Chemistry, as affording evidence of the wisdom of God : an introductory lecture delivered before the medical class of Transylvania University, on the seventh of November 1834 / by Lunsford P. Yandell.

Yandell L. P.

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AN INTRODUCTORY LECTURE

DELIVERED BEFORE THE MEDICAL CLASS OF TRANSYLVANIA UNIVERSITY,

ON THE SEVENTH OF NOVEMBER, 1834.

BY LUNSFORD P. YANDELL, M. D.
Professor of Chemistry and Pharmacy.

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LEXINGTON, December 5th, 1834.

SIR:—In behalf of the Medical class, we, a committee appointed for the purpose, tender you our thanks for the able Address delivered before us at the commencement of your present course of Lectures, and respectfully ask a copy for publication.

Yours &c.

E. P. TALLEY,
H. N. EDMUNDS,
M. L. LINTON.

LUNSFORD P. YANDELL, M. D.

LEXINGTON, December 6th, 1834.

GENTLEMEN:—A copy of the Lecture which, in behalf of the Medical class, you have politely requested for publication, is at your disposal. For this honor done me by the class, please offer them my grateful acknowledgments, and accept for yourselves assurances of the respectful regard of

Yours &c.

L. P. YANDELL.

Messrs E. P. TALLEY,
H. N. EDMUNDS,
M. L. LINTON.

CHEMISTRY, &c.

THE circle of science has grown too wide to be compassed by any human intellect however great. The man who knows the most will be free to admit that all his attainments are limited and humble, compared with what he does not know. A single branch may afford a field for the exercise of the most vigorous faculties through the longest life. *Ars longa, vita brevis*, was the first aphorism of the Father of medicine, in reference to his profession, more than two thousand years ago. How much more true is it of the science of the present day, enriched by the discoveries of so many successive ages! The mind cannot embrace all, but in the midst of a countless multitude of studies must fix upon those which promise the highest reward. Goodness, it may be affirmed, is better than greatness; purity is more excellent than power—virtue than knowledge. As those evils which touch nothing but the body or fortune, according to the fine sentiment of the heathen philosopher, are trivial in comparison with those which affect the soul, so those studies are above all others in value, which, while they strengthen the mind, purify the affections, and while they store it with knowledge, fortify it with just and elevated principles.

Among the branches of human knowledge which have given efficiency to labor, and multiplied the comforts and decencies of life, and which at the same time afford an agreeable and invigorating exercise to the mind, Chemistry holds a conspicuous place. It were easy to show, that it is connected with nearly every art in which the well-being of society is concerned—that every artizan or laborer, though he may not be aware of it, is guided and profited by its light—whether his occupation be agriculture, the parent and most useful of all, or that of the hatter, painter, tanner, druggist, tallow-

chandler or soap-maker. But it is not my intention to go into this proof on the present occasion. Leaving such details to be exhibited in the progress of our course, as they come up naturally in their place, it is my purpose, in this discourse, to ascend to some of the higher results of the Science, and inquire how far its testimony is favorable to the Wisdom of Him who is the author of its phenomena and laws.

So extended is the field covered by chemistry, and so prolific every portion of it, of those arguments which bear upon our subject, that our trouble is, not to find them, but, out of the mass, to select the most appropriate. Air, earth and water, as objects at once familiar and extensive—so common as to have formed subjects of attention and some study to the most listless observer, but so widely diffused, so potent and useful, that they are not surpassed in dignity by any other department of inanimate creation—may be chosen as affording, perhaps, the aptest illustrations—the earth, which forms the dwelling place of man, the air, which he breathes, and water, which enters into both, and imparts to them their most exquisite finish and beauty.

One of the most abundant substances of which chemistry treats, is atmospheric air. This fluid, it is well known, is indispensable to the existence of animals and vegetables. All these, from the highest to the lowest, are possessed of a respiratory apparatus. The zoöphyte and the plant are as dependent upon it for life, as the eagle which makes it his home. The first act of the new-born babe is to inhale the air, and the last effort of the expiring man to command its receding wave. This fluid, surrounding the earth to the distance of about fifty miles, the home of every thing that lives, the laboratory in which all the magnificent processes of nature go on, has been studied by the learned in every age. But it is within a short period only that light has been shed upon its true constitution. The most important element in it, namely, oxygen, was discovered by Dr. Priestly, just sixty years ago. Nitrogen, the other element, had been discovered by Rutherford two years before, but it was first separated

from the atmosphere, and proved to be one of its constituents, by Lavoisier, after the discovery of oxygen by Priestly. These more palpable truths having been so recently revealed, it is not strange that there are still phenomena connected with it which have eluded the researches of the best philosophers, and which fresh labors, and more extended analyses are required to explain.

But if we look into its qualities, as adapted to the wants of the beings which respire it, maintaining its purity in the midst of impurities, perpetually giving up a portion of its elements, but retaining each in a state of perfect equilibrium we shall find it a perfect link in a faultless chain.

