sides of the above mentioned buildings form part of the forum. The two enormous private dwellings flanking the City Hall tend to destroy the character of the square, and in place of the same some official building should have been erected. Notwithstanding all these defects, the square is grand and imposing, and the defects appear only after a close examination.

Ten years ago the ground now covered by these beautiful buildings was used as a parade ground for the garrison of Vienna, and the military authorities refused to permit their parade grounds to be used for city improvements, but had to yield to the imperative orders of the Emperor. The city of Vienna, in former years, was a fortress surrounded by enormous walls and moats, outside of which the nine suburbs were located. About twenty years ago the city walls were taken down and the moats filled, whereby a tract from one-quarter to one-half a mile wide was formed around the inner part of the city; and on this tract the well known Ringstrasse, the Natural History and Historical Museums, the Votive Church, the Exchanges, the Opera House—destroyed by fire a few years ago—the New Opera House, the City Hall, University, Houses of Parliament, Imperial Court Theater, and many private dwellings, palaces, buildings for the several departments, banks, etc., were erected; large tracts being reserved for parks.

The previous page, representing the new City Hall Park, is from the *Illustrirte Zeitung*.

SOURCES OF ELECTRICITY.

THE first of a course of six lectures adapted to a juvenile auditory, by Professor Tyndall, on "The Sources of Electricity," was lately delivered at the Royal Institution, London.

Professor Tyndall, in opening the course, said he knew that the delivery of such lectures caused pleasure to others besides himself. It was a pleasure to his colleague, Professor Dewar, and to their noble and good master, the late Professor Faraday, who in the later years of his life lectured to no one else but to those whom he loved to call the juveniles. Nine years ago he (Professor Tyndall) undertook to lecture upon the subject of electricity to boys and girls in that institution. At that time he took what he now called friction electricity, and he devoted the whole of the six lectures to that subject. His intention now was to give them a connected story, so to say, from beginning to end—commencing with the smallest germ, and showing them how it grew up until it had reached the development of the present time.

Many of them were aware that the name of this electricity was derived from the fact that first facts were observed by the ancients in the attraction of light bodies by amber. Amber was called, as many of them knew, electron—hence the name electricity, that was, that wondrous power of attraction which amber at first exhibited. It might be mentioned that amber was still found in various parts of the earth. It was found in Europe, especially along the shores of the Baltic, particularly after storms, when it was cast upon the waves and gathered there. There were also beds of fossil trees. In point of fact, along the shores of the Baltic the amber tree in distant times bloomed; and just as the poplar at the present time oozed out its gum, or the pine tree its resin, so the amber tree in those days dropped its precious gum into the sea; and where the amber had fallen and could be converted into lignite, they there found the amber diffused among the fossil amber trees.

The ancients had another story about amber. They considered it a very costly ornament, and paid dearly for it; and, indeed, at the present time, the revenue derived from the sale of amber is very considerable. The ancients told them that the daughters of the sun, for some reason, were converted into poplars, that these poplars wept tears at their sufferings, and that these tears, petrified, became amber. They would find the account in Sir George Cornewall Lewis' History of Ancient Astronomy. He would begin with the first experiment made with amber. He held in his hand a piece of amber made into the form of a stick consisting of the two mouthpieces of pipes fused together. By means of this stick he would show them the attraction of light bodies by amber. Rubbing the amber with catskin, he showed how some bran was attracted by the amber. [Experiment.]

The human mind was never contented with merely looking at a thing and seeing that thing occur; they were never contented with facts. Therefore, at an early time, the question occurred, Why did amber attract light bodies? The ancient philosopher was following the irresistible profundity of the human mind when he asked the reason of this. He supposed the amber to possess a soul, and in virtue of this soul attracted these light bodies. This was the theory of the celebrated Newton, the great astronomer and philosopher. There were various other ways of showing this attraction. For instance, [Experiment.] He placed a lath upon a point, and showed how a glass tube, after being rubbed as he had rubbed the amber, acted upon the lath. He ought, however, first to have stated that this attraction of light bodies by amber was the only thing known to the human mind for 2,000 years. Not until the year 1600 was the bond pierced by the celebrated Dr. Gilbert in the time of Queen Elizabeth. Dr. Gilbert said, "If you look at amber, it is a kind of gum. You see insects sometimes entangled in it. It would be very extraordinary if this were the only thing capable of attracting light bodies."

