PROFESSOR TYNDALL ON LIGHT--SECOND LECTURE.

THE PROCESSES OF SCIENTIFIC THOUGHT.

What is this thing which, under the name of "light," we have been generating, reflecting, refracting and analyzing? The question cannot be considered, much less answered, without transporting oneself to a world which underlies the sensible one and out of which, in accordance with rigid law, all optical phenomena spring. To realize this sub-sensible world, the mind must possess a certain pictorial power; it must visualize the invisible. The imagination must be exercised, and the magic of its art consists, not in creating things anew, but in so changing the relations of sensible things as to render them fit for the requirements of the intellect in the sub-sensible world. As an illustration of this subject, the case of Newton may be cited. Before he began to deal with light, he was intimately acquainted with the laws of elastic collision. With this previous knowledge, the material for theoretic images, he had only to change the magnitude of conceptions already in his mind to arrive at the emission theory of light. He supposed light to consist of elastic particles of inconceivable minuteness shot out with inconceivable rapidity from luminous bodies, and that such particles, impinging upon smooth surfaces, were reflected in accordance with the law of elastic collision. Dropping vertically downward toward the earth's surface, the motion of a body is accelerated as it approaches the earth. The particles of light Newton believed were acted upon in a similar manner, and he supposed that, on approaching a surface obliquely, they were drawn down upon it exactly as a projectile is drawn by gravity to the surface of the earth. This deflection, according to Newton, was refraction, and he imagined that differences in color were produced by particles of different magnitudes impinging upon the retina.

The verifications of physical theory occur in the world fo sense. Laying the theoretic conception at the root of matters, we determine by rigid deduction what are the phenomena which must of necessity grow out of this root: If the phenomena thus deduced agree with those of the actual world, it is a presumption in favor of the theory. If, as new classes of phenomena arise, they also are found to harmonize with theoretic deduction, the presumption becomes still stronger. If, finally, the theory confers prophetic vision upon the investigator, enabling him to predict the existence of phenomena which have never yet been seen, and if those predictions be found on trial to be rigidly correct, the persuasion of the truth of the theory becomes overpowering.

After alluding to the supporters of Newton's theory, among whom were Laplace, Malus, Biot and Brewster, the lecturer proceeded to explain the

UNDULATORY THEORY OF LIGHT AND ITS ORIGIN.

The conception of an ether was advocated by Huyghens and the mathematician Euler, but it was reserved for Thomas Young to discover the resemblances which exist between the phenomena of light and those of wave motion. Professor Tyndall paid an earnest tribute to the genius of this philosopher, placing him on a level but little below that of Newton, and then proceeded to describe the general theory of wave motion:

The propagation of a wave is the propagation of a form, and not the transference of the substance which constitutes the wave.

The length of the wave is the distance from crest to crest, while the distance through which the individual particles oscillate is called the amplitude of the oscillation. You will notice that in this description the particles of water are made to vibrate across the line of propagation. Picture two series of waves intersecting each other and proceeding from two centres of disturbance. The motion of every particle of water is the algebraic sum of all the motions imparted to it. If crest coincide with crest, the wave is lifted to a double hight; if furrow coincide with crest, the motions are in opposition and their sum is zero.

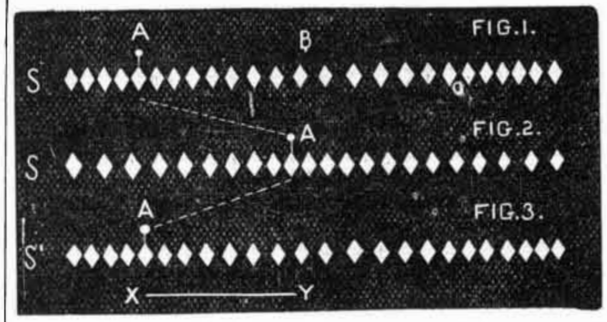
THE ANALOGY BETWEEN SOUND AND LIGHT.

