TYNDALL'S LAST LECTURE.

THE PROGRESS OF STUDIES IN THE PHENOMENA OF LIGHT.

What the Impractical Scientist has Discovered and the Practical Man has Utilized—An Interesting Survey of the Six Great Lectures—Brilliant Experiments.

The usual swarm of carriages stood around the Cooper Institute last evening, and a survey of the hall showed nothing but faces from the desk to the remotest corner. At 8 o'clock Prof. Tyndall, as punctual as a revolving planet, stepped on the platform, placed his hands on the table before him, and leaning thus began his discourse. In a short time the hall was in a state of almost total darkness, with a piece of bright rainbow on the wall behind the speaker. The Professor said:

We have employed as our source of light in these lectures the ends of two rods of coke rendered incandescent by electricity. The coke is particularly suitable for this purpose, because it can bear intense heat without fusion or vaporization. It is also black, which helps the light; for other circumstances being equal, as shown by Balfour Stewart, the blacker the body the brighter will be its light when incandescent. Still, refractory as carbon is, if we closely examined our voltaic arc, or stream of light between the carbon points, we should find there incandescent carbon vapor. We might also detach the light of this vapor from the more dazzling light of the solid points, and obtain its spectrum. This would be not only less brilliant, but of a character totally different from the spectra that we have already seen. Instead of being an unbroken succession of colors from red to violet, the carbon vapors would yield a few bands of color with spaces of darkness between.

THE THALLIUM TEST.

What is true of the carbon is true in a still more striking degree of the metals, the most refractory of which can be fused, boiled, and reduced to vapor by the electric current. From the incandescent vapors the light, as a general rule, flashes in groups of rays of definite degrees of refrangibility, spaces existing between group and group which are unfilled by rays of any kind; but the contemplation of the facts will render this subject more intelligible than words can make it. Within the camera is placed a cylinder of carbon hollowed out at the top to receive a bit of metal; in the hollow a fragment of the metal thallium, and now you see the arc of vapor with that of thallium. Here are two green bands instead of one. Adding to the silver in our camera a bit of thallium we obtain the light of both metals, and you see that the green of the thallium lies midway between the two greens of the silver. Hence this similarity of color. But you observe another interesting fact. The thallium band is far brighter than the silver bands; indeed, the latter has wonderfully degenerated since the bit of thallium has been put in. They are not at all bright as they were at first, and for a reason worth knowing. It is the resistance offered to the passage of the electric current from carbon to carbon that calls forth the power of the current to produce heat. If the resistance were materially lessened the heat would be materially lessened, and if all resistance were abolished there would be

NO HEAT AT ALL.

Now thallium is a much more fusible and vaporizable metal than silver; and its vapor facilities the passage of the current to such a degree as to render it almost impossible to vaporize the silver. But the thallium is gradually consumed; its vapor becomes less and less; the resistance rises, until finally you see the two silver bands as brilliant as they were at first. The three bands of the two metals are now of the same sensible brightness.

We have in these bands a perfectly unalterable characteristic of these two metals. You never get other bands than these two green ones from the silver, never other than the single green band from the thallium, never other than the three green bands that you have just seen from the mixture of both metals. Every known metal has its bands, and in no known case are the bands of two different metals alike. Hence these spectra may be made a test as to the presence or absence of the metals which they represent.

If we pass from the metals to their alloys we find no confusion. Copper gives us green bands, zinc gives us blue and red bands; brass, an alloy of copper and zinc, gives us the bands of both metals, perfectly unaltered in relative character. But we are not confined to the metals; the salts of these metals yield the bands of the metals. Chemical union is ruptured by a sufficiently high heat, the vapor of the metal is set free and yields its characteristic bands.

THE CHLORIDES OF THE METALS

are particularly suitable for experiments of this character. Common salt, for example, is a compound of chlorine and sodium; in the electric lamp it yields the spectrum of the metal sodium. The chlorides of lithium and of strontium yield in like manner the bands of these metals. When, therefore, Bunsen and Kirchhoff, after having established by an exhaustive examination the spectra of all known substances, discovered a spectrum where bands did not correspond to any known bands they immediately inferred the existence of a new metal. They were operating at the time upon a residue obtained by evaporating a ton of the mineral waters of Germany. In that water they knew the new metal was concealed, but vast quantities of it had to be evaporated before a residue could be obtained sufficient to enable ordinary chemistry to make the metal manifest. But they hunted it down, and it now stands among chemical substances as the metal *rubidium*. They subsequently discovered a second metal, which they called *cæsium*. Thus, having first placed spectrum analysis on a firm foundation, they demonstrated its capacity as an agent of discovery. Soon afterward Mr. Crookes, pursuing this same method, added to the list of metals the thallium, which yielded that bright monochromatic green band.

INVESTIGATION OF THE SUN AND STARS.