Dr. Gilbert therefore set to work, and found a vast number of other substances attracting light bodies, like glass, for instance, in its action on the lath in the experiment he had shown. They might use sealing wax instead of the glass tube he had used. The lecturer then, to illustrate this, showed several other experiments with a watch glass, an egg, a piece of sealing-wax, and a small wheel. He wanted to impress on them the quality of what was called a scientific mind. It had the quality of looking behind facts. They would observe in the experiment that the wheel followed the glass tube about as a carriage followed the horses harnessed to it. The question which a scientific mind asked was, "Is there anything between the glass tube and the wheel?" That was a question which occupied the mind of the great Sir Isaac Newton as to gravitation.

He asked himself, "How is it that the sun can control the earth in its orbit?" He was too cautious to express

any definite opinion on the matter, but his conclusion was that there was something there which enabled the sun to act upon the earth. In the same way he (the lecturer) now asked them this question—whether anything existed between that wheel and the glass tube? That question was one of the most important that occupied the minds of scientific men. They wanted to know whether there was a medium between that glass tube and that wheel. It was, as he had said, a point which was occupying the minds of scientific men, and perhaps they would not solve it in our day. Another experiment was made with regard to attraction by Sir Isaac Newton, who was a great experimenter as well as a great mathematician, and he was very much taken by this electrical attraction. He made this experiment: He wore a dressing gown; he got a plate of glass, and placed light bodies, such as bran, over that plate of glass, on which rested a ring of brass, placing over it a plate rubbed against his dressing gown.

Projecting the shadow of the brass upon the screen, the lecturer showed this experiment, and how the bran was acted upon. Incidentally he drew attention to the arrangements he had provided for keeping out of the theater all vapor and moisture, the arrangements being, he observed, to secure dryness, and not warmth or heat. Passing on to the laws of this attraction which they had just seen, he said he would give them an experiment which was first made by a sturdy old fellow, the burgomaster of Magdeburg, in Prussia, Otto Guericke, who invented the air pump. He noticed that when one brought an electrified body to and near a suspended feather, one saw it attracted there. He noticed after it was attracted, and after it touched the attracted body, that it was repelled. [This experiment the lecturer then showed, using the glass tube before mentioned.]

He might, he explained, use sealing-wax, or shellac, or a variety of other bodies. Showing how the feather was drawn toward a stick of gutta percha, and driven away by a glass tube, he stated that in this exhibition they had the first notion of the difference between electricity on the surface of the glass and upon the surface of gutta percha. The one attracted, the other repelled, the feather. He would now show them an experiment which he himself first made that morning, guided, of course, by the principles of electricity. They had seen him, he first observed, communicate the electricity upon the surface of the glass tube to the feather, and that when the feather had upon it the same electricity as the glass tube, the feather was repelled.

Taking a stand and resting it upon the table, he remarked that he wanted something to interpose between the stand and the table, which would not allow the electricity to pass from the lath placed upon it to the table. He found this something in a piece of shellac, but he might use common resin, or sealing-wax, or India rubber. He would, however, use the shellac, and he now knew that any electricity he might communicate to the lath would be prevented from going to the earth. He was forestalling matters a little, but in a few moments they would understand all he was saying. The experiment would be attended with some risk, as when he first made it that morning he wore a different coat, and he did not know whether the coat he was wearing at that time would behave as the coat he wore in the morning did.

He then requested his assistant (Mr. Cotterill) to strike him with the catskin, thus electrifying him. At the same time he drew his hand over the lath, explaining that in that way he was communicating to the lath the same electricity that Mr. Cotterill was exciting upon his body. They would observe how the lath followed his hand—a movement he afterward stopped, observing in continuation that he had communicated to the feather the electricity upon the glass, the self-same electricity proving itself repulsive. In the same way in the experiment he had just given, the electricity communicated to his hand had caused his hand to repel the lath. He would ask them to go fully into this matter with him, because it underlay the whole of electrical science. Sir Isaac Newton found his dressing gown was better for his glass than other substances. It was soon found that the electricity excited depended a good deal upon the rubber—a towel would not excite the same electricity as a catskin.

