the shores of the Welle-Makua, and though they saw the white man for the first time, the people gave him a most hospitable reception. They had already received some years ago a visit from the slave-raiding Soudanese from the north; but they had managed to defend themselves, and to inflict a pretty severe defeat upon the slave hunters, since which time the latter had never returned. In fact there is at present *no Arab influence whatever* exerted in this country. Cannibalism prevails in it to some extent, but would be easily stopped by the residence of a white man among the people. The state inflicts a fine for every cannibal feast.

Where are the ambassadors for Christ for all these newly opened lands? Where is the steamer for the Welle-Makua? Where are the evangelists for the Sakkara nation?—*Regions Beyond.*

ADIABATIC COMPRESSION AND THE VELOCITY OF SOUND.

By Prof. HENRY A. MOTT, LL.D.

As the part adiabatic changes have to do with accounting for the propagation of sound, according to the wave theory, is not generally understood, it has occurred to me that as few, if any, works make the subject perfectly clear, possibly an article showing the connection as it is understood would be of interest.

When Newton endeavored to calculate the velocity of sound from the elasticity and density of the air, he adopted the formula

$$\mathrm{V} = \sqrt{\frac{\mathrm{K}}{\rho}}$$

Where K represented the coefficient of elasticity, and which is equal numerically to the pressure in the air if the temperature is constant.

That is, if the pressure of the air be represented by 762 mm. (30 inches) of mercury and the pressure is slightly increased, and this increased pressure be divided by the diminution of the unit volume, we will have the elasticity which is numerically equal to the pressure exerted by 762 mm. (30 inches) of mercury. If, on the other hand, the pressure of the atmosphere were 701·2 mm. (28 inches) of mercury, the same experiment would give as a result the elasticity represented by the elasticity due to 701·2 mm. (28 inches) of mercury.

Naturally, the elasticity of the air varies from day to day, just as the barometer varies, but, since the density of the air varies in the same ratio, this change of elasticity does not affect the velocity of sound.

$$\therefore \mathrm{V} = \sqrt{\frac{p}{\rho}} = \sqrt{\frac{1{,}013{,}660}{0{\cdot}01292}} = 27{,}997 \text{ cm. per second.}$$

Where $\rho = 0{\cdot}012932$ grammes per cubic cm. at 0° C. and 76 cm. barometric pressure at Paris, and $p =$ 1,013,660 dynes per sq. cm., the atmospheric pressure. Experiment has shown, however, that the velocity of sound in air is 5,203 cm. greater than 27,997 cm. per second, or 33,200 cm. per second. Newton attempted to explain away this discrepancy, and, without referring to his arguments, which were discarded, we will proceed to consider the explanation formulated first by Laplace and afterward developed by other acousticians.

It is a self-evident fact that if the volume of the air is increased, without any alteration of temperature, energy must be supplied to the air to enable it so to increase in volume, and if, on the contrary, the volume remains constant but its temperature diminishes naturally, heat must be withdrawn; if, however, the air increases in volume and diminishes in temperature concurrently, it is possible that these two changes may be so adjusted that while the air undergoes two changes, heat is not lost, neither is energy acquired from without. Such expansion is called *adiabatic expansion*—expansion during which the substance neither gains nor loses heat by conduction or radiation to or from surrounding objects. If, on the other hand, the air diminishes in volume and increases in temperature concurrently, it is also possible that these two changes may be so adjusted that while the air undergoes two changes heat is not lost, neither is energy acquired from without. Such contraction is called *adiabatic contraction* and corresponds to the supposed *condensation* of a sound wave, while *adiabatic expansion* corresponds to the *rarefaction.*

Now, assuming a condensation (*i. e.*, contraction) to take place in the propagation of sound, and the heat developed in the compressed half of the wave had no time to be conducted or radiated away, then the velocity of sound would be equal to

$$\mathrm{V} = \sqrt{\frac{k\ \mathrm{K}}{\rho}}$$

Where k is the ratio between the two elasticities, or, what is the same thing,* the ratio between the two specific heats, *i. e.*, specific heat at a constant pressure (S_1) and the specific heat at constant volume (S_2).†

The specific heat at constant pressure is 0·2375 for air.