This relates to chemical discovery upon earth, where the materials are in our own hands. But Kirchhoff and his associate asked whether analysis might be applied to the investigation of the sun and stars, and on his way to this result he solved a problem which had been long an enigma to natural philosophers. A spectrum is pure in which the colors do not overlap each other. We purify the spectrum by making our slit narrow and by augmenting the number of our prisms. When a pure spectrum of the sun has been obtained in this way it is found furrowed by innumerable dark lines. Four of them were first seen by Dr. Wollaston, but they were afterward multiplied and measured by Fraunhofer with such masterly skill that they are now universally known as Fraunhofer's lines. To give an explanation of these lines was, as I have said, a problem which long challenged the attention of philosophers.

Now, Kirchhoff had made thoroughly clear to his mind the principles which linked together the emission of light and absorption. Indeed, he had proved their inseparability for each particular kind of light and heat. He had proved for every specific ray of the spectrum the doctrine that the body emitting a ray absorbed with special energy a ray of the same refrangibility. Consider then the effect of knowledge such as you now possess upon a mind prepared like that of Kirchhoff.

We have seen the incandescent vapors of metals emitting definite groups of rays; according to Kirchhoff's principle those vapors if crossed by solar light ought to absorb rays of the same refrangibility as those which they emit. He proved this to be the case; he was able by the interposition of a vapor to cut out of the solar spectrum the band corresponding in color to that vapor.

THE PHOTOSPHERE OF THE SUN.

Now, the sun possesses a photosphere or vaporous envelope, doubtless mixed with violently agitated clouds; and Kirchhoff saw that the powerful rays coming from the solid or the molten nucleus of the sun, must be intercepted by this vapor. One band of Fraunhofer, for example, occurs in the yellow of the spectrum. Sodium vapor is demonstrably competent to produce that dark band; hence Kirchhoff inferred the existence of sodium vapor in the atmosphere of the sun. In the case of metals which emit a large number of bands, the absolute coincidence of every bright band of the metal with a dark Fraunhofer line raises to the highest degree of certainty the inference that the metal is present in the atmosphere of the sun. In this way solar chemistry was founded on spectrum analysis.

I have now to make plain to you, if I can, through the analogy of sound, the physical meaning of emission and absorption. I draw a fiddle bow across this tuning fork and it immediately fills the room with a musical sound; the fork. A few days ago, on sounding this fork, I noticed that when its vibrations were quenched the sound seemed to be continued, though more feebly; the sound appeared to come from under the table, where stood a number of tuning forks of different sizes and rates of vibration. One of these, and one only, had been started by the fork, and it was one whose rate of vibration was the same as that of the fork which started it. This is an instance of the absorption of the sound of one fork by the other. Placing two forks thus near each other, sweeping the bow over one of them and then quenching the agitated fork, the other continues to sound. Placing a cent piece on each prong of one of the forks, we destroy its perfect synchronism with the other, and then no communication of sound from the one to the other is possible. I will now do with light what has been here done with sound. Placing a tin spoon containing sodium in a Bunsen's flame, we obtain this intensely yellow light which corresponds in refrangibility with the yellow band of the spectrum. I will send the light from our lamp through that flame, and prove before you that the yellow flame intercepts the yellow of the spectrum, producing to all intents and purposes a dark Fraunhofer's band in the place of the yellow.

SCIENCE THE CHILD OF THE AGES.

Mutually as well as physically every age of the world is the outgrowth and offspring of all preceding ages. Science proves itself to be a genuine product of nature by growing according to this law. We have no solution of continuity here. Every great discovery has been duly prepared for in two ways; first, by other discoveries which form its prelude; and secondly, through the sharpening by exercise of the intellectual instrument itself. Thus Ptolemy grew out of Hipparchus, Copernicus out of both, Kepler out of all three, and Newton out of all the four. Newton did not rise suddenly from the sea level of the intellect to his amazing elevation. At the time that he appeared the table land of knowledge was already high. He juts, it is true, above the table land as a massive peak; still he is supported by it, and a great part of his absolute height was the height of humanity in his time. It is thus with the discovery of Kirchkoff. Much has been previously accomplished; this he mastered, and then by the force of individual genius went beyond it. He replaced uncertainty by certainty, vagueness by definiteness, confusion by order; and I do not think that Newton has a surer claim to the discoveries that have made his name immortal that Kirchkoff has to the credit of gathering up the fragmentary knowledge of his time, of vastly extending it, and of infusing into it the life of great principles.

SPLENDID RESULTS.

Splendid results have since been obtained, in relation to which both England and America have played an honorable part; but splendid as they are, they are but the sequel and application of the principles established in his Heidelberg laboratory by the German investigator.

I have now come almost to the end of my task in this city, and, indeed, in America. My desire has been to show you, with as little breach of continuity as possible, the past growth and present aspect of a department of science in which have labored some of the greatest intellects the world has ever seen. My friend, Prof. Henry, in introducing me at Washington, spoke of me as an apostle; but the only apostolate that I intended to fulfil was to place, in plain words, my subject before you, and to permit its own intrinsic attractions to act upon your minds. In the way of experiment, I have tried to place before you the best which, under the circumstances, could be provided; but I trust that each experiment has had a distinct intellectual value, for experiments ought to be the representatives and expositors of thought—a language addressed to the eye as spoken words are to the ear. In association with its context, nothing is more impressive or instructive than a fit experiment; but, apart from its context, it rather suits the conjurer's purpose of surprise than that purpose of education which ought to be the ruling motive of the scientific mind.