It is the only fluid which could support the respiration of animals. No other combination of gases could replace it. Oxygen is the vitalizing principle. It is to imbibe it, that animals breathe. It imparts vitality to the blood, suffuses the cheek with the ruddy glow of health, and gives elasticity and vigor to the frame. Nitrogen is an inactive fluid, and serves no other purpose that we can perceive, than to dilute the oxygen. But it is the only diluent that can be employed. Hydrogen may be made temporarily to take its place, and an atmosphere composed of oxygen and hydrogen, may be respired by animals for a short time, and vegetables might possibly grow in it; but derangement of the vital functions would be the inevitable consequence of its continued respiration. Animals immersed in it, after a few hours become stupid, as if exposed to a narcotic influence. Were such an atmosphere substituted for the vital fluid which now surrounds us, a universal sleep would seize upon all animate nature, now so full of life and motion.

But not only so. These gases, oxygen and hydrogen, form a most explosive compound, which would take fire at every contact with a burning body, and subject the individual expiring it to disastrous accidents. Fires in such an atmosphere would be unknown, but the first spark that was kindled, or the first stream of electricity that descended through it, would light up a conflagration by which the earth would

be shaken to its centre, and the atmosphere condensed into water. Of the various elementary bodies known to the chemist, all capable of assuming the state of vapor, oxygen and nitrogen are the only two, out of which an atmosphere answering all the demands of the living world could have been formed. It is then wisely constituted. The best materials were employed in its formation. But this is not all. The proportions in which they are combined are precisely those which are required for the maintenance of life in full vigor, and for the natural term. If oxygen abounded more, the principle of life would be exhausted by the intensity of its action, as the flame is soonest extinguished which burns with greatest fury. The machinery of the system would run on at a feverish pace, and the frame would sink consumed before it had reached maturity. The life of man, extended now to three score years and ten, would truly be narrowed down to a hand-breath. Oxygen, too stimulating to be inhaled in its pure state, like the light of the sun which we enjoy most when reflected from objects which mitigate its splendor, has been wisely blunted by its combination with nitrogen.

But were the dilution carried farther, and the azote made to predominate, which now only corrects, a hebetude as that from the artificial air of oxygen and hydrogen would fall upon the living world, alike fatal and enduring. The system would languish under the lack of its necessary stimulus. The blood, no longer crimsoned by its wonted contact with vital air, would creep in a purple current along lifeless tubes; the brain, robbed of its needed stimulus, oxygenated blood, would grow feeble and dull; and mind would no longer put forth its accustomed strength. The wings of the imagination would become powerless and tame; poetry would lose its inspiration; eloquence would fail; and even judgment, slow now in its operations, moving with a cautious and wary step, would lose the power to act.

Thus whether we remove either of its constituents, or vary their proportions, whether we exalt or reduce its tone,

disorder and confusion are equally the result. Thus, as forcibly expressed by the philosophical poet,

> From nature's chain, whatever link we strike,
> Tenth or ten thousandth, breaks the chain alike.

But this balance, so exquisite and so uniform, is warred upon by every thing that breathes or burns, and but for a provision as wise as its constitution is perfect, the air, pure, elastic and invigorating at first, and pronounced, at its creation, good, would long since have lost its purity, and become more pestilent than the air of an infected city.

How, amid all the disturbing forces which continually assail it—the countless fires, and myriads of animals which abstract its oxygen, and load it with another gas hostile to life —is this balance maintained; the oxygen allowed neither to diminish nor to increase, to predominate nor fail, and the carbonic acid gas, evolved during every moment of time, and over the whole face of the globe, checked, and restrained within limits that render it harmless? By what magic influence is this beautiful adjustment preserved, in the midst of perpetual strife, and harmony made to triumph over the principles of discord?

Carbonic acid is more than twice as heavy as atmospheric air, and but for another law, which controls the law of gravity, it would settle along the surface of the earth, as water sinks below oil, and thus gradually lift up the atmosphere by its increasing volume until the poisonous flood had risen above the level of our heads; and the earth, like the grotto at Naples, should become filled with a vapor destructive of life.

Lavoisier, a brilliant name in the annals of chemistry, believed, that the lighter gases do ascend to the top of the atmosphere, and there taking fire give rise, by undergoing combustion, to the aurora-borealis, and other phenomena. He was ignorant of the beautiful law, discovered after his day, upon which the just equilibrium between the fluids in the atmosphere depends. According to this law, the particles of each gas press only upon their fellows, offering

slight obstacles to the motions of other gases. Hence the two gases in the atmosphere readily permeate the interstices of each other. The carbonic acid though much heavier than the air, rises readily into it, because the particles of the air rest upon each other, and are to the acid, as if a vacuum existed above it. And for the same reason, neither of the constituents of atmospheric air can ever accumulate in one region, or be permanently diminished in another. The particles of oxygen rest upon other particles of the same fluid, and the particles of azote upon their fellows. And whenever, from any cause, oxygen is consumed, the oxygen of a neighboring region, little obstructed by the nitrogen around, rushes in to fill the partial vacuum. When nitrogen is removed, other particles of nitrogen hurry to supply its place. In cities where numberless fires and lungs are continually abstracting oxygen, there is a perpetual tendency to a loss of the equilibrium between the fluids—to a deficiency of oxygen, and an accumulation of nitrogen, as well as the other gas, carbonic acid, which is evolved by combustion and respiration. But the law just mentioned counteracts this tendency. Oxygen from other regions—from over the green fields of the country, and the mountain tops, pours in perpetually to supply the waste; while the carbonic acid ascends to a higher region, where fewer of its particles exist. On the summits of the highest mountains it is found as prevalent, as in the air of the crowded city. And the aëronaut, at the point of his greatest ascension, has detected no diminution of this fluid.