The specific heat at constant volume is 0·1685, and is deduced as follows: One gramme of air occupies V c. c. at absolute zero of temperature T. T = 273. P = constant pressure in grammes per square centimeter = 1,033. The volume of 1·293 grammes of air = 1 liter = 1,000 cm.

$$\therefore \mathrm{V} = \frac{1000}{1{\cdot}293};\ \frac{\mathrm{V\,P}}{\mathrm{T}} = \frac{1000}{1{\cdot}293} \times \frac{1033}{273}$$

= 2,928·4 gramme centimeters, which is the work done in the expansion of 1 gramme of air at any constant pressure when raised 1° C., and its thermal equivalent is the excess of the specific heat at constant pressure above the specific heat at constant volume, or 0·0690,

$$\text{as } \frac{2928{\cdot}4}{42400} = 0{\cdot}0690$$

For 42,400 = gramme centimeter and gramme degree (Joule equivalent).

As the specific heat of air at constant pressure is 0·2375, the specific heat at constant volume will be 0·1685, as 0·2375 — 0·0690 = 0·1685

The ratio of these two specific heats is:

$$k = \frac{\mathrm{S}_1}{\mathrm{S}_2} = \frac{0{\cdot}2375}{0{\cdot}1685} = 1{\cdot}4094$$

The elasticity of the air in the adiabatic condensation is naturally increased over what the air would normally possess if the temperature were not raised or was constant. Substituting the value of k in the formula, we have

$$\mathrm{V} = \sqrt{\frac{k\ \mathrm{K}}{\rho}} = \sqrt{\frac{1{,}013{,}660 \times 1{\cdot}4094}{0{\cdot}01292}} = 33{,}253 \text{ cm. per sec.}$$

Now, it has been stated that experiment has shown that the velocity of sound through the air is 33,200 cm. per second, and by the above formula we deduce 33,253 cm. per second, which certainly compares most favorably.

The velocity of sound, then, is always the square root of the elasticity divided by the density, or $\mathrm{V} = \sqrt{\frac{\mathrm{E}}{\mathrm{D}}}$ meaning by the elasticity the ratio of any small increase of pressure to the corresponding decrease in the unit of volume.

If the compression takes place very slowly, giving time for all the heat generated to escape, that ratio is numerically equal to the pressure; if the compression takes place suddenly, allowing time for none of the heat whatever to escape, the ratio is the adiabatic elasticity, and is about 1·4094 times the value in the former case. Compressing the air a given amount adiabatically would require a certain added pressure; compressing it twice that amount would require twice that pressure, but the *ratio*, which is the elasticity, is the same, and, therefore, whether the amplitude of vibration in a sound wave be much or little, the velocity of the sound would be the same so long as the compressions and rarefactions occur so frequently that all the heat developed or absorbed remains in the wave where it is developed or absorbed. The quantity represented by "E" in the formula for the elasticity of sound, or the modulus of elasticity, as it is sometimes called in the tables, is then the ratio of the compressing force to the amount of compression, and is not the compressing force itself.

Therefore, if a small pressure is exerted upon air and a slight compression is produced, the elasticity is the ratio of that compressing force to the compression. If the compressing force be doubled, double the compression will be produced, but the ratio will remain the same, the adiabatic elasticity varying with the pressure. As the amount of compression and rarefaction due to the passage of sound waves is usually extremely small in comparison to the total pressure to which the air is always subjected, the amplitude of the sound wave does not affect the velocity, which accounts for sounds of varying intensity, in which the amplitude of the air particles varies considerably, traveling with the same velocity.

In case of explosions or in the firing of a cannon, where the compression is great, it is found that the amplitude does affect the velocity and increase the same, but after such sound has proceeded for a very short distance the amplitude of vibration becomes vastly less in consequence of the increasing size of the wave, and it is only for a very short distance from the source that the velocity even of such intense sounds differs from that of sounds of ordinary intensity.

The reason for the increased velocity in the sound generated by an explosion is that the amplitude of vibration is large in comparison with the length of the wave.