Taking two sticks of sealing-wax, and balancing one on the cradle, he rubbed the second stick, and showed the attraction and afterward the repulsion of the two substances electrified in the same way. He subsequently repeated the experiment with two pieces of gutta percha, and said he might go on with sulphur and sulphur, two paraffin candles, or paraffin and wax, or he might take ebonite and ebonite. Taking an ebonite comb, he passed it through his hair, and then showed how it repelled another ebonite comb, which was balancing in the cradle. Sealing-wax was a common substance, and might be taken as representative of the whole class of the so-called resinous bodies. Taking a stick of gutta percha, however, he proceeded to show the effect on it of a vitreous body. [Experiment shown.] Instead of repulsion, they saw powerful attraction. He might go through the whole of these bodies, and in each case show that a resinous body repelled a resinous body, and a vitreous body repelled a vitreous body. Suspending a glass tube, and exciting it by rubbing it, he took another glass tube, and having rubbed it, demonstrated the repulsion of the one from the other. Having repeated the experiment with two sticks of sealing-wax, he placed the glass tube in the balance, and showed the attraction between it and a resinous body—a piece of the sealing wax.

He wished them to bear in mind that they were here at the fundamental law of electricity—like electricities repelled each other, unlike electricities attracted each other. The terms "vitreous" and "resinous" electricities were at the present time abandoned, and the electricity developed by glass they called positive electricity, the electricity developed by sealing-wax and the resinous bodies being called negative electricity. There was, however, no reason whatever why one should be called positive and the other negative; it was simply done by agreement among scientific men, in order that they might understand each other when they talked of positive and negative. He next showed two pieces of ribbon electrified alike "standing at utter enmity to each other;" and afterward placed a sheet of paper on a wooden board. There was not, he said, the least attraction between the two, but having passed a stick of India rubber over the paper, he showed that he required to use some force to get the paper away from the board.

With two slips of paper he next illustrated the law that similar electricities caused repulsion. Several strips of paper suspended and insulated were then brought forward by the lecturer's assistant, and the former rubbed a glass tube and held it toward the strips, which at once commenced to diverge from each other entirely, owing, the lecturer observed, to the repulsion of the same kind of electricity. Calling attention next to the electroscope, he cast its shadow on the screen behind him, showing two pieces of gold leaf suspended. He then placed two balls, separated, on stands, took an arch of thick copper wire, and made the distance between the two balls sufficient to enable him to span them with the arch. Neither ball, he explained, had any power of attraction at present, but having communicated electricity to one of them by means of a glass tube, he spanned the two with the arch of copper wire, and showed how the electricity from the one was thus communicated to the other ball. This had been done by what was called a flow of electricity, and hence the motion of an electric current. To illustrate this principle still further, he attached a piece of copper wire to the arch, connecting it with the electroscope; and having touched one of the balls with the arch, he showed how a portion of the electricity thus communicated to the ball went through the wire to the electroscope, making the pieces of gold leaf diverge considerably.

By means of a further experiment, he caused the gold leaf again to collapse, and resume its former position. Detaching the piece of copper wire from the arch, he replaced it by a piece of dried twine, and having electrified the ball as before, showed that the twine had no power to conduct the electricity—a power, however, which he afterward showed was possessed by ordinary undried twine. He wished to impress on their minds in a manner never to be forgotten the influence of moisture. The dried twine was rendered an insulator; the ordinary twine was a conductor. He repeated this experiment with a piece of silk, first in a dry and afterward in a wet or damp state, and showed that in its former condition it was an insulator, while in its moist state it conducted the electricity. In the early part of his lecture he had spoken of the tendency of the human mind to inquire into the hidden causes of things; and as to these phenomena, those hidden causes were entirely beyond the range of sense. They must be seen by the scientific intellect. He wished to give them an idea of a notion long entertained by scientific men regarding electricity. There were two kinds, they said, positive and negative; and they further said that these positive and negative electricities were mixed together in all bodies.