Another provision tends powerfully to preserve the equilibrium,—a provision strikingly evincive of the wisdom with which all that relates to our atmosphere has been arranged. Vegetables find in the carbonic acid which animals evolve their acceptable food. They drink it up with avidity, liberating in a pure state the vital principle, oxygen, and assimilating the other principle, carbon, to themselves. In this way, the myriads of growing vegetables, the grass of the fields and the trees of the forest, contribute to restore the

wasted oxygen. Water also absorbs carbonic acid, thus counteracting its inordinate increase; and, like vegetables, returns oxygen in its place.

By these means the balance is maintained. Nor, under the operation of these laws, can any deleterious agent remain long stationary in any place. The poison of the pestilence floating in the air, is gradually diffused and rendered powerless, by becoming diluted; and an evil which might become settled, and thus desolate countries, is transient and partial under the existing laws of nature. The air can never become stagnant. Its constituents, we have seen, penetrate each other with facility, and are continually changing place. The particles gliding easily over one another currents are forming at every moment—a wise provision, co-operating with the other powers to preserve the salubrity of the atmosphere. That portion which is heated is rarefied and made lighter by another chemical law, and rises to a higher point; while the colder and heavier body from above descends to take its place. The volume which rests at one moment upon the earth, expanded by the reflected rays of the sun, may be ascending the next to the region of frost—to return again to the earth, as it grows heavier by becoming colder, and breathe among flowers on the warm plains below. The wave which floated to-day over an iceberg at the poles, to-morrow may be moving over the sunny plains of the south; and the sultry air of the equator may be gliding at the same time, over the loftier fields of air, to temper the inclemency of northern skies. Thus the great aerial ocean is never at rest. That which is heated rises, and there is a rush, more or less violent as the rarefaction is greater or less, to fill up the vacuum.

Hence winds, which truly may be called the spirit of the atmosphere, to which it owes its vitality and power, its purity and sweetness, its health and life-giving influence. And though the tempest, in its fell sweep, may occasionally dash the towers of man's strength to the ground, and whelm him, with his navies in ruin, winds are a part of that splendid ma-

chinery by which the air is preserved untainted—of that class of fearful remedies, which the physician of the universe sometimes employs, to secure health to the great family of man.

Another quality of the air, which displays wisdom and design, is its capacity to transmit caloric. It is one of the worst conductors of heat. It carries heat, when not in motion, slowly and with difficulty from the body. The tongue placed upon a spoon or a knife blade, in a morning when the thermometer is within a few degrees of zero, adheres to it instantly by freezing, because the metal, being a perfect conductor, rapidly abstracts its heat; and the fingers are quickly blistered by frozen mercury, for a similar reason—it draws off their caloric more rapidly than it can be generated. Suppose the air were endowed with such conducting powers? Our warmest vestments would be a poor barrier against it. In spite of furs, and wool and down, the heat of the body would soon be exhausted, and the human race, at a temperature above 32°, the freezing point of water, would become extinct. Now, man braves the most intense cold of the polar winter, where mercury freezes in the open air, and where the arctic fox alone of animals is seen abroad after sunset. In motion, it is true, air does soon sink the temperature of the body, because each new wave takes off a portion of its heat. But nature has wisely ordered that winds rarely blow in winter, in the coldest climates; and it has clothed the animals of those regions with furs and down, which, confining the air in their porous textures, become the worst of all conductors. Profiting by the indications of nature, man has appropriated these admirable substances to himself, and clad in such panoply, fearlessly commits himself to the cold of the polar winter.

Water is not less affluent, than the element we have examined, in facts evincive of divine wisdom. It is most curiously made. It consists of bases, which kindle the most intense flame at the moment of their union. The antagonist and enemy of fire, every fire that blazes forms it. Diffused

every where, above the firmament and below it, it performs an infinite variety of offices, for which, were a separate agent necessary, the earth would be encumbered by the multiplicity of objects, standing in each other's way. We have dwelt at some length upon the admirable properties of atmospheric air. But with all its lofty attributes, it is imperfect without the aid of water. Deprive it of this, and what is now the evening zephyr, or the refreshing sea-breeze, would become the blasting sirocco, from which we should be glad to escape by burying our faces beneath the sand. But water is always present in it. Wherever this fluid exists, solid or liquid, evaporation goes on. In winter, as in summer, at the poles as at the equator, from the humid earth, and from ice and snow, the invisible and silent vapor is continually ascending. The Mediterranean gives up more water in this way, than it receives from all the great rivers that empty into it. Thus the moisture of the atmosphere can never fail, and parched winds traverse but a small portion of the globe.

But why is this vapor not speedily condensed, like that which issues from the pipe of the steam engine, or the spout of the coffee pot, and the atmosphere at all times clouded with precipitating moisture? In this way, the vapor indispensable to life would draw a dark veil over the glories of the heavens, and fill the earth with gloom. But it is arranged that sunshine and cheerfulness shall succeed to cloud and storm. In ascending, vapor combines with electricity, whereby its particles become self-repellent, —for it is an ascertained law, that bodies charged with the same electricity repel each other—they thus assume the form of vesicles; and these constitute cloud. The clouds are buoyant by virtue of their electricity. They are confined, by some agency not well understood, to a limited portion of the atmosphere. The aëronaut may ascend into them, and after being lost in darkness for a time, emerge from their gloom into the light of day. And the traveller among mountain scenery is often presented with the sublime

spectacle of the storm raging at his feet, while all around him and above him is sunshine and calm—a phenomenon thus happily alluded to by Goldsmith:

> "As some tall cliff that lifts its awful form,
> Swells from the vale, and midway leaves the storm;
> Tho' round its breast the rolling clouds are spread,
> Eternal sunshine settles on its head."