If a sound *could* be produced so intense that the amplitude of vibrations at the source of such sound was equal to a wave length, so that the movement forward of the air particles would be equivalent to the whole length of the wave and would set the wave forward by that amount, then, naturally, the sound at the beginning would move forward, not only in consequence of the transfer of the motion from particle to particle, but also in consequence of the movement of the particle itself.

The increase of velocity due to the amplitude is a quantity of the second or third order. Therefore, when the amplitude is reduced to a fraction of the wave length, then the increase of velocity of the sound due to it would be infinitesimally small. Ordinary sounds, therefore, of varying intensity travel with the same velocity, which of necessity has to be the case, otherwise all synchronism would be destroyed, as the sound from one instrument in a band of music playing at a distance would reach the ear in advance of the others, which we know is not the case.

In considering the reasonableness of the application of the theory of *adiabatic condensation* to the wave theory of sound, it must be obvious that both adiabatic expansion or contraction is a kind of operation which could only be realized in practice if the expansion or contraction were almost infinitely rapid. In answer to this, the supporters of the wave theory claim that in the progress of sound waves the air is alternately compressed and rarefied, the compression and rarefaction occurring in such rapid succession that there is no time for any transfer of heat.

If the heat produced in the compression (*i.e.*, condensation) had time to become diffused, or if, as certainly would be the case in excessively slow vibrations, the air had time to *flow round* the vibrating object supposed to produce such compression, so that it could not become compressed or evolve heat, the speed of propagation of the sound pulse would have to be represented by the formula

$$\mathrm{V} = \sqrt{\frac{\mathrm{K}}{\rho}}$$

which has been shown does not represent the actual **velocity of sound in the air.**

Prof. Daniel* says: "Air will not oscillate in waves such as can be propagated to a distance, unless there be some *well marked compression* or *rarefaction* produced at the center of disturbance. . . . A vibrating body, before it can act as a sounding body, must produce alternate compressions and rarefactions in the air, and these must be well marked. If, however, the vibrating body be so small that at each oscillation the surrounding air has time to *flow round* it, there is at every oscillation a local rearrangement—a local flow and reflow—of the air, but the air at a little distance is almost wholly unaffected by this."

Tyndall† says: "When a common pendulum oscillates, it tends to form a condensation in front and a rarefaction behind, but it is only a *tendency;* the motion is so *slow,*‡ and the air so elastic, that it moves away in front before it is sensibly condensed and fills the space behind before it can become sensibly dilated. Hence waves or pulses are not generated by the pendulum."

Helmholtz § says: "The pendulum swings from right to left, with a uniform motion. Near to the end of its path it moves slowly, and in the middle fast. Among sonorous bodies which move in the same way, *only very much faster,*‖ we may mention tuning forks."

Tyndal¶ also says: "The prong of the fork in its *swift*‖ advancement condenses the air." And Sir Wm. Thomson says: "If I move my hand *vehemently* through the air, I produce a condensation." It is perfectly evident, then, according to the supporters of the wave theory, that to produce a "well marked" compression, the motion of the vibrating body must be "faster" than the motion of the pendulum, and, in fact, must be "swift" or "vehement" motion.

Now, if it can be shown that while the tuning fork is still producing sound, and, in fact, sounding audibly, the motion of the prong is not "swift," "vehement," or "faster" than the motion of a pendulum, but exceedingly "slow" motion, having only a velocity at its swiftest point of about 14·9 in. in five minutes, then surely the learned supporters of the wave theory will willingly admit that no "well marked" condensation can be formed, and consequently no sound could be produced. For, surely, in this enlightened nineteenth century, the rational mind will not permit itself to be persuaded into the belief that if a body is moved forward and back with a velocity of about one foot in five minutes, a condensation and rarefaction will be produced in the mobile and free (not confined) air, but would naturally believe that the air will "flow" around and not be compressed.

It is clear that all we have to consider is *one* forward and backward motion of the prong of the tuning fork, for if the air is not compressed at the velocity with which it moves, then there is no need of considering any other forward and backward motion; for if one forward and backward motion at a given velocity fails to produce a condensation and rarefaction, then ten or one million would fail at a like velocity.