THE GREAT LECTURES SUMMARIZED.

And now a brief summary of our work will not be out of place. Our present mastery over the laws and phenomena of light has its origin in the desire of man to know. We have seen the ancients busy with this problem; but, like a child who uses his arms aimlessly for want of the necessary muscular exercise, so these early men speculated vaguely and confusedly regarding light, not having as yet given the discipline needed to give clearness to their insight and firmness to their group of principles. They assured themselves of the rectilineal propagation of light, and that the angle of incidence was equal to the angle of reflection. For more than a thousand years—it might say, indeed, for more than fifteen hundred years subsequently—the scientific intellect appears as if smitten with paralysis, the fact being that, during this time, the mental force, which might have run on in the direction of science, was diverted into other directions.

THE ARABIAN PHILOSOPHER'S INVESTIGATION.

The course of investigation as regards light was resumed in 1100 by an Arabian philosopher named Alhazan. Then it was taken up in succession by Roger Bacon, Vitello, and Kepler. These men, though falling to detect the principle which rules the facts, kept the fire of investigation constantly burning. Then came the fundamental discovery of Snell, that corner-stone of optics, as I have already called it, and immediately afterward we have the application by Descartes of Snell's discovery to the explanation of the rainbow. Then came Newton's crowning experiments on the analysis and synthesis of white light, by which it was proved to be compounded of various kinds of light of different degrees of refrangibility.

In 1676 an impulse was given to optics by astronomy. In that year Olaf Roemer, a learned Dane, was engaged at the Observatorys of Paris in observing the eclipses of Jupiter's moons. He converted them into so many signal lamps, quenched when they plunged into the shadow of the planet, and relighted when they emerged from the shadow. They enabled him to prove that light requires time to pass through space, and to assign to it the astounding velocity of 140,000 miles a second.

BRADLEY'S DISCOVERY.

Then came the English astronomer, Bradley, who announced that the fixed stars did not really appear to be fixed, but described in the heavens every year a little orbit resembling the earth's orbit. The result perplexed him, but Bradley had a mind open to suggestion, and capable of seeing, in the smallest fact, a picture of the largest. He was one day upon the Thames in a boat, and noticed that as long as his course remained unchanged the vane upon his mast-head showed the wind to be blowing constantly in the same direction, but that the wind appeared to vary with every change in the direction of his boat. "Here," as Whewell says, "was an image of his case. The boat was the earth, moving in its orbit, and the wind was the light of a star." You will immediately understand the meaning of Bradley's discovery. Imagine yourself in a motionless railway train with a shower of rain descending vertically downward. The moment the train begins to move the rain drops begin to slant, and the quicker the train the greater is the obliquity. In a precisely similar manner the rays from a star vertically overhead are caused to slant by the motion of the earth through space. Knowing the speed of the train, and the obliquity of the falling drops, the velocity of the drops may be calculated; and, knowing the speed of the earth in her orbit, and the obliquity of the rays due to this course, we can calculate just as easily the velocity of light. Bradley did this, and the "aberration of light," as his discovery is called, enabled him to assign to it a velocity almost identical with that deduced by Roemer from a totally different method of observation.

NEWTON'S TRIUMPHS.

Up to his demonstration of the composition of white light, Newton had been everywhere triumphant—triumphant in the heavens, triumphant on the earth, and his subsequent experimental work is for the most part of immortal value. But infallibility is not the gift of man, and soon after his discovery of the nature of white light, Newton proved himself human. He supposed that refraction and dispersion went hand in hand, and that you could not abolish the one without at the same time abolishing the other. He maintained this opinion to the end of his life, and thus retarded the progress of subsequent discovery. Dollaud at length proved that, by combining together two different kinds of glass, you might abolish the color and still leave a residue of refraction; and he applied this residue to the construction of achromatic lenses—lenses which yield no color, which Newton thought an impossibility. But Newton committed a graver error than this. Science, as I sought to make clear to you in our second lecture, is only in part a thing of the senses.

THE ROOTS OF PHENOMENA.

The roots of phenomena are embedded in a region beyond the reach of the senses, and less than the root of the matter will never satify the scientific mind. We find, accordingly, in this career of optics the greatest minds constantly yearning to pass from the phenomena to their causes—to explore them to their hidden roots. They thus entered the region of theory, and here Newton, though drawn from time to time toward the truth, was drawn still more strongly toward the error, and made it his substantial choice. His experiments are imperishable, but his theory is dead. For a century it stood like a dam across the course of discovery; but, like all barriers that rest upon authority and not upon truth, the pressure from behind increased, and eventually swept the barrier away. This, as you know, was done mainly through the labors of Thomas Young, and his illustrious French fellow worker, Fresnel.