Young's fundamental discovery was the principle of interference applied to light. We can imagine the air of a room to be traversed by a series of sound waves, and that a second series be propagated, so related to the first that condensation coincides with condensation and rarefaction with rarefaction. The consequence would be a louder sound than would be produced by either set of waves singly. But we can also imagine a state of things where the condensations of the one system fall upon the rarefactions of the other, when the two systems neutralize each other, and thus by adding sound to sound we produce silence. Now, in a similar manner, by adding light and light together, we may obtain darkness. There is, however, a fundamental

DIFFERENCE BETWEEN LIGHT AND SOUND WAVES.

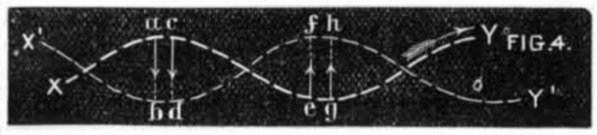
Could we see the air through which sound waves are passing, we would observe every individual particle of air oscillating to and fro in the direction of propagation. Could we see the ether, we would also find every individual particle making a small excursion to and fro; but here the motion above referred to would be across the line of propagation. The vibrations of air are longitudinal, those of ether, transversal.

To illustrate this point, Professor Tyndall threw on the screen a line of light dots as at Fig. 1, representing air particles in a wave of sound. At A is a condensation, at B a rarefaction. These were drawn upon a blackened glass disk and placed in the lantern. When the disk was rotated, the dots that were closed at A separated, and those that were separated, as at B, closed, the motion being kept up along the whole line. From Fig. 1, combined with Figs. 2 and 3, the motion of a particle of air acted upon by sound may be determined. Let A be such a particle in Fig. 1, in the midst of the condensed portion of the wave. In Fig. 2 the wave of condensation has become one of rarefaction, and the particle A has travelled along half a wave length, or to the center of



the rarefied wave. In Fig. 3 this same particle has returned to its former position. It has consequently made an excursion to and fro over the length, X Y, oscillating, in other words, throughout this distance.

An undulation, X Y, Fig. 4, composed of a series of par-



ticles in spiral shape, then appeared upon the screen. By rotating a disk similar to the one above described, these waves alternately appeared as in X Y and X' Y'. Now, bearing in mind the example of a wave in water, we may understand how an undulation may progress while the particles of fluid simply oscillate up and down. Let us consider *a c* as two particles on the crest of the undulations X Y, and *e g* as other particles in a furrow. Imagine these waves to roll on in the direction of the large arrow until a furrow is substituted for a crest and *vice versâ*, or until the medium takes up the undulation X' Y'. Then the particles *a* and *c* will have descended to *b d* and the particles *e g* ascended to *f h*. Consequently the particles will not advance longitudinally (as we explained those in Figs. 1, 2 and 3 did on the line X Y), but will simply rise and fall on the vertical lines *ab*, *cd*, *fe*, etc.

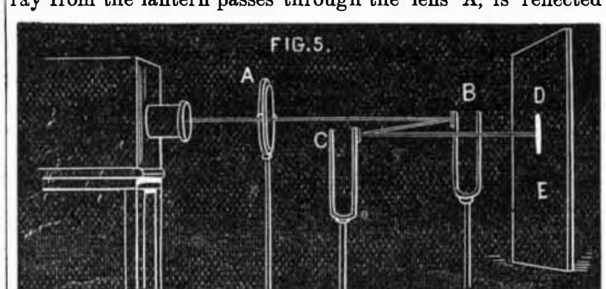
INTERFERENCE.

The most familiar illustration of the interference of sound waves is furnished by beats in music, which are produced by two musical sounds slightly of tune. Professor Tyndall here brought forward two large tuning forks tuned in unison, and swept a bow across each. A loud musical note filled the air. He then attached a cent to one of the forks, which somewhat retarded its vibrations. He explained that if, for instance, the difference between the forks now were such that while one fork made 100 vibrations the other made 101, it would result that at every hundredth vibration the wave would combine to form the highest wave, that is, the loudest sound, and half way between these the crest of one wave would meet the furrow of the other, making the least wave and the lowest sound. This effect of increasing and decreasing sound was very plainly audible. The speaker then put another cent on the loaded fork and the differences of sound succeeded each other with greater rapidity.