Now the facts are that the actual distance the prong of a C^3 tuning fork of 256 full vibrations travels when first bowed is about $\frac{1}{15}$ to $\frac{1}{20}$ of an inch, and that if actual measurements are made after it has been sounding for over a minute, the actual distance of its travel will be found to be $\frac{1}{17000}$ of an inch, and as it makes 256 full vibrations, the actual distance the prong travels in one second will be $\frac{512}{17000} \times 1{\cdot}5708$ (correction obtained from comparing the conical and reciprocating pendulum), or 14·9 inches in five minutes, and still the tuning fork continues to sound audibly for five minutes, and the distance the prong travels over still continues to diminish.

It may be argued that when a body is moving uniformly in air, with very moderate velocity, then if we neglect all friction, there is no sensible condensation; the air is "under way," as a sailor would say. But stop the body and cause it to return, then will the inertia of the air carry the same onward, causing a condensation in front and rarefaction behind which will be propagated off with the velocity of sound—the condensation and rarefaction not *alone* being produced by the vibrating body, but by the inertia of the air in front, or by the momentum it acquires from the moving body.

This line of argument seems extremely plausible, if we were not compelled to take into consideration the mobility of the air, its ability to flow around a slowly advancing body and not be pushed ahead or be "under way," so to speak.

When heat is applied to water, at 100° C., it is found that 536 C. H. units must be added to one pound to do the mechanical work of expanding the water 1,740 times its volume into steam, and keep it so expanded; and if heat be applied to *liquid* air it will likewise expand, and the heat so added must be present to keep the air in its expanded condition, and it does such mechanical work all the time. Now just as the so-called latent heat of steam gives to it its elasticity or spring power, so does the latent and sensible heat in air give to it its elasticity or spring power, on which its ability to flow around and not be compressed depends, and it must be clear that *until* this property of mobility or fluidity is overcome by a motion of the required velocity, the free air will not be compressed or driven onward in such a way that by stopping the forward motion of the moving body and returning any condensation or rarefaction can occur by any supposed momentum acquired, for until this point is reached there will be no air possessing such momentum.

Naturally, if the velocity be great, the property of mobility and fluidity of the air will be overcome, and air will be carried on and condensed in advance of the moving body, and if such body's movement be stopped and reversed, a rarefaction will be produced behind, caused by the high velocity, while the spring power of the air will afterward endeavor to establish a normal equilibrium again.

Taking, then, the mobility and fluidity of the air into consideration, is it possible for any one to believe that the forward and backward motion of a vibrating body, traveling at a velocity of about one foot in five minutes, is sufficiently rapid to overcome this property

* Δt = small increment of temperature; $\mathrm{E_t}$ elasticity for const. temp.; Δp, increase of pressure; $\mathrm{E_h}$ is the elasticity under the condition that no heat enters or escapes; $\mathrm{C_p}$ —$\delta\, p$ H, constant pres.; $\mathrm{S}\,p$, reduction of increment of pressure; $\mathrm{C_v}$ — $\delta\, p$ H, constant vol.

$$\frac{\mathrm{E_h}}{\mathrm{E_t}} = \frac{\dfrac{\Delta p}{\propto \mathrm{V_0}\,\Delta t}}{\dfrac{\delta p}{\propto \mathrm{V_0}\,\Delta t}} = \frac{\Delta p}{\delta p} = \frac{\Delta p}{\Delta p\,\dfrac{\mathrm{C_v}}{\mathrm{C_p}}} = \frac{\mathrm{C}}{\mathrm{C_v}}$$

See Text Book of Phys., Anthony and Bracket, p. 198.

† See Nat. Philos., Dexhauel, p. 464.

* Daniel's Phys., p. 367.

† Third edition Sound, p. 38.

‡ Italics are the author's.

§ Sensation of Tone, by Helmholtz.

‖ Italics the author's.

¶ Loc. cit., p. 28.

of fluidity and produce condensations and rarefactions?

It is clear that we must look for some more rational explanation than adiabatic compressions to assist us in explaining the velocity of sound. If we look upon hearing as the sensation of sound, and upon sound as a modification of a force element which has objective existence and which is an entity in as true a sense as matter, though not material, and then upon the air as a conductor through which pulses of this force are transmitted, we will arrive at a rational and consistent explanation of the phenomena of sound.