He must now come to what he called a very beautiful experiment, which occurred to him two days previously. [Experiment shown on the screen.] In front of the lamp they had a brass ball suspended and connected by wire with a cylinder of brass. Mr. Cotterill would place upon that some loose bran, and then they would see what would occur. He would excite his glass tube, which he then passed over the cylinder. This glass tube would attract the negative electricity, and the other electricity, the positive, would flow toward the brass ball, and if it reached the ball and electrified it, the bran underneath ought to jump up to it. In this experiment he had not touched the cylinder with the glass tube. Supposing, however, he touched the cylinder before he brought the glass tube to bear upon it, they would see that there was no jumping of the bran. Why? Because the positive electricity, instead of going to the bran, had flowed through his body to the earth. The moment he removed his hand the liberated positive flowed toward the bran, which they saw jumping again. With this experiment the first lecture of the course was concluded.

ON PERSONAL SAFETY WITH ELECTRIC CURRENTS.

By Professor A. E. DOLBEAR.

THE serious accidents which have occurred within the past four or five years through accidental contacts with wires carrying strong electric currents have seemed to call attention to the necessity of providing safeguards against such mishaps. It is probable that carelessness has been the cause of most of the accidents reported, and it is true that if weak currents only were used nobody could be hurt. It is, however, worth while to consider the electrical relations of the human body in order to learn where danger lies. I have noted in various places the opinions of different persons as to what constituted a safe current. In one of the old books it is stated a "spark 18 in. long begins to be dangerous." In another place one says that a difference of potential of 800 volts is too high an electromotive force for individual safety.

Now a difference of potential of 1000 volts will not give a jumping spark the hundredth of an inch long. The electromotive force developed by the Holtz electro machine may be as high as 50,000 volts, and the spark from it will at most give a spasmodic jerk to the elbow, and no manner of hurt come of it or of repeated shocks from it, so that more than difference of potential must be considered in determining what is dangerous about electricity. The ability of electricity to do work of any kind, destructive physiological work as well as any other, depends upon both difference of potential and current strength, and the amount of work is proportional to the time also. Now the discharge from a Holtz machine through a short wire may give a very strong current; for example, let $E = 50,000$ volts, $R = 0.001$ ohm, then $\frac{50,000}{0.001} = 50,000,000$ —fifty mil-

lions of amperes; but the wire may show no sign of being injured, for the time of the current passage was too short, probably less than the millionth of a second. If the discharge had continued for an appreciable part of a second the wire would have been vaporized. The discharge is probably equally quick when taken on the knuckles, but there is not enough energy to hurt anything. Again, the amount that will traverse any conductor, with a given difference of potential between its ends, will vary inversely as its resistance, and for the human body it may only roughly be calculated. The resistance of the body is very great. Many measurements, made with different individuals taking wires in their fingers and hands, give a resistance varying between 6,000 and 15,000 ohms; but this depends in a large degree upon the moisture of the skin when con-

tact is made. Hands which are ordinarily dry have a high resistance; the same hands moist with perspiration or purposely wetted may lose half their resistance. Dr. Stone, of London, has made many experiments, and finds that the resistance of the body may be reduced to 500 ohms or less, by having the skin soaked.

On an arc light circuit with forty lamps the difference of potentials will be about 2000 volts. If a man with a dry, thick skin were to grasp the terminals at the dynamo, the current that would go through him would be $\frac{2000}{10000} = 0.2$ of an ampere, and in one second two-tenths of a coulomb would have traversed his arms. If the same hands were soaked, the current might be $\frac{2000}{500} = 4$ amperes, or 4 coulombs per second. In the first case there would have been spent in him an amount of energy equal to $2000 \times 0.2 = 400$ watts, or more than half a horse-power, and in the second case $2000 \times 4 = 8000$ watts, or $\frac{8000}{1000} = 8$ horse-power in the interval of one second. Now, any electromotive force above about 1.5 volts is sufficient to decompose water, and it has been shown that the fluids of the body are better conductors of electricity than any of the tissue, even the nerves; it may fairly be inferred that such a current with such an electromotive force might decompose a notable quantity of the fluids of the body into their constituent gases.

