants: a department of botany yet in an imperfect state because many extensive regions remain unexplored.

One of the most important laws respecting the distribution of plants on the globe is that the less perfect the organization of the body the more widely is its distribution. Thus we find the fungi algae hepatica and musci in almost every spot on the land and in the water on mountains and in valleys. The same is true of animals since we find the infusory animalculae *[microscopic creatures, protozoa]* in all zones. I speak here however of orders and genera rather than of species since the cryptogamic botany in the remote countries has been studied with so little attention and species have not in many instances been accurately identified. Brown however a witness of high authority tells us that almost two thirds of the lichens of New Holland *[Australia]* are identical with those of Europe and about one third of the mosses.

The more perfect plants are less widely diffused. Yet there are exceptions. Sonchus oleaceous Hydrocotyle vulgaris and Potentilla anserina are natives of this country of Europe and of New Holland. About one seventh part of the plants of North America are found in Europe.

The same distance from the Equator north and south we find an agreement in families and genera but rarely in species. In regard to latitude how so different is the climate in the same latitude in different hemispheres and on different continents and even on different sides of the same content that…

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…the same latitudes often possess a Flora very distinct from each other. Hence we must seek for countries whose mean temperatures correspond rather than their latitude if we would compare their vegetation.

Another circumstance that greatly affects the floras of different regions is the different nature of the soil in those regions. This may probably be denominated the "*Geology of Plants*." We find everywhere particular plants requiring particular kinds of soil (Illustrate by reference to the greenstone ridges along the Connecticut). Salt soils are characterized by peculiar plants found no where else. Volcanic countries exhibit the like peculiarity as do also calcareous soils which produce the most numerous and distinguished forms - it is said that the primitive mountains almost every where separate the Floras of countries as the Pyrenees the Alps the Carpathian mountains.

A circumstance of still greater importance to be noticed in the geography of plants is the elevation of their place of growth above the level of the sea. As we ascend mountains we passed through all the variations of climate which occur between the equator and the polls and hence we should conclude that the plants of high mountains would be very similar to those near the poles. It must be recollected however that the polar summer is shorter and hotter than near the line of perpetual congelation on mountains in temperate and tropical latitudes. And we find accordingly so far as observers has extended that an almost totally different class of vegetables is found on high mountains and in the polar regions. Humboldt has done much in this department by his labours in the Andes.

We observe as much diversity in regard to the social habits of plants if such an expression may be tolerated as among individuals of the human family. While some species are clustered together in countless numbers others stand insulated and scattered and apparently so difficult of reproduction that they would become extinct were it not for the wonderful provisions the Creator has made for their continuation. Continuance.

It is generally stated that ferns constitute the 60th part of the vegetable kingdom. In some countries however they make up one half others one quarter in others one eight and in others one third and others one sixth etc. Grasses are uniformly about one tneth or one fifteenth of the whole flora. The umbelliferous plants about…

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…one thirtieth of the plants besides the grasses. The Leguminous plants form one twelfth of the tropical floral - less in the temperate zone and as one to 35 in the polar regions.

In regard to the cultivation of useful plants Cocoa Coffee Anatto Cloves and Ginger are limited to tropical countries. The sugar cane Indian figs dates indigo and Battatas pass the tropics as far as 40° North latitude. Cotton rice chives figs pomegranates Agrimaes and myrtles grow as far north as 45 or 46°. The vine flourishes best in Europe within the 50° latitude. Plums peaches wheat flax tobacco gourds will not grow in the west of Europe beyond 60°. In the east of Europe apples pears plums and cherries will not grow beyond the 57° but hops tobacco flax hemp brick wheat and peas grow even under 60°. Hemp oats barley rye and potatoes are raised by the Norwegians under the polar circle and the strawberry flourishes at the North Cape in 68° North latitude.

<u>History of the distribution of plants</u>

A curious and as it would seem at first view rather useless question has been discussed among botanist whether all plants have been distributed from one point on the surface of the earth or they were originally natives of the country in which they grow. Linnaeus undertook to defend the former opinion viz. that they all proceeded from one point but subsequent research is unfavorable to his view. He supposed that a single example only of each genus of plants was created at the beginning along with a single pair of all the animal tribes and that these were placed upon the highest mountain ridge of the earth and were then distributed to all countries in the process of time.

That plants do migrate in similar climates in many cases - that some from very distant countries become naturalized in opposite continents cannot be denied. But to suppose that the many thousands spread over the globe were scattered in any such manner seems highly…

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…improbable: and the idea that so many species as now grow on the earth in the most opposite climates soils and situations should have been originally collected in a single spot and that too a high mountain ridge seems altogether too absurd for belief too unimportant to require a further examination.