MEMORY.*

By J. O. HIRSCHFELDER, Prof. Clinical Med., Cooper Med. College.

IN one of his charming little plays the genial Moliere depicts the astonishment of a peasant who learns for the first time that he has been speaking prose all his life and did not know it. So many of us will probably be amazed when our attention is called to the marvelously beautiful pictures that we have collected and stored in the gallery of the brain. And we shall learn with equal surprise that all of our fellow beings are not similarly gifted, but that some register their impressions in one manner and some in another.

It is only within the last few years that the attention of psychologists has become directed to this highly interesting department, and, as is so often the case, have found that the instinct of the race had already preceded in its march of discovery—that the fact was crystallized in the language of almost every nation. Until Francis Galton first directed our attention to the subject some eight years ago, probably few of us realized that the word *imagine* was to be translated literally, or why it was that in so many different tongues a similar expression is employed to indicate an act of memory.

Almost all of our definite knowledge of our relation to the outer world reaches us through the medium of sight, hearing, and touch, to which latter the muscular sense is added. Just in what manner memory occurs—that is to say, by what mechanism we recollect—we do not know, but we do know that it must be due to some change in the nervous elements involved in the perception. Whenever an impression is made upon the body, that impression is made upon the nervous system. When we see an object, for example, the retina of the eye, which is simply a sheet of nerve tissue spread out over its posterior portion, becomes irritated by the rays of light falling upon it, and a change occurs in the delicate structure of that organ. The change extends from it along the optic nerve, which is in direct communication with it, and passes into the brain, reaching the surface of that organ, where it terminates in a well known and clearly defined region of gray matter. Now when the optic nerve has become irritated by light impinging upon the retina, the irritation extends through the entire line of nerve communication to the gray matter of the brain just referred to, and in all of these parts a peculiar, but as far as we know transient, alteration in the structure occurs. What bridges over the immense chasm between the excitation of the final nerve elements and the thought which arises in consequence we do not know. This is the great mystery which no scientist has yet been able to fathom—this is the boundary line between mind and matter, that no scientific investigation has yet been able to pass.

Memory has been well defined as the power to recall, represent, and reknow the objects which have been previously known or experienced in the soul. It is the most important of all the faculties, for without it the exercise of the others would be impossible. As stated by Dr. Reid: "The senses give us information of things only as they exist in the present moment; and this information, if it were not preserved by memory, would vanish instantly and leave us as ignorant as if it had never been." It is the servant of thought and the conservator of our acquisitions. This was well understood by the Greeks, who made Mnemosyne the mother of the muses.

Memory seems to be a quality inherent in organized matter. We see signs of it already in the inorganic world. A photographic plate is exposed to the action of the light in a camera, and is laid aside for months. Under the influence of the developing fluid the picture that had long ago been impressed upon the silvered surface is evolved, and what had been a simple white plate a few minutes before becomes a photographic negative.

This property is shared by many substances. If an object be laid upon a sheet of white paper and exposed to the action of the sunlight, the paper, when put aside in the dark, will show an image of the object used in the experiment.

We have the best illustration of memory in organized matter, however, in the acts which are learned by experience, and which, when sufficiently often repeated, become automatic. Let us consider the art of swimming as an example. During the first period the would-be swimmer must exercise his volition directly upon each set of muscles that is called into play, and in so doing, numerous unnecessary accessory movements are made. Probably many of you know how much exercise an inexpert swimmer can get out of a very short swim. Each time, however, the act is performed, an impression is made upon the muscles and nerves involved, and a portion of this impression remains.

It is remembered, so that the next time the act becomes easier, and finally no attention upon the part of the swimmer is required. He simply wills to swim, and glides along the water, each muscle acting at the proper time without any special effort. Here we have an example of organic memory. Each act suggests the one that is to follow, and it, therefore, takes place.

The extent to which this organic memory in which no element of consciousness exists may be developed is quite remarkable. Thus Carpenter relates the instance of a celebrated pianist who executed a difficult piece of music while asleep. Soldiers on foot have been known to fall asleep during the march, and to have continued to walk on in spite of their somnolence. Even horsemen in the saddle make the delicate adjustments necessary to maintain their position while asleep.