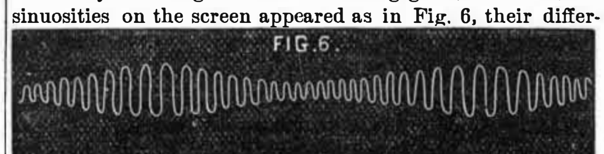
To show these facts optically, the light was reflected from a small mirror on the prong of a tuning fork to the screen, appearing as a small luminous circle. By vibrating the fork the circle lengthened out into a line, by reflecting which from a looking glass and sweeping the same rapidly about, a luminous scroll appeared, showing by the depth of its sinuosities the amplitude of the vibrations.

OPTICAL DEMONSTRATION OF INTERFERENCE.

Fig. 5 shows the apparatus used for this purpose. The ray from the lantern passes through the lens A, is reflected



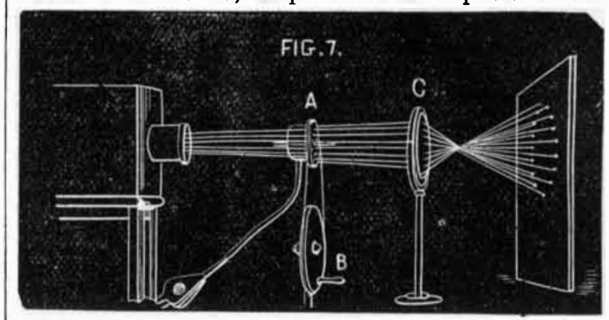
from a small mirror on tuning fork B, thence to another mirror on fork C, and thence to the screen. When the forks vibrated in unison a luminous band, D E, appeared. When one, as the lecturer expressed it, was "jockeyed" with the weight of a cent, the band alternately shortened and lengthened. By reflecting this from a looking glass, as before, the sinuosities on the screen appeared as in Fig. 6, their differ-



ing depths expressing the intensity of the alternate increase and diminution of the sound.

PITCH.

The pitch of a sound is wholly determined by the rapidity of the vibration, as the intensity is by the amplitude. To show the rise of pitch by the rapidity of the impulses, Professor Tyndall explained a form of siren shown in Fig. 7. At A is a perforated disk rotated by the wheel B over a cylinder. In the end of the latter against which the disk revolves are orifices similar to those of the disk, so that coincidences occur. Air is forced into the cylinder from the bellows. When the apertures in the disk coincide with those in the cylinder, a puff escapes; and when these puffs succeed each other so as to form a musical sound, the more rapid the rotation of the disk is, the quicker are the impulses and the



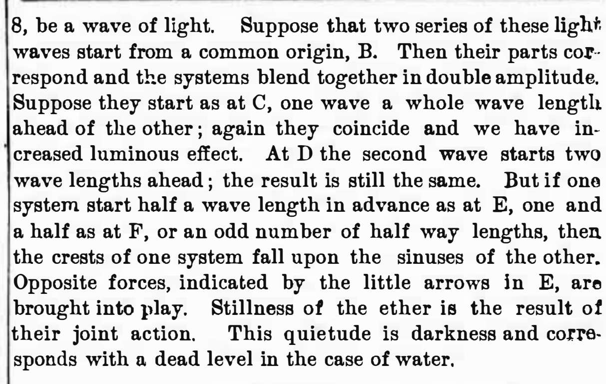
higher the pitch of the note. By this means any number of vibrations due to a sound may be determined. Passing the light through the cylinder and lens, the perforations appeared on the screen as shown. Then by forcing in air and rapidly revolving the disk, producing a dismal species of caterwaul, the lecturer reflected the luminous dots on the screen from a hand mirror. On vibrating the latter the most curious undulatory sinuosities appeared—circles interwoven with each other wonderfully intricately, besides other singular combinations of form.

PITCH IS THE ANALOGUE OF COLOR.