The clouds float by virtue of their electricity, which prevents their vesicles from collapsing. But the earth charged with electricity in an opposite state, attracts them, and the storm begins. The electrical fluid flashes into the earth; the vesicles collapse, and the rains descend. But the balance is restored again; spots of azure break out in the troubled sky, and the bow of hope and promise spans the vault. Mountains thus stand, in every country, as guardian giants to collect the showers, and disperse them over the vales consigned to their care. More rain falling upon them numerous springs are formed; rivers there take their rise, and fertility is borne upon their bosoms to the distant plains below. But the whole beauty of the law has not yet been unfolded. Water, it is well known, comprises about three fourths of the globe, and this vast surface is the source of perpetual exhalation. What would be the result, were the water, thus sent up, to revert immediately to the bosom of the deep? Barrenness would spread over the earth, and the race of animals, robbed of sustenance, would die. But witness the provision. The clouds of the ocean are charged with the same electricity as the ocean itself, and consequently are repelled by it. The vesicular form of the vapor is maintained, and the buoyant clouds float over the sea to the most distant shores, there to be drawn down by hills and mountains, to spread fertility over the land—again to be gathered by the universal slope to the parent ocean; and thus to pursue the magnificent circle of changes, until the power which ordered them shall bid them cease.

Another interesting phenomenon, connected with the precipitation of atmospheric moisture. All have seen the tum-

bler of iced water suddenly covered with moisture on a warm summer's day. This is the vapor of the atmosphere condensed by cold. So the earth is cooled more rapidly than the air, when the sun has gone down, and becomes a condensing body. The dews descend. But who has not been charmed with that beautiful provision made for the living world, as he has walked abroad in the early spring morning, and beheld each spire of grass, and every leaf pendant and dripping with the dews of the night, while the dry earth, which needed it not, had imbibed but little of the refreshing moisture? The living vegetables are better radiators of heat—they give up their caloric more rapidly, than the dry, hard earth, and hence the dew is distilled more richly upon them. The law is as simple, as the phenomenon is beautiful; and in all this, how exquisite is the adaptation of the cause to the effect!

Water is universal; but it is the only beverage universally relished—the best adapted to allay thirst. It is more grateful to the sick man's palate, than the choicest wines. The first and the last cry of the patient parched with fever, is for cold water. The weary traveller, in a thirsty land, famished and ready to expire, would give kingdoms for a drop of cold water. Water is the emblem of purity. The waters were troubled to heal the sick at the pool of Siloam. Next to pure air, who does not rank cold, gushing, living water, at the head of earthly comforts? The most common, it is the most necessary—the most precious, it is the most free, of all the goods of life. Laws entail other property; water is the property of all. The covetous man adds acre to acre, until his domain is measured by leagues; and the ambitious man conquers nation after nation, until his sceptre gives law to a continent; while his poor subject commands him only enough of mother earth to conceal his ashes when he dies. Not so water. The meanest slave enjoys a competency of it; the proudest monarch can enjoy no more. A bountiful Providence has made it free as the air, or as sunshine, and sends his rain alike upon the just and the unjust.

Water it has been stated evaporates perpetually at every temperature. But the evaporation is in the direct ratio of the heat; and hence in warm climates it is much more copious than in cold. It is most abundant in tropical countries, where it answers the beautiful end of mitigating the intense fervor of the sun—less copious at the poles, which have no heat to spare, and which would be impoverished, and made more inhospitable, by the process.

The mode of its descent differs equally in the two regions. At the poles, it comes down in a gentle, almost perpetual mist, and warms the air by its condensation and fall. If it fell thus in hot climates, the continual clouds would check evaporation, and render the air intolerably sultry; the rains falling slowly would sink into the earth, and vegetables by the excessive humidity would rot before they ripened; and the face of the country in such quarters would be converted into an extended marsh, exhaling every fetid and poisonous effluvium, a fit residence only for lizards and aquatic animals. But there it descends in sudden, drenching showers, running rapidly away; the clouds soon dispersing, and the sun breaking out in power, to renew the process of evaporation, dissipate the useless moisture, and refresh and cheer the inhabitants with an elastic atmosphere.

The specific gravity of water is precisely that which fits it for the numerous offices it must perform, in the present constitution of things. As the result of it, it floats the seeds of vegetables to plant new colonies upon remote continents and islands, extending thus the dominions of the living world. The ocean too is whitened with the sails of commerce; human enterprise, and the light of science are extended to every quarter of the globe, and civilization and the arts are spread as far as there are winds to waft or waves to roll them. Fruitfulness is brought down from the mountains, and spread over vallies and plains for the use of the husbandman. A home, adapted to their forms, answering to all their wants, is furnished for the myriads of aquatic animals which swim upon its surface, or glide swiftly through its waves. Increase

its density, as to that of quicksilver, for example, and ships of iron with platinum for ballast alone could navigate it in safety. Or make it lighter, and the light canoe would not float upon it, and the splendid barque that now "walks the water like a thing of life," would be engulphed and lost beneath its waves.