In each of the automatic acts in the commencement, while skill is being acquired, consciousness is present, and exerts its influence strongly, but that factor gradually operates less and less, and finally, when the act has become automatic, it is performed entirely without consciousness, dependent only u on the organic memory for its performance.

That consciousness is not necessary for action is proved by pathological conditions, such as epilepsy, in the lighter forms of which consciousness is absolutely lost, but acts begun before the attack are sometimes continued during and after the seizure. A very interesting account is given by Coleridge of a servant girl in Germany, who was very ill of typhoid fever, accompanied with violent delirium. In her ravings she repeated long passages from classical and rabbinical writers which excited the wonder and even the terror of all who had heard her, most of whom thought her inspired by a good or evil spirit. Some of the passages which were written down were found to correspond with literal extracts from learned books. When inquiries were made concerning the history of her life, it was found that several years before she had lived in the family of an old and learned pastor, who was in the habit of reading aloud favorite passages from the very writers in whose works those extracts had been discovered. These sounds, to her unintelligible, were so distinctly impressed upon her memory that under the excitement of delirious fever they were reproduced in her mind and uttered by her tongue.

Such examples as these prove conclusively that no impression made upon the brain is ever completely effaced, that every sensation and every thought is faithfully recorded, and requires but the magic touch of memory to evoke it from its hiding place. As De Quincey says: "I feel assured that there is no such thing as ultimately forgetting; traces once impressed upon the memory are indestructible; a thousand accidents may and will interpose a veil between our present consciousness and the secret inscriptions on the mind. Accidents of the same sort will also rend the veil. But alike, whether veiled or unveiled, the inscription remains forever."

In what is ordinarily termed memory, however, consciousness is the most important factor. An act of memory of a past event consists in calling up in the mind a representation of that occurrence, as it took place, and the further recognition of the fact that we know it to have occurred before.

How do we remember? What is the connection between the occurrence in the past and the picture that arises in the mind?

Various have been the answers to this query, and even to-day the opinions upon the subject differ.

Conscious memory consists of three different acts:

1. The retention of certain states.
2. Their reproduction.
3. Their localization in the past.

There is a memory which enters into consciousness and a memory which does not. The first may be termed psychic memory, the second organic.

In the form which we have termed organic memory, there is only retention of the impression and its recall, but no localization in time. In psychic memory we have all three. It is the localization in time which is the distinctive quality of consciousness.

By localization in time we mean that the concept enters into relations with other concepts that have preceded and followed it, and so becomes to our minds a portion of our past experience.

As was stated a short time ago, all persons do not recollect in the same manner, their form of memory depending partly upon some inherited condition of the brain and in part upon the direction in which the mind has been cultivated.

The first condition of memory is that an impression has been made upon the brain. The channels through which these influences pass are the senses. These have well been termed the gateways of the soul.

In what manner the information conveyed by the senses is registered and stored up in the mind we do not know; but certain facts observed lead us to infer that every impression made upon the brain, whether it had entered into consciousness or not, leaves a permanent record behind—a record which can become translated into thought under favorable circumstances, in other words, can be remembered.

Under certain pathological conditions a hyperæsthesia of the memory occurs, which proves to what extent such a registration of events does really occur. It is of frequent occurrence in fevers, in mania, ecstasy, hypnotism, and sometimes in the early stages of brain disease. Under conditions of great mental excitement the same increase of memory has been observed. Numerous individuals who had been saved from death by drowning relate that when asphyxia began, they seemed to review in an instant the whole of their past life with all its details. One man affirmed that every instant of his former life seemed to glance across his recollection in a retrograde succession, not in mere outline, but the picture being filled with every minute and collateral feature, forming a kind of panoramic picture of his entire existence, each act of it accompanied by a sense of right and wrong.

De Quincey gives a graphic description of a hyperæsthesia of memory caused by opium. He says: "I sometimes seemed to have lived for seventy or a hundred years in one night. The minutest details of childhood or forgotten scenes of later years were often revived. Placed as they were before me in dreams like intuitions, and clothed in all their evanescent circumstances and accompanying feelings, I recognized them instantly."

In order that we should perfectly remember a scene, for example, it is necessary that we should recall every one of its features, together with all the occurrences that transpired, and that we should know when and where we viewed it. If any one of these elements is not fully developed, we have imperfect memory.