A FRENCH PHILOSOPHER'S DISCOVERY.

In 1808, Malus, looking through Iceland spar at the sun reflected from the window of the Luxembourg Palace in Paris, discovered the polarization of light by reflection. In 1811 Arago discovered the splendid chromatic phenomena which we have had illustrated by plates of gypsum in polarized light; he also discovered the rotation of the plane of polarization by quartz-crystals. In 1812 Seebeck discovered the polarization of light by tourmaline. That same year Brewster discovered those magnificent bands of color that surround the axes of biaxal crystals. In 1814 Wollaston discovered the rings of Iceland spar. All these effects, which, without a theoretic clue, would leave the human mind in a hopeless jungle of phenomena without harmony or relation, were organically connected by the theory of undulation. The theory was applied and verified in all directions, any being especially conspicuous for the severity and conclusiveness of his proofs.

AN IRISH PHILOSOPHER'S DISCOVERY.

The most remarkable verification fell to the lot of the late Sir William Hamilton of Dublin, a profound mathematician, who, taking up the theory where Fresnel had left it, arrived at the conclusion that at four special points at the surface of the ether-wave in double refracting crystals the ray was divided not into two parts, but into an infinite number of parts, forming at these points a continuous conical envelope instead of two images. No human eye had ever seen this envelope when Sir William Hamilton inferred its existence. Turning to his friend Dr. Lloyd, he asked him to test experimentally the truth of his theoretic conclusion. Lloyd taking a crystal of arragonite, and following with the most scrupulous exactness the indications of theory, cutting the crystal where theory said it ought to be cut, observing it where theory said it ought to be observed, he found the luminous envelope which had previously been a mere idea in the mind of the mathematician.

But while I have thus endeavored in these lectures to illustrate before you the power of

THE UNDULATORY THEORY

as a solver of all the difficulties of optics, do I therefore wish you to close your eyes against any evidence that may arise against it? By no means. Science cannot shrink from the contemplation of truth because it may be for the moment disagreeable. You may urge, and justly urge, that a hundred years ago another theory was held by the most eminent men, and that, as the theory then held had to yield, the undulatory theory may have to yield also. This is perfectly logical, but let us understand the precise value of the argument. In similar language a person in the time of Newton, or even in our own time, might reason thus: "Hipparchus and Ptolemy, and numbers of great men after them, believed that the earth was the centre of the solar system. But this deep-set theoretic notion had to give way, and the theory of gravitation may, in its turn, have to give way also." This is just as logical as the first argument. Wherein consists the strength of the theory of gravitation? Solely in its capacity to account for all the phenomena of the solar system. Wherein consists the strength of the theory of undulation? Solely in its competence to disentangle and explain phenomena a hundred fold more complex than those of the solar system. Be as skeptical as you like regarding the undulatory theory; if your skepticism be philosophical, it will wrap the theory of gravitation in the same or greater doubt.

Nevertheless, this great theory of undulation, like many another truth, which in the long run has proved a blessing to humanity, had to establish, by

HOT CONFLICT,

its right to existence. Great names were arrayed against it. It had been enunciated by Hooke, it had been applied by Huyghens, it had been defended by Euler. But they made no impression; and indeed the theory in their hands was more an analogy than a demonstration. It took the force of proof to demonstrated verity in the hands of Thomas Young. He brought the waves of light to bear upon each other, causing them to support each other and to extinguish each other at will. From their mutual actions he determined their lengths, and applied his determinations in all directions. He showed that the standing difficulty of polarization might be embraced by the theory. After him came Fresnel, whose transcendent mathematical abilities enabled him to give the theory a generality not attained by Young. He grasped the theory in its entirety; followed the ether into its eddies and estuaries in the hearts of crystals of the most complicated structure, and into bodies subjected to strains and pressures. He showed that the facts discovered by Malus, Arago, Brewster, and Biot, were so many ganglia, so to speak, of his theoretic organism, deriving from it sustenance and explanation. With a mind too strong for the body with which it was associated, that body became a wreck long before it had become old, and Fresnel died, leaving a name behind him immortal in the annals of science.

FRESNEL'S RECOGNITION OF YOUNG.

One word more I should like to say regarding Fresnel. There are things, ladies and gentlemen, better even than science. There are matters of the character as well as matters of the intellect, and it is always a joy to those who wish to think well of human nature, when high intellect and high character are combined. They were, I believe, combined in this young Frenchman. In those hot conflicts of the undulatory theory he stood forth as a man of integrity, claiming no more than his right, and ready to concede their rights to others. He at once recognized and acknowledged the merits of Thomas Young. Indeed, it was he and his fellow countryman Arago who first startled England into the consciousness of the injustice done to Young in the *Edinburgh Review*. I should like to read you a brief extract from a letter written by Fresnel to Young in 1824, as it throws a pleasant light upon the character of the French philosopher:

"For a long time," says Fresnel, "that sensibility, or that vanity, which people call love of glory, has been much blunted in me. I labor much less to catch the suffrages of the public than to obtain that inward approval which has always been the sweetest reward of my studious labors. Amidst the difficulties and discouragement, I have often needed the spur of vanity to excite me to pursue my researches. But all the compliments I have received from Arago, De la Place, and Biot, never gave me so much pleasure as the discovery of a theoretic truth, or the confirmation of a calculation by experiment."