One of the most admirable laws of water is, that it freezes. This subserves a hundred most important purposes. Water gives out heat in freezing, and thus in the coldest quarters of the globe, as it is congealed by frost, it is liberating vast volumes of caloric, and the process of congelation is in this way counteracted, and at last arrested, by the heat which itself sets free. Freezing is a warming process. Every fall of snow, it has been computed, imparts more heat to the atmosphere than would be afforded by the same quantity of pulverized red hot glass. But evaporation is a cooling process. Extended oceans spread their bosoms to the sun, in equatorial regions, and the vapor which they send up tempers the fervor of his vertical rays. It is borne along to the north by the upper current in the air, and descending in the form of sleet or snow, sets at liberty the heat which it absorbed in the south. Thus by the same splendid operations which cool the temples of the children of the sun, are the horrors of the polar winter softened and made supportable. The aurora-borealis, the glory of northern climates, is also an effect of the same arrangement. The electricity which is transfered thither in combination with the vapor, descending with the caloric and accumulating upon the ice at the poles, at last breaks through the atmosphere into the vacuum above, and in hastening back towards the tropics gives out light to cheer the long winter nights of those regions.

Other advantages grow out of the congelation of water, and the circumstances which attend this process. Most bodies grow smaller as long as they continue to grow colder, contracting when they freeze. Water is of a smaller class which obey another law; a law fruitful in most beneficent consequences. It expands in freezing; by which we see bottles holding it

broken; tubes conducting it bursted; and the strongest metals confining it riven asunder. Mark, then, the operation of this law. The earth, after receiving the rains of autumn, is congealed by the winter's frost. The water in it being expanded, the soil is pulverized, and made light, and prepared for the roots of the tender, growing vegetables in spring. But more. Ice, as a consequence of it, forms first on the surface of our rivers and streams. The intestine motion which goes on in water when subjected to a change of temperature ceases at a particular point. Cooled down to 40° of Fah., it attains its maximum density; and as the cooling proceeds, those particles which are reduced below this point float upon the surface, being lighter, and finally arriving at 32°, are frozen. In the mean time the warmer water below being heavier, remains at rest; its heat being in some degree kept in by the covering of ice above. Did water continue to grow heavier, as it became colder, until it arrived at the freezing point, a cake of ice would form first at the bottoms of our rivers; the whole of their waters would be reduced to the point of freezing before congelation began; and their fish by affording a nucleus would be among the first objects to be incarcerated by the hardening ice. The cold of a few nights would congeal deep rivers, and the ice lying far below, would not be softened by the returning suns of summer. The inhabitants of water would perish. Coasts would cease to afford, as now, the most genial climates and luxurious homes.

So much turns upon the simple law, that water grows lighter before attaining the point of congelation, and expands in freezing.

Water freezes at the right temperature. Alcohol has never been frozen by the cold of the polar winter, or by the most intense freezing mixture. Suppose such was the law of water. We should indeed have frozen oceans no longer, and the explorer of northern seas would find a liquid surface as far as there were winds to propel his barque. But we should have rains much colder than ice or snow,—rains that would sink

the thermometer to zero—that falling upon the earth and penetrating the soil, would chill it beyond what the heat of returning summer could restore, and blight and destroy the seeds and roots of all vegetation.

But now, reduced to the temperature of 32°, it loses its liquid form, gives its latent heat to the ambient atmosphere, and descending as fleecy snow, throws around the earth a mantle which shields it from the more intense degrees of cold. For snow is a very imperfect conductor of caloric. The earth is often little lower than 32°,—of the temperature merely of ice—while the air is 50° below zero.

But inconceivable disasters would flow from its easier congelation. The cold of a night might arrest commerce—the wide ocean would be covered with ice, our springs cease to run in winter, and a solid crust bind up the earth where now the plough of the husbandman finds a pulverized and genial soil ready to receive the seeds of the future harvest.

No common liquid undergoes ebullition at the same temperature with water. Ether boils at 98°, alcohol at 175°, mercury at 650°, water at 212°. If it boiled at 98° with ether, we should be frozen in mid-summer, as we freeze water by the evaporation, in other words, by the boiling, of ether under the exhausted receiver of the air pump. If it boiled, with alcohol at 175°, still the earth and our bodies would be too much cooled by the rapid evaporation; while we should be forced every day to complain, with the Augustine Monks on the great St. Bernard, that the water could not be made hot enough to prepare our soup. But if instead of boiling at these reduced temperatures, it reached the point at which mercury boils, before ebullition commenced, it would disorganize and destroy all materials of aliment, and become useless as a culinary agent.

But, although the boiling point of water is so much below that of mercury, its capacity for heat is about thirty times as great. Thirty times as much heat is necessary to raise water to 212° as to bring mercury up to that point, and consequently water is

heated thirty times more slowly than that liquid. In boiling, water combines with much heat which becomes latent, and is not appreciated by the thermometer.—Ice in melting does the same. Hence the boiling of water, and the melting of ice, are processes which go on slowly. Were the law otherwise, and did not the great capacity of water for caloric exist, when it became heated up to 212°, it would instantly flash into steam, and no boiler, however powerful, would be able to prevent an explosion. And in like manner ice would instantly liquify, when it was raised to the temperature of 32°. Instead, as now, of softening gradually under the increasing heat of spring, the accumulated snows of winter would be melted by the heat of a single day, and pour down from hills and mountains in wide-wasting inundations.