Malformations and Diseases of Plants

Plants like animals are subject to disease. They are also liable to malformations or anomalies which are distinguished from diseases by the circumstance that in malformations all the organs continue to be developed in their due proportion which is not the case in disease. Malformations are distinguished from the abortion degeneration and union of organs and being less permanent and not inconsistent with the health of the entire plant. In most instances malformations arise from cultivation and too great luxuriancy of a growth and these disappear when the plant is introduced into a more sterile soil or is treated in a coarser method. The speckled structure observed in certain kinds of wood which is much admired may be considered as an instance of malformation and arises from a mixture of numerous knots arising from the half formed buds. Discolouration of leaves as in the vanity grass of the gardens is another example of malformation. Mention also the case of a species of Juncus and Cyperus and exhibit examples .

The causes that produce diseases and plants are numerous. Among these may be named light and heat. For although a certain degree of these is essential to the growth of plants yet in excess of these operates as upon animals to produce disease.

In like manner too little heat or light produced disease - cold particularly is productive of this effect.

Electricity too little as we know of its nature has no small influence upon the health of plants. The discharge of positive electricity has been found to be one of the most powerful stimulants to the vital action of plants. Hence we see the…

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…reason why grain is sometimes blighted by lightning when it grows in low lands. In like manner buckwheat fails of being productive when exposed to lightning. In these cases the electric fluid seems to be too powerful a stimulant.

That form of electricity denominated galvanism undoubtedly exerts a powerful influence over vegetable nature. For the solid and fluid parts of wood form galvanic circuits more or less perfect: and it is suggested by Sprengel not without reason that many of those chemical changes going on in vegetables by which substances so different in their properties are secreted may be in a great measure dependent upon galvanic action. If so an excess or deficiency of this action must produce disease.

The purity of the atmosphere must affect the health of plants as well as animals. Oxygen is nearly as essential to the former as to the latter although a few plants will flourish in nitrogen and hydrogen. When therefore the atmosphere is impregnated with sulfurous acid gas as is sometimes the case an overexcitement and parching are produced and the lively green of the foliage is changed into a dirty yellow.

That a deficiency or excess of moisture has a great effect on the health of plants is too well known to require any illustration.

But vegetables are subject to still more numerous diseases from parasitic plants and insects. (The Orobanche an example of the former - show the root of the tree). These abstract the nourishment of the plant on which they fasten and then check its growth to produce diseases. The most numerous class of parasitic plants is the lichens mosses and fungi. Lichens and mosses attach themselves to trees in their most healthy state. But the fungi are rarely found except on those plants already partially decayed through the influence of disease. Indeed in very many cases some excess in the secretions of the plants attracts insects and parasitic vegetables. In this way is explained…

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…the blight or mildew of grain. Powerful heat following rain produces an exudation of slime and sweet drops called the honey dew. This attract swarms of insects whose young brood spread over the leaves like powder and prevent them from the performance of the requisite functions.

The nature of ergot in grain is still a matter of dispute among the learned. The most probable opinion however is that it is a degeneration of the grain by which a parasitic fungus (Class Selotium of Decandolle) is produced - and that the disease of the grain is produced by the puncture of an insect in search of honey (See American Journal of Science vol. 9 pg. 359. General Field.)

The barks of trees are liable to cracks - to the flowing of resinous matter and to what are called the leprosy and the scale. In some instances a superabundance of raw juice is produced in plants rendered feeble by frost or bad management the dropsy is produced.

Blotches frequently appear in valuable trees manifested by dark spots in the bark and produced by the sterility of the soil and other enfeebling causes. Attacks the mulberry in July.

The canker proceeds mostly from the hardening of the bark which renders the juice acid and corrosive and these making their way beneath the bark gradually consume it and the wood beneath.

A great variety of parasitic fungi besides those already alluded to produce a blight in plants under certain circumstances. And these diseases seem to be very infectious so that it is difficult to prevent their recurrence in subsequent years.

The disorders produced in plants by the different insect tribes by which they are attacked are too numerous to be here detailed. A great number of excrescences are formed upon our oaks produced by the puncture of insects and the deposition of their larvae (Exhibit several of these). Also drawings of the excrescence on the Andromeda.

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Whortleberry - rhododendron (azalea) Lysimachia etc.

The May Bug (Melolantha vulgaris) is one of the most destructive insects. It remains four years in a larva state underground and is known by the name of grub - as an analogy to roots. When it changes its state it is equally injurious to the leaves and buds of orchard and other trees. Equally injurious but less common the spring beetle (Elator segetes) the larva remain in the ground five years. The Botrychus typographer's lines upon the inner bark of the pine and a few years since a million and a half of these trees fell a sacrifice to it in the Havr. alone. They Arborium tessalatum or death witch devours both living and decayed wood. Butterflies in the caterpillar state are very injurious to orchards and garden vegetables.