This, ladies and gentlemen, is the core of the whole matter as regards science. It must be cultivated for its own sake, for the pure love of truth, rather than for the applause or profit that it brings.

THE SCIENTISTS' INCENTIVE.

And now my occupation is gone. Still I will bespeak your tolerance for a few concluding remarks in reference to the men who have bequeathed to us the vast body of knowledge of which I have sought to give you some faint idea in these lectures. What was the motive that spurred them on? what the prize of their high calling for which they struggled so assiduously? What urged them to those battles and those victories over reticent Nature which have become the heritage of the human race? I believe firmly and strongly that not one of those great investigators, from Aristotle down to Stokes and Kirchhoff, had any practical end in view, according to the ordinary definition of the word "practical." They did not propose to themselves money as an end, and knowledge as a means of getting it. For the most part they nobly reversed this process, made knowledge their end, and such money as they possessed the means of obtaining it. We may see today the issues of their work in a thousand practical forms, but the reward thus yielded sufficient to justify if not ennoble their efforts. But they did not work for such issues; their reward was of a totally different kind. In what way different? We love clothes, we love food, we love fine equipages, we love money, and we love the power that the wealth imparted of his efforts in life justifies these efforts before all the world. In America and England more especially he is a practical man. But I would appeal confidently to this assembly whether such things exhaust the cravings of human nature? Given clothes, given food, given carriages, given money—is there no pleasure beyond what these can cover which the possessor of them would still covet?

THE JOYS OF THE INTELLECT.

The very presence here for six inclement nights of this audience, embodying, I am told, to a great extent, the mental force and refinement of this city, is a satisfactory answer to question. I need not tell such an assembly that there are joys of the intellect as well as joys of the body, or that these pleasures of the spiritual constitute the reward of our great investigators. Led on by the inexhaustible beauty of truth, through pain and self-denial they often pursued their work. With the ruling passion strong in death, some of them, when no longer able to hold a pen, dictated to their friends the results of their labors, and thus departed from them forever.

Could we have seen these men at work without any knowledge of the consequences of their work, what should we have thought of them? To many of their contemporaries it would have appeared simply ridiculous to see men whose names are known throughout the universe of science straining their attention to observe an effect of experiment almost too minute for detection. To the uninitiated they might well appear as big children playing with not very amusing toys. But, at this hour, could you watch the true investigator—your Henry or your Draper, for example—in his laboratory, unless animated by his spirit, you could hardly understand what keeps him there. Many of the objects which rivet his attention might appear to you utterly trivial; and, if you were to step forward and ask him what is the use of his work, the chances are that you would confound him. He might not be able to express the use of it in intelligible terms. He might not be able to assure you that it will put a dollar into the pocket of any human being living or to come. That scientific discovery may put not only dollars into the pockets of individuals, but millions into the exchequers of nations, the history of science amply proves; but the hope of its doing so is not the motive power of the investigator. It never can be his motive power. I know that I run some risk in speaking thus before practical men. I know what De Tocqueville says of you. "The man of the North," he says, "has not only experience but knowledge. He, however, does not care for

SCIENCE AS A PLEASURE,

and only embraces it with avidity when it leads to useful applications." I wonder whether the great historian and analyst of democratic institutions would repeat these words to-day? If so, I would ask him where, in his hopes of useful applications which have drawn you so many times together in spite of snowdrifts and biting cold? What, I would ask, are useful applications? Is man's body alone to be the object and arbiter of what is useful? Is there no nakedness of the mind to be clothed as well as nakedness of the body?—no hunger and thirst of the intellect to satisfy? Surely no two terms were ever so much distorted and misapplied with reference to man in his higher relations than these terms useful and practical. Let us expand the definitions of these terms until they embrace all the needs of man, his highest intellectual needs inclusive. It is specially on this ground of its administering to the higher needs of the intellect; it is mainly because I believe it to be wholesome as a source of knowledge and as a means of discipline, that I urge the claims of science upon your attention.

But with reference to material needs and joys, surely pure science has also a word to say. People sometimes speak as if steam had not been studied before James Watt, or electricity before Wheatstone and Morse; whereas, in point of fact,

WATT AND WHEATSTONE AND MORSE,

with all their practicality, were the mere outcome of antecedent forces, which acted without reference to practical ends. This also, I think, merits a moment's attention. You are delighted, and well, with good reason, with your electric telegraphs, proud of your steam engines and your factories, and charmed with the productions of photography. You see daily, with just elation, the creation of new forms of industry—new powers of adding to the wealth and comfort of society. Industrial England is heaving with forces tending to this end, and the pulse of industry beats still stronger in the United States. And yet, when analyzed, what are industrial America and Industrial England? If you can tolerate freedom of speech on my part, I will answer this question by an illustration. Strip a strong arm, and regard the knotted muscles when the hand is clinched and the arm bent. Is this exhibition of energy the work of the muscle alone? By no means. The muscle is the channel of an influence without which it would be as powerless as a lump of plastic dough. It is the delicate unseen nerve that unlocks the power of the muscle. And without those filaments of genius which have been shot like nerves through the body of society by the original discoverer, industrial America and industrial England would I fear be very much in the condition of that plastic dough.