The science connected with the freezing and liquifaction of water, its evaporation, boiling, and capacity for heat, is curious and instructive beyond that of almost any other department of nature. If I have failed to make it clear in these remarks, the consolation is left us, that the subject will be resumed and treated at greater length, at a future period of our course. We pass on to other properties of water.

As a drink for animals and man, and for most common purposes, it was necessary that water should be free from active foreign ingredients. But the ocean abounds in salts, and for the wisest of ends. One of them, the ordinary condiment of man, is indispensable to the comfort and the very existence of a large class of animals, deprived of which their bodily powers decline, and they droop and finally die of loathsome diseases. The immense store-house provided in the bosom of the deep can never be exhausted. Water becomes vapour and rises. The salt, more fixed in its nature, remains behind. The cloud as it ascends from the surface of the ocean bears limpid, tasteless water. But there is this further advantage in the present constitution of the sea. The countless rivers which disembogue in it, bearing upon their bosom, from cities and forests every form of destructible matter, but for some counteracting principle would con-

vert its waters into a mass of putrefaction more pestilent than the Dead Sea, diffusing stench and disease throughout the whole extent of the atmosphere. Salt is this antiseptic. It resists the tendency to putrefaction, and preserves its waves pure and untainted. Thus the sea, perpetually the recipient of corruption, is perpetually giving back to the earth and the atmosphere water free from taint or adulteration.

Another end is attained by this constitution. The ocean would freeze but for the presence of its salts, and thus commerce would be compelled to fold her wings for half the year; the temperature of maritime countries would be greatly reduced; the dominions of frost would be extended, and sterility would gradually stretch its withering arms over what are now the fairest portions of the earth.—But its salts also confine the ocean to its bed, restrain its proud waves and appoint the limits beyond which they may not go. If otherwise, its waters must have penetrated and filled every cavity of the earth, polluted all our springs, and, far, as now when wisely restrained, from being a blessing, have grown into a momentous evil.

It has been observed that but for the presence of water in the atmosphere animals could not respire it, and we have seen that the air is continually receiving moisture from every sea, and river, and lake and humid surface, in every climate, and at every temperature. But atmospherical air is equally indispensable to the perfection of water. Without it, it would be a less agreeable beverage, and an unfit dwelling for its countless inhabitants. Its fish would as speedily perish as if removed from their native element; which may easily be shown by immersing them in recently boiled water, or that which has been deprived of its air by the exhausted receiver. Hence if a pond be frozen over in winter its fish die for the want of the vital fluid; and if an opening be made in the ice before the catastrophe occurs they collect about it in numbers, as the unfortunate human beings in the Black Hole of Calcutta crowded to the narrow window of their ship,

each struggling to gain a breath of refreshing air. Hence also the reason why these animals congregate about the rapids in our streams, where the agitated water has imbibed more copiously of the atmosphere—a fact well known to the experienced angler. And hence the cause of the long journeys which certain tribes of fish perform, impelled by the instinct for preserving their offspring, stemming the current and leaping over cataracts and dams, to deposite their eggs upon shallows and heaps of gravel as near as possible to the source of the stream, where the water is most fully combined with air. And why other tribes again, inhabiting deep and still waters, commit their eggs to the care of aquatic plants, which by the influence of solar light constantly preserve the water in a state of aeration;—movements which, while they exhibit the unerring nature of instinct, impress forcibly upon us the wisdom with which water has been formed in reference to living beings.

In a word, what offices does not water perform, or aid in carrying forward? It is the vehicle for electricity and odors, and regales us with fragrance; the solvent of our aliments, and thus enables us to taste; it refracts light in its passage through the eye, and hence contributes to the perfection of vision; it gives the deep blue to the vault of the heavens, and thus the glory of the firmameut; it imparts fluidity to the blood, and thus continues the ever-ceaseless motion of the vital current. Plain and vulgar as it has become by long familiarity, how rich in philosophy do we find it when closely analysed—how wide and wonderful its agency in nature—in all its phases how beautiful, and how full of proof of the wisdom and beneficence of its Author!

We have thus glanced at a few of the qualities of air and water, and for all the ends of their creation, find them perfect—abounding in evidences of design, exhibiting contrivances so wise, and harmonies so exquisite, that in their full light one would think the sturdiest skepticism must yield. A hasty examination into the most prominent chemical attributes of the earth will complete the plan of this discourse.

It is plain that the earth was created as a dwelling place for living beings—the two great races, animals and vegetables; the last and lower to minister to the comfort and happiness of the higher. A being guided by wisdom and prompted by benevolence in the creation of the world would select those elements most conducive to the enjoyment of his sentient and rational creatures. How far is it fitted to this purpose? Could better materials have been employed or more judiciously arranged? Its physical configuration, the flattening of its poles, its obliquity to the ecliptic, to which we owe the delightful variety of the seasons, its mountains and vallies and its universal slope towards its oceans, forming the beds of rivers and tracks for inland commerce, and for conducting the excess of its waters to the parent bed, all this is passed over, though abundant in proof of an agency equally wise, powerful and good, as belonging rather to physical geography than to chemistry.