The waves of light have been measured, and it has been found that the more refrangible the light, the shorter are its producing waves. The shortest are those of the extreme violet, the longest, those of the extreme red. The length of a wave of the latter is such that it would require 36,918 placed end to end to cover one inch; of the former, 64,631 would be needed to occupy a similar space. The number of shocks on the retina corresponding to red is four hundred and fifty-one millions of millions, to violet, seven hundred and eighty-nine millions of millions. All space is filled with matter oscillating at such rates, and in ether, just as in water, the motion of every particle is the algebraic sum of all the separate motions imparted to it.

WHAT IS DARKNESS?

The principle of interference applies to the waves of light the same as it does to waves of water or sound. Let A, Fig.



8, be a wave of light. Suppose that two series of these light waves start from a common origin, B. Then their parts correspond and the systems blend together in double amplitude. Suppose they start as at C, one wave a whole wave length ahead of the other; again they coincide and we have increased luminous effect. At D the second wave starts two wave lengths ahead; the result is still the same. But if one system start half a wave length in advance as at E, one and a half as at F, or an odd number of half way lengths, then the crests of one system fall upon the sinuses of the other. Opposite forces, indicated by the little arrows in E, are brought into play. Stillness of the ether is the result of their joint action. This quietude is darkness and corresponds with a dead level in the case of water.

CONDITIONS FOR THE GENESIS OF COLOR.

If we have in interference an agency by which light may be self extinguished, we have in it the conditions for the production of color. Whence, then, are derived the colors of the soap bubble? Imagine a beam of white light impinging on a bubble. When it reaches the first surface of the film, a known fraction of the light is reflected back. But a large portion of the beam enters the film, reaches the second surface and is again in part reflected. The waves from the second surface thus turn back and hotly pursue the waves from the first surface. And, if the thickness of the film be such as to cause the necessary retardation, the two systems of waves interfere with each other, producing augmented or diminished light, quadrupling it, or totally extinguishing it, as the case may be. But, inasmuch as the waves of light are of different lengths, it is plain that, to produce self-extinction in the case of the longer waves, a greater thickness of film is necessary than in the case of the shorter ones. When, therefore, the red is quenched, the blue and green are not quenched; hence the production of color in the case of thin plates.

Various beautiful experiments illustrating this theory were then made. The colors of a thin layer of oil on the surface of water were projected upon the screen. Also, the hues derived from a thin film of air, compressed between two pieces of glass; and lastly, reflected light was thrown through a soap bubble, covering the screen with the most gorgeous prismatic tints.

NEWTON'S RINGS

were then carefully explained, and on curved flat surfaces being pressed together, the curves were beautifully apparent when thrown by the lantern upon the screen. The interference of the waves caused by the varying thickness of the film of air was described and the colors produced pointed out. Then tinted glasses were interposed, and by the monochromatic light the number of rings was greatly increased, so that the whole light circle given by the instrument seemed to be covered with a ripple of alternate light and darkness.

Professor Tyndall then entered upon a lengthy explanation of Newton's method of accounting for the above phenomena in connection with the emission theory. The reference to

OTHER COLORS DUE TO INTERFERENCE

concluded the lecture.

Fine scratches drawn upon glass or polished metal reflect the waves of light from their sides; and some, being reflected from opposite sides of the same furrow, interfere with each other and quench each other. But the obliquity of reflection which extinguishes the shorter waves does not extinguish the longer ones, hence the phenomena of color. These are called the colors of striated surfaces. They are well illustrated by mother-of-pearl. This shell is composed of exceedingly thin layers, which, when cut across by the polishing of the shell, expose their edges and furnish the necessary small and regular grooves. The most conclusive proof that the colors are due to the mechanical state of the surface is to be found in the fact that, by stamping the shell carefully upon black sealing wax, we transfer the grooves, and produce upon the wax the colors.

Correspondence.

Certain Properties of the Solar Rays.

To the Editor of the Scientific American:

I thank you for giving insertion in the SCIENTIFIC AMERICAN (November 16) to my paper on the solar rays, and also for recently calling attention to the importance of the inquiry. Having myself often derived pleasure and instruction from your editorial articles on the higher branches of physics, I may be permitted to express my sense of the great value, as well as of the enlightened spirit pervading its columns, of the influential organ of scientific information over which you preside.