A NATIONAL WANT.

At the present time there is a cry in England for technical education, and it is the expression of a true national want; but there is no outcry for original investigation. Still without this, as surely as the stream dwindles when the spring dries, so surely will their technical education lose all force of growth, all power of reproduction. Our great investigators have given us sufficient work for a time; but if their spirit die out, we shall find ourselves eventually in the condition of those Chinese mentioned by De Tocqueville, who, having forgotten the scientific origin of what they did, were at length compelled to copy without variation the inventions of an ancestry who, view than themselves, had drawn their inspiration direct from Nature.

To keep society as regards science in healthy play, three classes of workers are necessary. Firstly, the investigator of natural truth, whose vocation it is to pursue that truth, and extend the field of discovery for the truth's own sake, and without any reference to practical ends. Secondly, the teacher of natural truth, whose vocation it is to give public diffusion to the knowledge already won by the discoverer. Thirdly, the applier of natural truth, whose vocation it is to make scientific knowledge available for the needs, comforts, and luxuries of life. These three classes ought to coexist, and interact upon each other. Now,

THE POPULAR NOTION OF SCIENCE,

both in this country and in England, often relates, not to science strictly so called, but to the applications of science. Such applications, especially on this continent, are so astounding—they spread themselves so largely and unbrageously before the public eye—as to shut out from view those workers who are engaged in the profounder business of discovery.

Take the electric telegraph as an example, which has been repeatedly forced upon my attention of late. I am not here to attenuate in the slightest degree the services of those who, in England and America, have given the telegraph a power so wonderfully fitted up for public use. Assuredly they have reaped great reward, and assuredly they have received it. But I should be untrue to you and to myself if I failed to tell you that, however high in particular respects their claims and quality may be, practical men did not discover the principle of the telegraph. The discovery of the electric telegraph implies the discovery of electricity itself, and the development of its laws and phenomena. Such discoveries are not made by practical men, and they never will be made by them, because their minds are beset by ideas which, though of the highest value from one point of view, are not those which stimulate the original discoverer. The ancients discovered the electricity of amber; and Gilbert, in the year 1600, extended the force to other bodies. Then followed other inquirers, your own

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among the number. But this form of electricity, though tried, did not come into use for telegraphic purposes. There appeared the great Italian, Volta, who discovered the source of electricity, which bears his name, and applied the most profound insight and the most delicate experimental skill to its development. Then arose the man who added to the powers of his intellect all the graces of a human heart, Michael Faraday, the discoverer of the great domain of magneto-electricity. Œrsted discovered the deflection of the magnetic needle, and Arago and Sturgeon the magnetization of iron by the electric current. The voltaic circuit finally found its theoretic Newton in Oken, while at Princeton Henry pushed forward the course of experimental inquiry.

Here you have all the materials employed at this hour in all the forms of the electric telegraph. Nay, more; Gauss, the celebrated astronomer, and Weber, the celebrated natural philosopher, both professors in the University of Gottingen, wishing to establish a rapid mode of communication between the observatory and the physical cabinet of the university, did this by means of an electric telegraph. The force, in short, had been discovered, its laws investigated and made sure, the most complete mastery of its phenomena had been attained, nay, its applicability to telegraphic purposes demonstrated by men whose sole reward for their labors was the noble joy of discovery, and before your practical men appeared at all upon the scene.

THE GREAT FOUNTAIN.

Are we to ignore all this? We do so at our peril. For I say again that behind all your practical applications there is a region of intellectual action to which practical men have rarely contributed, but from which they draw all their supplies. Cut them off from this region and they become eventually helpers. In no case is the adage truer, "Other men labored, but ye are entered into their labors," than in the case of the discoverer and the lover of natural truth. But now a word on the other side. While I say that practical men are not the men to make the necessary antecedent discoveries, the cases are rare in which the discoverer knows how to turn his labors to practical account. Different qualities of mind are needed, different habits of thought are needed in the two cases; and, while I wish to give emphatic utterance to the claims of those whose claims, owing to the single fact of their intellectual elevation, are often misunderstood, I am not here to exalt one class of workers at the expense of the other. They are the necessary supplements of each other; but remember that one class is sure to be taken care of. All the material rewards of society are already within their reach; but it is at our peril if we neglect or discourage those men whose studies and pursuits which have no such rewards, and from which, therefore, the rising genius of the country is incessantly tempted away.