The solid crust of the globe consists principally of sand, clay and lime, long considered simple bodies, now treated of in books of chemistry as oxides of metals. Out of no other substances with which we are acquainted, could a world so perfect have been formed. Clay is tenacious, insoluble and retentive of moisture. It is the basis of every good and lasting soil, supporting the rich vegetable mould, and retaining water and the food of plants within their reach. In a soil destitute of clay, these principles sink through its porous body, and recede beyond the roots of growing vegetables, and for lack of nutriment they languish and die. To the same quality of clay, we owe also our springs and wells of water, for which it forms an impermeable foundation, as with lime and sand, the solid bottoms of brooks and rivers.

But silex qualifies the tenacity of clay, which if pure, the tender roots of vegetables could not penetrate, nor could water follow them to supply the necessary moisture. With silex it is perfect, neither too bibulous and dry, nor too retentive of water. Into this compound, the nutritive principles of the soil easily subside—not hastily to descend too

deep, or be evaporated, as they would in sand--nor be retained to the detriment of the growing plant, as they would in a bed of clay. When to this two-fold partnership we add lime, we have a soil the most favorable to the growth of vegetables;—and this is just the composition of the soil in the most fertile and favored regions of the earth.

Of the fifty two elements known, about forty are metals, and contribute to the solid crust of the globe. But an equal diffusion of these would be worse than a useless expenditure. As they are constituted, it would be a source of infinite disorder. Accordingly we find that they exist for the most part in small quantities, and being many of them virulent poisons, are so qualified in their native state as to be insoluble and harmless. Copper and arsenic, and even gold and silver, if generally diffused through the earth, and in a state, to be dissolved by water would mingle poison with all our drinks.

But there is one metal, without which, society could never have become highly refined—art could not have acquired its efficiency, nor science its elevation—without which fields could not have been successfully tilled, nor seas skilfully navigated. This I need scarcely say, is iron—the cheapest, the most valuable of the class; diffused more widely than the races of men; blended with every soil; piled up in mountain masses; entering into all the processes of life—the hardest, the toughest; naturally the plainest and least showy, but susceptible of the highest lustre—which alone with the flint strikes fire—which, (the touching emblem of man's own social and dependent nature) when broken asunder can be united again with its former strength; by which the mariner in the storm, in the darkness of night, and in the midst of unknown seas, guides his struggling bark in safety to the distant port; and, to crown its radiant catalogue of virtues, the only one which, in all its forms, is safe and friendly to the economy of man—making one of the constituents of his blood, and for his health "gushing in a thousand springs."

In a point of view not yet presented, the light of chemistry

is eminently instructive. As we look around upon the world, we see that change is written upon all things earthly.

"——— Day follows night, and night
The dying day; stars rise and set, and rise;
Earth takes the example; tis revolution all."

Flowers blossom but to fade. The leaves of summer fall before the chilling winds of autumn. But chemistry teaches that what seems annihilation in all this is but a change of form, and that in following seasons the same elements, once possessed of life, will be combined anew, and bud and blossom in a renovated and more perfect shape. The race that expires, having marked the circle appointed by the Creator, prepares the bed in which a new generation springs up to regale the air and the earth with their beauty and their fragrance, and then give place in turn to other generations. Chemistry teaches that the dew-drop that glitters in the sun, and the passing cloud, and the morning mist, very emblems of evanescence and decay, though they vanish after a little season yet are not lost, but reappear in another type to endure as long as the moon and stars. Every drop of water that existed when the ocean was gathered into its place, is in existence now, either locked up in solid crystal, or floating in the cloud or mist, or concreted in the bodies of animals or vegetables, or congealed into ice or snow, or flowing in rivers, or piled up in the depths of the sea. Matter cannot be destroyed unless by that power which gave it being. Finite power can but change its form. The fire which in cheering the social hearth, seems burning to destroy, is only transforming matter into new shapes. Thus the pit coal, the remains, it may be, of the plants of an antediluvian world, and which for thousands of years has retained the elements of life locked up within it, gives them out once more under the influence of combustion. Its carbon uniting with the oxygen of the atmosphere, assumes an aerial form, and its hydrogen combining with the same principle ascends in the form of invisible exhalation. This stream of vapor is gradually condensed into clouds and falls to the earth in fructify-

ing showers; and the carbonic acid gas, by other chemical agencies is also brought down again, to hasten the growth of vegetables, enter into their systems, expand in their leaves, paint the gorgeous tints and go abroad in the aroma of their flowers. What more beautiful than such a series of changes? The plants which adorned the earth in its early freshness, having slumbered for ages in lifeless masses of coal, again made active, and after warming in the fire, and cheering in the brilliant gas-light, and, as the generator of steam, setting a thousand wheels in motion for the maintenance of our race, recalled once more to the living world, to an appointed place among kindred plants, until it shall be the will of Him who created them to call them to their last repose!

In such a survey of the great operations of nature, the mind is filled with wonder that so extended a system should be so perfect in all its parts—that one mind should embrace all its details, direct all its movements, and pervade the whole with unbroken harmony.