With respect to the repetition of my experiments, you will, I am sure, agree with me as to the indispensable necessity, in any such steps, of reproducing carefully and fully the essential conditions present when the original observation was made. It would hence obviously be quite useless to attempt to obtain here, in the midst of a freezing December, illustrations of solar power equal to those witnessed last July and August, when the thermometer at noon was seldom under 90°, and when people were every day prostrated by heat in the streets of New York.

My latest experiments, those with albumen, were performed at the end of September, when the sun's power had considerably declined, and within a month I placed at the disposal of a scientific journal, circulating throughout the civilized world, a simple statement of the chief facts noticed, and of the conditions under which the observations were made, authenticating this statement by attaching to it my name and professional status in England. I really do not see that I could have done more.

In taking this course, I expected and hoped that my experiments would speedily be repeated and verified. For among the numerous readers of the SCIENTIFIC AMERICAN, many doubtless reside in tropical districts, where conditions similar to those existing here last midsummer continue throughout the greater part of the year. The experiments are so simple (merely requiring an ordinary lens such as those used for examining photographs) that any person can repeat them. If any of your readers, thus favorably circumstanced, should be willing to perform this service in the cause of science, it would be a satisfaction to me to know the results, positive or negative, the actual conditions present as to season, place, temperature, clearness of atmosphere, etc., being detailed; or, if more agreeable, these communications can be addressed to you editorially.

If, in experimenting, any more minute directions should be required, I shall be glad to give any information in my power in reply to letters addressed to me, post office box No. 2,622, New York.

It will be observed that the experiments arrange themselves into three groups, namely: 1. Those on living animal tissues under water. 2. Those with albumen. 3. Those on the penetration by the sun's rays of certain opaque and other media. And, as a general rule, the solar power required to produce satisfactory results in each group follows the same order.

In reference to my mode of experimenting, I may observe that an eminent telegraphic engineer in India has successfully employed the nerves of the finger and tongue to detect the escape of electricity from badly insulated wires, and has found this plan preferable in practice to any artificial test. Neither should it be forgotten that an apparently trivial physiological observation was the seed from which sprung the science of galvanism with all its ubiquitous and magnificent associations.

Nor are my experiments on the penetrating power of the sun's rays at all inconsistent with the facts observed by various eminent philosophers, or with the legitimate inferences from these facts Thus Melloni found that the penetrating power of rays of heat, emanating from various artificially heated bodies, as tested by different media, was directly proportioned to the actual temperature of the body from which those rays proceeded. What then can be more natural than that the concentrated rays of by far the hottest body known to us—the sun—should possess an extraordinary power of penetrating even many opaque media? The truth is that the facts of nature are always in harmony with each other. It is only man's reasonings and speculations on these facts that are liable to change and error.

In one respect you have slightly misunderstood the purport of my paper. I "claim" nothing but to have performed certain experiments, under certain specified conditions and with certain uniform results. I merely alluded to one or two possible explanations of the phenomena described, but expressly reserved any definite conclusions until more facts bearing upon the question should be accumulated, either by myself or others. And in the concluding sentence I referred pointedly to the obscurity still surrounding the subject, and to the necessity for its further systematic investigation.

In employing this guarded language I had in view chiefly the physiological relations of the solar forces, a field of research yet almost untrodden, but of the highest importance both to science and to humanity. For while every practical physician and every student of hygiene feels compelled to recognize the great influence which the solar emanations exercise upon the human body in health and disease, how little do we know of the rationale or conditions of their action! It has often seemed to me remarkable that, notwithstanding our boasted modern progress, the ancients actually knew more or at least made more practical use in the arts and in medicine of the heating and stimulating effects of the sun's rays than we do.

The whole subject demands extensive experimental examination, for the range of the inquiry is immense. Each sunbeam may indeed be regarded as a little world, peopled by a host of active forces, so intimately commingled and united that the utmost ingenuity of man has not yet succeeded in thoroughly unraveling and clearly individualizing a single thread of that mystic cord.