When

THE PILGRIM FATHERS

landed at Plymouth Rock, and when Penn made his treaty with the Indians, the new comers had to build their houses, to chasten the earth into cultivation, and to take care of their souls. In such a community science, in its more abstract forms, was not to be thought of. And at the present hour, when your hardy Western pioneers, whose should clearly like to twist nature face to face with stubborn Nature, piercing the mountains and subduing the forest and the prairie, the pursuit of science, for its own sake, is not to be expected. The first need of man is food and shelter; but a vast portion of this continent is already raised far beyond this need. The gentlemen of New York, Boston, Philadelphia, Baltimore, and Washington, have already built their houses, and furnished them; they have secured their dinners, to the excellence of which I can bear testimony. They have, in fact, reached that precise condition of well-being and independence when a culture as high as humanity has yet reached may be justly demanded at their hands. They have reached that maturity, as possessors of wealth and leisure, when the investigator of natural truth, for the truth's own sake, ought to find among them promoters and protectors. Among the many grave problems before this country this will be one to solve, whether a republic is able to foster the highest forms of genius.

THE DANGERS OF SCIENCE IN AMERICA.

You are familiar with the writings of De Tocqueville, and must be aware of the intense sympathy which he felt for your institutions; and this sympathy is all the more valuable from the philosophic candor with which he points out not only your merits but your dangers. Now, if I come here to speak of science in America in a critical and captious spirit, an invisible radiation from my words and manner will enable you to find me out, and will guide your treatment of me to-night. But if I in no unfriendly spirit—in a spirit, indeed, the reverse of unfriendly—venture to repeat before you what this great historian and analyst of democratic institutions said of America, I may be permitted that you will hear me out. He wrote some three and twenty years ago, and perhaps would not write the same today; but it will do nobody any harm to have his words repeated, and, if necessary, laid to heart. In a work published in 1850 he says: "It must be confessed that among the civilized peoples of our age there are few in which the highest sciences have made so little progress as in the United States." He declares his conviction that had you been alone in the universe, you would speedily have discovered that you cannot long make progress in practical science without cultivating theoretic science at the same time. But according to De Tocqueville you are not alone. He refuses to separate America from its ancestral home; and it is here, he contends, that you collect the treasures of the intellect without taking the trouble to create them.

De Tocqueville evidently doubts the capacity of a democracy to foster genius as it was fostered in the ancient aristocracies. "The future," he says, "will prove whether the passion for profound knowledge, so rare and so fruitful, can be born and developed so readily in

DEMOCRATIC SOCIETIES

as in aristocracies. As for me," he continues, "I can hardly believe it." He speaks of the unquiet feverishness of democratic communities, not in times of great excitement, for such times may give an extraordinary impetus to ideas, but in times of peace. "There is then," he says, "a small and uncomfortable agitation, a sort of incessant rubbing of man against man, which troubles and distracts the mind without imparting to it either animation or elevation." It rests with you to prove whether these things are necessarily so, whether the highest scientific genius cannot find in the midst of you a tranquil home. I should be loath to gainsay so keen an observer and so profound a political writer, but, since my arrival in this country, I have been unable to see anything in the constitution of society to prevent any student with the root of the matter in him from bestowing the most steadfast devotion on pure science. If great scientific results are not achieved in America, it is not to the small agitations of society that I should be disposed to ascribe the defect, but to the fact that the men among you who possess the genius for scientific inquiry are laden with duties of administration or tuition so heavy as to be utterly incompatible with the continuous and tranquil meditation which original investigation demands.

OUR CAPITALISTS' LIBERALITY.

I do not think this state of things likely to last. I have seen in America a willingness on the part of individuals to devote their fortunes in the matter of education to the service of the commonwealth, for which I cannot find a parallel elsewhere. This willingness of private men to devote fortunes to public purposes requires but wise direction to enable you to render null and void the prediction of De Tocqueville. Your most difficult problem will be not to build institutions, but to make men; not to form the body, but to find the spiritual embers which shall kindle within that body a living soul. You have scientific genius among you; not sown broadcast, believe me, but still scattered here and there. Take all unnecessary impediments out of its way.

You have asked me to give these lectures, and I cannot turn them to better account than by asking you in turn to remember that the lecturer is usually the distributor of intellectual wealth amassed by better men. It is not as lecturers, but as discoverers, that you ought to employ your highest men. Keep your sympathetic eye upon the originator of knowledge. Give him the freedom necessary for his researches, not overloading him either with the duties of tuition or of administration, not demanding from him so-called practical results—above all things, avoiding that question which ignorance so often addresses to genius,

"WHAT IS THE USE OF YOUR WORK?"

Let him make truth his object, however impractical for the time being that truth may appear. If you cast your bread thus upon the waters, then be assured it will return to you, though it may be after many days.