But this wonder grows, when by aid of instruments we look into that world too small for the naked eye, and find there schemes not less beneficent, and contrivances not less admirable, than mark the higher departments of nature. The microscope reveals to us animals, full of life and motion, which to the mite are as the size of the bee is to that of the horse; others, one hundred of which would not exceed the size of a single hair; and others, of a different species, ten thousand of which are not larger than a grain of sand. The most powerful glasses unable to follow nature farther, discover only points in motion gradually decreasing until they become imperceptible to the view. Yet these animalcules enjoy every variety of motion; receive food, grow, and decay, feel pleasure and pain, engage even in the business of murderous war; and must therefore have organs of digestion and locomotion; absorbents for the waste and growth of their bodies, and nerves to connect them with the world in which they live. But our senses can carry us no farther, and we are left to conjecture. Its objects infinitely multiplied, infinitely

reduced in size, even the imagination fails to compass. No limits can be affixed to that world, the objects of which are multiplied to an extent which in the poverty of language we call infinite—in their number and size beyond the power of imagination to conceive. But the contrast has not yet been fully exhibited. Our earth seems vast. Its population is almost beyond number. Its mountains out-top the clouds. Its multiplied objects, its countless phenomena, its curious laws, no human genius has been found mighty enough to comprehend and arrange. But, besides our earth, belonging to the solar system, astronomy informs us there are six other planets. One of these, Jupiter, is twenty times larger than our orb, requiring twelve of our years to perform his journey round the sun. The sun, ninety millions of miles from us, is eight hundred times as far from Saturn, and twice that mighty distance from Uranus.

These orbs, with the sun, fill up in space, an area of five thousand millions of miles. But this is a small section of the heavens. The fixed stars number not less than one hundred thousand, the nearest one of which is two hundred thousand times farther from us than the sun. But it is supposed that the most powerful telescopes reveal only a few of that host which with emphasis has been called countless—that the Milky Way may be a cluster of stars so distant, that their blended light makes but a luminous track in the heavens. These stars have all motions. They have all a luminous fluid, which, in character, is like that of the sun. A few of them, in distant ages, have shone out with uncommon splendor, and then grown dim, as if some destructive conflagration had swept over their surface.

Now analogy points strongly to the inference, that each one of these fixed stars, mere shining points, or too distant to be viewed by the naked eye, may be a central sun, like ours, with planets revolving around it. Each sun, with its planetary system, may occupy a space as great as that which belongs to ours, and thus have we five thousand million of miles of space multiplied by one hundred thousand.

But analogy permits us to go farther and suppose that this stupendous array of systems, that our luminary, and the one hundred thousand other suns, which tell only by their feeble glimmering the simple fact of their existence—that these are but planets of some common centre—some orb in the illimitable regions of space of such vast dimensions, that the sun of our world bears no greater proportion to it, than does the smallest satellite in our system to that glorious orb. And these suns, with the innumerable planets which attend them, may be the homes of human beings constituted as we are—shone upon by genial lights—enjoying the same magnificent prospects—and exulting in the goodness of the same beneficent Creator. By the side of such a multitude of systems, our world with all its splendid schemes, its wise and curious laws, and teeming population, sinks into insignificance. It is no exaggeration to say with one of the most eloquent of living writers, "that the glories of an extended forest would suffer no more from the fall of a single leaf, than the glories of this extended universe would suffer, though the globe we tread, and all that it inhabit, were dissolved."

But the mind which planned, is mighty to preserve. The hand which spans the heavens, stoops to clothe the lilly of the vallies. A sparrow cannot fall to the ground without His knowledge. And the hairs are all numbered on the head of the meanest pauper, who would hardly attract our passing notice in the streets, and whose death-knell would occasion no more sensation among all the sons of men, or a longer pause from their callings, than does the sound of that clock which we scarcely hear in the round of daily business.

Thus does the imposing splendor of astronomy unite with the milder but not less steady light of chemistry, in reflecting honor upon the omniscient author of its laws; and thus, as leaf after leaf in the volume of nature shall be turned over, as fact after fact shall be added to the pyramid of science, until its summit shall have reached the heavens—when every stream shall have been traced out to its end, then will each tributary be found swelling the ocean of truth, and the voices of all

will unite at last in one grand chorus of praise to Him, whose works, whether above or below, on a scale stupendously great or infinitely small, exhibit an adjustment equally perfect, an arrangement equally wise, and results equally harmonious.

In this way does science improve the temper of the mind and raise it from grosser objects to the contemplation of a scheme of things all-perfect and beautiful. Thus intellect supplies food to the affections, and the mind, as it expands by the increase of knowledge, rises in dignity, and grows strong in virtue.

The view which we have now taken of the scheme of nature, as exhibited by the science in which it is made my business to lead your studies for the next few months, recommends itself to us not the less, by impressing us with sentiments of humility—humility, in view of the exceeding smallness of our highest possible attainments, in comparison with the vast ocean which spreads out before us, and which must remain forever unexplored and unknown, and in view of how small an atom we form amid the myriads of human beings in which we are lost, even in this world, and the still more countless millions who probably people the worlds which circulate in celestial space. But it affords ground for gratitude also, that we were permitted to be the tenants of so fair a world; that winds and waves have been made to labor for our good; that seed-time and harvest return at the bidding of lovely seasons; that water and air, fire and earth are constituted to be sources of our ceaseless gratification; that with senses so responsive to pleasure, we have been endowed with minds capable of holding such large discourse with nature; that at every moment of our restless history, in the vigor of manhood and in the weakness of infancy, amid suns and systems, the small speck that we are, our footsteps have been watched with parental kindness; and that our happiness has been studied in all the plans of this vast Universe.