What do we know positively of the nature of light or heat or actinism, or of their relations to each other and to electricity and to the vital forces?

In conclusion, I need scarcely say that it will be very gratifying to me if the rude, desultory observations, commenced amid the fogs of the east coast of England, should obtain even a partial fruition under the more potent sun and brighter skies of America.

New York city. GEORGE ROBINSON, M. D.

Are not the Elements Molecules?

To the Editor of the Scientific American:

One of the tenets of the modern atomic theory, namely, that no compound can exist where the valences of its component elements are not all satisfied, is universally acceded to by writers on chemistry; but in the very face of this statement, they nearly all rush into what appears to the writer to be a rank absurdity and inconsistency, and perhaps on the very next page they will assert that certain elements, for instance tin, antimony, platinum, etc., are endowed with the extraordinary faculty of behaving as dyads, triads, tetrads, or pentads, indifferently, according to circumstances. A convenient and full explanation occurs to me, by which this apparent inconsistency may be accounted for. *Imprimis:* To me it appears just as irrational to assert that an element can exist where its valences are not all satisfied as that a compound can. What then becomes of the other two valences of the tetrad tin, in the case of stannous chloride, $Sn\,Cl^2$? or of the other two, in the case of antimonious chloride, $Sb\,Cl^3$? My answer to these queries is, not that the valences have vanished, but that they are fully active in satisfying those of another similar molecule, or, in other words, the respective formulæ for the above salts are

$$\begin{array}{l} Sn^{IV}\ Cl^2 \\ \| \\ Sn^{IV}\ Cl^2 \end{array} \quad \text{and} \quad \begin{array}{l} Sb^{V}\,Cl^3 \\ \| \\ Sb^{V}\,Cl^3. \end{array}$$

And now for the deduction from the following facts: If antimony be dissolved in HCl, the trichloride, $SbCl^3$, is only obtained, and in the case of tin, the bichloride, $SnCl^2$, whereas, by projecting powdered Sb into chlorine gas, the pentachloride, or, of tin, the tetrachloride, is obtained. My deduction is that tin, antimony, or any other element, as a single atom, cannot exist, but that every atom, in the uncombined state, is bound by all its valences to one of its own number. Antimony, then, is

$$\begin{array}{l} Sb^{V}, \\ \| \\ Sb^{V} \end{array}$$

and when acted on by HCl, where the negative affinity of the Cl is in a measure masked by the H, it is only capable of separating three of the Sb valences, and

$$\begin{array}{l} Sb\ Cl^3 \\ \| \\ Sb\ Cl^3 \end{array}$$

results. Project antimony, on the other hand, into Cl gas, and now the powerful negative affinity of the Cl, not being diluted by the H, is capable of cutting apart all five of the antimony valences, and $Sb\ Cl^5$ is obtained. The same is true of tin, and, in fact, instances might be added *ad infinitum*; but is not the above sufficient? My conclusion, then, is, that the elements are constant in their saturating power, and under all circumstances are endowed with the maximum number of valences which they show under any circumstances. R. D. W.

Well Equipped Railroads.

To the Editor of the Scientific American:

The instances of great railroad corporations being completely equipped with all the latest improvements, to render their patrons and employees secure and add to their comfort, are so rare that I request a small space of your valuable, most widely circulated, and carefully read paper to give publicity and due credit to a great line of travel to the far west, embraced in three roads, the Chicago, Burlington and Quincy, Hannibal and St. Joseph, and Kansas Pacific. These have tried all the real improvements offered and have adopted the best, consequently the air brakes, jointed rails, self-couplings for cars, a complete arrangement for heating and ventilating; smooth, well ballasted road bed, and efficient system of signals are adopted by them; these, with a well paid and consequently a good class of conductors, engineers and brakemen, who, feeling that the spirits administering these lines mean to excel, are to a corresponding degree inspired to exert greater care and attention to their duties, render these roads great public benefactors.