And now my work among you is done, and I have only to add a last word of thanks to my friends for the aid which they so kindly tendered and rendered me. I have to thank Mr. Hewitt for his constant care; Prof. Joy and Mr. Hallock for active help most liberally given. To the Messrs. Appleton I owe much, while the labors of Prof. Youmans are simply a continuation of a life-long devotion to the furtherance of science. I can never forget the sympathy and offers of friendly aid which the loss of my assistant in Philadelphia, evoked from my scientific brethren in New York. One helper still remains to me intact, and you have had throughout these lectures constant evidence of his skill and devotion. Finally, ladies and gentlemen, I have to thank you for your unswerving attention throughout this course of lectures. The circumstances under which you assembled to hear me can never escape my recollection. I wish you a warm good-by, and a thrice happy New Year!

THE MEMPHIS DISASTER.

Four Steamers Totally Destroyed and Nineteen Others Badly Damaged—Seventy Coal and Flatboats Sunk.

From the Memphis Avalanche, Dec. 28.

The perilous situation of twenty-three steamers and a large number of other crafts lying in our harbor culminated about 1 o'clock yesterday morning in one of the most serious disasters that ever at one time befel marine property anywhere south of the Ohio river. Between daylight and midnight of Thursday the river opposite this city rose by the Government water gauge three and a half feet. This, it was supposed, was due to the breaking of an ice gorge some sixty miles above the city, a gentleman having arrived here from Randolph on Thursday who reported the river gorged at that point. Be this as it may, the ice, which began to float by this city last Sunday night, gradually increased in volume until it formed great fields, extending several hundred yards from each bank of the river, and leaving only a narrow channel for the passage of heavy floes, which moved sluggishly along with the current.

BOATS CRUSHED LIKE EGG SHELLS.

All the boats in the harbor were held as if in the grasp of Titans, firmly imbedded in their icegirt surroundings. Their condition was considered dangerous by many, but they lay quietly at their mooring places until an hour after midnight yesterday morning. Then the fields began moving from the effects of the rise and the heavy bodies of ice which floated down the bend against the Tennessee side. A general crushing of every wooden craft within reach immediately followed. Hulls of steamers were crushed like egg shells, and great timbers were broken like pipe stems. The crashing and snapping in twain of planks sounded like the roar of thunder, and from the mouth of Wolf river to the foot of Court street, a distance of fully three quarters of a mile, some twenty boats of various kinds were tossed together as if they failed to be crushed to pieces and totally wrecked were either greatly damaged or became helpless and unmanageable.

The dry docks were moored near the mouth of Wolf river. The cables and chains were snapped like threads, and the docks were moved to the foot of Exchange street.

THE FATE OF THE BELLE PIKE.

The steamer Belle Pike lay next below the docks, and was carried downward against other vessels, which she smashed and damaged as she passed. She finally brought up, with her bow against the shore, at the foot of Adams street, where some coal and flat boats under her stern kept her from sliding upon dry land. She was the boiler or cabin deck. Her hull, however, was smashed in forty places, and early yesterday hands were set to work saving her cargo and cabin outfit. She left here last Monday and went some twelve miles above, but, finding the ice too heavy, returned Tuesday morning, and fast below the docks, near Wolf river, in what was supposed to be a safe harbor, paid off her crew and laid up. Only three or four persons were on board at the time of the smash, and all escaped unhurt. Last evening she appeared to be settling fast, and fears are that she will sink out of sight. Some four hundred bales of her cotton have been taken out, and the whole will eventually be recovered.

GREAT LOSS OF COAL.

The coal fleet, comprising some five boats, two barges, and several pieces of boats, in all about 150,000 bushels, was moored chiefly above the mouth of Wolf river. Only about 30,000 bushels lay near the foot of Poplar street. With the exception of two boats it all belonged to Messrs. Brown & Jones, and their loss will be fully $125,000, upon which there is not a dollar of insurance. Some 30,000 bushels is still afloat, but the boats containing it are leaking and lie in a perilous condition, so that it is not safe to consider any out of danger. The fleet was torn loose and carried in one inextricable mass, all jumbled together, or scattered among the steamers between Poplar and Adams streets. One boat had its end frozen and stood nearly up from the top of the river bank, and with the other end sunk it still lies where it stopped, apparently immovable. Others are either sunk or have their ends sticking partially above water.

FLATBOATS SUNK.

A number of flatboats and produce crafts were smothered, sunk or destroyed. Some half dozen produce crafts lay at the levee when the ice began and have gone down. One of these belonged to Mr. Carey of Rome, Ind., and had a cargo of 2,000 barrels of potatoes and 500 barrels of apples on board. Another belonged to Pankey Bros. of Elizabeth, Ky., and had on 2,000 barrels of potatoes. Mr. Wm. Wolf of Elizabeth, Ky., lost a boat loaded with potatoes. A hay boat and several other produce boats were lost. J. R. Anderson of this city lost a small empty flat worth $75. E. J. Davis, also of this city, had a flat worth $50 crushed to atoms, and several wood boats and other craft were knocked to pieces.

The steamer Nettie Thomas, a neat little transfer ferryboat belonging to the Cairo and Fulton Railroad, was crowded against the bank, and her cabin and upper works were totally demolished. Col. James Loughborough had some $3,000 worth of valuable furniture on board, all of which is either ruined or seriously injured. The