Mention the ravages of insects in the County of Essex upon the evergreens this year (1831) - also the attacks of worms upon apple trees in Enfield Connecticut this year and two years ago.

Poisonous Plants

It is not easy to get any specific rules that shall be of any great service in enabling us to determine whether a plant be poisonous or not without an actual trial of its effects upon the animal system. Not a few of our most useful plants are in a slight degree poisonous in some parts, for example common potato. Some remarks however on the subject may not be useless.

The family of the grasses are never poisonous nor those whose stamen stand upon the calyx.

Those with cruciform and papilonaceous cowls rarely poisonous - and those with labiate cowls with naked seeds - also the compound flowers.

Plants that emit a nauseous and sickly odour are suspicious though not always poisonous.

If such belong to the fifth class and have dull-coloured corollas the probability is still stronger that they are poisonous - as Datura – Nyosaynamus stropa and Nicotiana.

If plants of this description are umbelliferous and growing in wet places they are often poisonous. Examples Conium maculatum. (Its effects on Socrates Science Digest Med. Bot. pg. 196 vol. 1)

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Sirium latifolium etc. If such grow in dry land the the smell is pleasant they are not poisonous. Sweet Examples Sweet Cecily, fennel, dill, caraway.

Plants from which issue a milky juice when broken are using more or less poisonous except those with compound flowers. Example Asclepius and Apocynum.

Chestnut tree Celdrate one on Mt. Etna 200 feet in circumference Lib. Ent. Knowledge Vol. 2 pg. 88.

Transplanting large trees. See same work pg. 102.

Walnut - its bark used by the Gypsies for staining the shoes[?] of children that they have stolen. Same work pg. 139.

Lance wood – Guatteria virgate and Hassogamy wood - used for the handles of spears among the natives of the South seas.

Mulberry - Rearing of silk worms introduced into Europe at Constantinople about A.D. 550 - into Venice 1204 - to England by James I - and France by Henry 4th

Paper mulberry – Broussonetia papyrifera – Sil. Ent. Thrumb pg. 145.

Mahogany - Same work pg. 149

Sandal Wood - employed chiefly for burning incense for the gods and for cabinet work. Santalum album - but my specimen from the Sandwich Islands does not agree to this species.

Tri Root – Dracaena terminalis - A sweet root used by the natives of the Sandwich Islands for making an intoxicating liquor .

Trees from which caoutchouc is obtained – from the Artocarpae or Breadfruit but chiefly from the Euphorbiaceae.

Bohon upas of Java - the most deadly poison in the world from the Artocarpae - Lindley pg. 93, 101, 109, etc.

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[Loose sheets inserted between pgs. 5 and 7.]

Botany is divided by Decondolle (Philosophy of Plants by Decandolle and Sprngel p. 1. Edinburgh 1821) into two principal departments: 1. The <u>Natural History</u> of Plants   2. The <u>Natural Science</u> or Physics of Plants.

The natural history of plants comprehends the external marks of plants and the means of distinguishing them. It has three subdivisions:

1. The Nomenclature – or the terms by which the different organs of plants and their properties are designated
2. Taxonomy – The Theory of the Classification of vegetables.
3. Phytography – or Descriptive Botany – the art of describing plants in a conformable manner.

2 The Natural Science or Physics of Plants –called also Phytonomy or Phytology and is synonymous with the Physiology of Plants. It has also three subdivisions:

1. Anatomy or the doctrine of the structure of plants – called by Decanolle their Organography.
2. Phytochemy – or the chemistry of plants or a knowledge of the composition of plants.
3. Explanation of the manner in which plants originate grow from their parts and propagate themselves. This is the true phytonomy or philosophy of plants.

Give a general account of the Linnaean classes and orders.

Dissect several plants before the class.

Direct how to collect, dry and preserve plants.

Corrosive sublimate dissolved in alcohol the most effective remedy against insects.

Describe a common Herbarium of paper.

Describe an herbarium on the plan of Linnaeus.

To these principal divisions of botany may be added the following:

1. The History and Literature of Botany. In no science are these more necessary to be understood.
2. The Geography of Plants or an account of the different locations or stations of plants.

3. The Anomalies of Plants – including their diseases and malformations – a very difficult part of the subject.

4. The applications of botany to the arts and business of life.
   1. Medical botany
   2. Oeconomical botany or a knowledge of those plants which are employed in husbandry and agriculture
   3. Technical Botany - a knowledge of those used in the arts and trades
   4. Botany of Forests – a knowledge of Forest Trees.