By publishing this, you may wake up some of the managers of the dormant roads, who can never see the benefit derived from making improvements. JOHN WHITEFORD.

Detroit, Mich.

Lieutenant Wheeler's Expedition.

To the Editor of the Scientific American:

I was a member of a party which, for the purposes of exploration, was fitted out last July at Camp Douglas, Utah, and left on the 28th of that month for Eastern Nevada and Northern Arizona. The expedition was divided into two main bodies, one intending to take a line south as far as Beaver, the other to go to Nevada, and thence to Beaver, and to explore all the country between the first party and the Nevada State line. From Beaver, we divided ourselves into four sections, and continued south. The country was found to be very rich with silver, coal, and iron, and may be described as a good field for the geologist and the artist. The scenery is beautiful, and there is every variety of stone, limestone, sandstone, and granite being very plentiful. There are diamonds as good as in Arizona to be found in Utah, within 100 miles of Salt Lake city. The great drawback to the locality is poor water and no rain in summer. There is now being constructed, southward from Salt Lake city, a railroad of which about 35 miles is complete. It will run to or near St. George, which is a lively Mormon settlement. Here cotton, castor beans, peaches, grapes, and all fruits needing a warm climate, grow in abundance. Cotton and woolen mills are scattered through the country. The whole of the party will have arrived back in Camp Douglas, by December 20, except one man who was drowned.

Utah Territory. A. F. M.

Explosions produced by High Notes.

A large portion of the explosives known to chemists contain more or less nitrogen. The simplest, and one of the most unstable, of these is the compound of iodine with nitrogen. The iodide of nitrogen, as it is called, is very easily prepared by dissolving finely powdered iodine in concentrated ammonia and filtering. The filter paper is removed from the funnel while wet, and is torn in small strips, which are spread around to dry. Although entirely harmless while moist, as soon as it is dry the compound explodes by the slightest touch with a loud report. What seems most remarkable is that it may be exploded by certain high notes and sharp sounds.

The following interesting experiments with this substance were recently made by Champion and Pellet: Two long glass tubes 13 millimeters in diameter and 2·4 meters in total length were joined by a strip of paper, and pieces of paper with 0·03 grammes iodide of nitrogen placed in each end. Upon detonating one of these with a hot wire, the other also exploded. That the explosion was not occasioned by the pressure of the air was proved by placing a small light pendulum in the tube, and this pendulum was not swayed by the explosion any more than it would be by blowing into the tube with the mouth. Small quantities of the iodide of nitrogen were fastened on the deep strings of a contra-bass, bass viol and violin, and the string caused to vibrate. The deep tones produced no explosion, but a loud one instantly followed when the vibrations exceeded 60 in number. The very high notes produced by touching the strings between the bridge and the tail piece also exploded the iodide.

Experiments tried with Chinese tamtams gave the same results; the bass instrument failed to explode it, but the more rapidly vibrating one, which gave a higher note, always caused the explosion. Two parabolic concave mirrors, 20 inches in diameter, were stationed 8½ feet apart, and paper containing a few grammes of iodide of nitrogen placed in the focus of one mirror and half way between the mirrors. In the focus of the other mirror a drop of nitro-glycerin was exploded, which caused the explosion of the iodide in the focus of the first mirror but not of that half way between the mirrors. Although other explosives fired off in the focus of the second mirror will produce a like effect, yet this is not due, as might be claimed, to the heat, since 0·03 grammes of nitro-glycerin, which produces no more heat than 0·9 grammes of gunpowder, will produce an explosion requiring 8 to 10 grammes of powder. The mirrors were then obscured with smoke, when 10 grammes of powder were unable to explode the iodide, but, even under these conditions, 0·03 grammes of nitro-glycerin sufficed to accomplish the result.

A MAN out West wants a patent on an invention calculated to prevent the bungling method of executing criminals, that has now grown so common. In case the vertebræ of the condemned are not scientifically dislocated at the first fall, the rope instantly lowers the victim safely to the ground, lassoes the sheriff and his assistants, jerks them fifty feet into the air and drops them on the nearest picket fence This device is known as the "Automatic Avenger."