To determine the highest limit of safety would require experiments which no human beings would be willing to submit to. Animals might be employed perhaps; but if 800 volts have at any time proved to be dangerous, one may set a lower limit to the resistance of the body and determine the current strength $\frac{800}{1000} = 0.8$ ampere. That result looks threateningly large, but it is because the resistance is made so low. I have never found one less than 5000 ohms, then $\frac{800}{5000} = 0.16$ amperes. But that represents 128 watts—a quantity of energy no one would care to have spent in him. After all, what would be safe for one would be entirely unsafe for another; so that each individual would have his own factor of safety, or the difference of potential which he could work with, with impunity. From what we now know, it would seem as if one-tenth of an ampere current body was as much as any one could safely have traverse his body for one second. If, then, he fixes his minimum resistance, the product of the two will give him the electromotive force which he may feel timidly safe with. Thus, if one's resistance with wet hands is found to be 8000 ohms, then $8000 \times 0.1 = 800$ volts; while if his resistance was only 1000 ohms, he could only venture to touch wires having a difference of potential of $1000 \times 0.1 = 100$ volts. The ordinary incandescent light circuit would be on his limit.

ELECTRO-CHEMICAL RINGS COMPARED WITH THOSE OBTAINED BY PHYSICAL, MECHANICAL, OR CHEMICAL WAY.

I.

WHEN a plate of glass that has been regularly compressed around its circumference or at certain points is placed between an analyzer and polarizer, we observe

FIG. 1.

through its substance concentric iridescent waves which are the more marked in proportion as the compression has been stronger. What is remarkable is that these optical rings are like those that are produced upon plates by making them vibrate under a fiddle stick after covering their surface with fine sand. The figures thus obtained with circular plates always exhibit rings mixed with radiating lines of more or less regularity, while with square plates circular figures are quite rare.

Colorations analogous to those of annealed glass are again produced by the bending of a plate of glass, or by an expansion or a sudden cooling of the glass in a metallic frame, and by the hardening of fish glue in

FIG. 2.

glass moulds—the observations being always made with polarized light.

It occurred to Nobili to compare electro-chemical rings with the acoustic figures of Chladni, Paradisi, and Hart, but no result was obtained.

In my hydrodynamic experiments, similar to those that I performed upon the vibratory forms of plates, I have had an opportunity to establish several analogies between such figures and those obtained by electro-chemical way. Figs. 1, 2, 3, and 4 represent the com-

FIG. 3.

FIG. 4.

FIG. 5.

parative forms of the rings that are produced under corresponding conditions. The analogy between these four is evident enough. I might have joined thereto the thermic and chemical rings, which are very similar

FIG. 6.

FIG. 7.

FIG. 8.

in form and color to the electro-chemical ones. Fig. 1, which represents electro-chemical rings with radiating lines, requires an explanation, since Nobili's rings have no radii, a fact that seems to establish an important

FIG. 9.

difference between them and hydrodynamic rings. Nevertheless, under special conditions, it is possible to ascertain the presence of radiating lines in electro-chemical rings. In fact, Mr. Guebard has remarked

FIG. 10.

that upon employing very thin silvered sheet copper for the production of these rings, we observe white filaments running from the circumference of the latter to the center, if the point is negative. These filaments,

FIG. 11.

which are nothing else than very fine bubbles of gas derived from the electrolysis of the liquid, correspond to the radii of our hydrodynamic rings.

Figs. 5 and 6 exhibit quite a remarkable approximation between the optical colored rings obtained by

means of annealed or compressed glass, and the acoustic figures obtained upon vibrating glass covered with a thin stratum of water containing red lead in suspension. During the vibratory motion, the water assumes the form of a regular network, with meshes of varying size,

according to the diameter of the plate. When the vibrations cease, the red lead deposits, and preserves in doing so the form of the liquid network. After the evaporation of the water, the deposit adheres to the

plate, and copies may be taken from it just as with an ordinary photographic negative.

Figs. 7 and 8 exhibit an analogy of another order.

FIG. 12.

The optical figure, 7, whose six equidistant radii are iridescent, was produced by diffraction, while the light

FIG. 13.

was passing through a small aperture having the form of an equilateral triangle. The acoustic figure, 8, was

FIG. 14.

produced upon a vibrating plate besprinkled with sand. The six radii represent the lines of rest, and the nodes those of vibration.

Figs. 9, 10, and 11, to which might be joined their analogues among the thermic and chemical rings already