The location of this memory was formerly supposed to be the brain only. The Greeks imagined that the seat of memory was between the eyebrows, and the Romans placed it in the laps of the ears, while the Chinese supposed it to be in the larynx. The phrenologists gave it a local habitation in the brain, but taught that each of the numerous faculties of which the mind is constituted has a special memory appropriate to itself. There is no one seat of memory, but special seats for each memory. "The eye records what it sees, the ear what it hears, and the other senses what comes within their several spheres, as well as the intellect what it thinks, the emotions what they feel, the will what it commands, and the muscles what they do, not only so, but each different class of sensations of any of the senses, each form of activity of any of the senses, every different kind of voluntary movement of any part of the body, has its distinct memory. Wherever we have distinction of action we have distinction of memory—which is the action's record, the traces left of its activity; and where the action is the most developed there the memory is the strongest."

As Bain says: "We must regard it as well nigh demonstrated that the renewed feeling occupies the very same parts, and in the same manner, as the original feeling." Wundt has observed a most striking example which proves this fact. If we look at a bright colored object for some time the retina becomes fatigued, so that then if we look at a white surface we see the image of the object we had before looked at, but in the complementary color. Now, the very same thing ensues if instead of looking at a bright object we close our eyes and imagine it intently. Upon opening our eyes and looking at a white surface we will see the object imagined in the color complementary to that imagined, showing that the retina has become exhausted as in actual vision, and that it must have participated in the act of memory.

In order that this should be possible, it is necessary for us to suppose that every impression made upon the organism leaves its traces behind. What the nature of this alteration is we do not know. It is not a coarse change that the microscopist or the chemist can detect, but is a molecular alteration, an analogue of which is found in the change that occurs in the violin that has long been played upon, in which the harmonies it had evolved seem in part to be stored up within it, giving forth a richer, purer tone with increasing use. But in addition to the impression made upon the nervous system, something more is necessary to memory. There must likewise be established dynamic associations between these impressions. Unless an impression made upon the organism have entered into relations with other impressions, it could not be recalled. This is the well known law of association.

That which makes memory possible is the power of one mental state to call into existence, or as we say to suggest, another. This association of thought occurs in virtue of a law called by psychologists the law of re-integration, which reads: Objects that have been previously united as parts of a single mental state tend to recall or suggest one another. This is simply a paraphrase of the well known fact that the nervous system tends to act again more readily in a manner or form which is similar to any in which it has acted before.

From this general law secondary laws of memory may readily be deduced.

1. Association of thought readily occurs through relations of place. Of things that have been seen together, each suggests the other. Thus the thought of a shoe or a glove will call to mind its mate.

2. Associations of thought occur through relations of time. Thinking of one event will suggest others which preceded or followed it. Thus the thought of the rebellion will suggest the emancipation of the slaves.

3. Association of thought may occur through similarity. If I see a face that resembles that of a friend, it will bring that friend to mind.

4. By contrast. Cold makes us think of heat, and light of darkness.

5. By relations of cause and effect. The cause may recall the effect, and the effect the cause.

6. The whole may suggest the part or the part the whole. In the same manner the genus and species suggest each other. Similarly a concrete idea may call to mind an abstract one or vice versa. Thus the quality of strength may suggest the lion.

7. Association of thought may occur through similarity of sound. Memory of rhyme is in part due to this fact.

The completeness with which the original thought will be recalled will depend upon many conditions. The most important condition is the amount of attention directed upon the primary perception. The more intense the original impression, the more accurate will be its recollection. This fact is too familiar to require illustration. Sir William Hamilton says: "The act of attention, that is an act of concentration, seems thus necessary to every act of consciousness, as a certain contraction of the pupil is requisite to every exertion of vision. Attention is to consciousness what the contraction of the pupil is to sight, or to the eye of the mind what the microscope or telescope is to the bodily eye. It constitutes the better half of all intellectual power." "It is a law of the mind that the intensity of present consciousness determines the vivacity of future memory. Vivid consciousness, long memory; faint consciousness, short memory; no consciousness, no memory."

"By attention we mean the fixing of the mind intently upon one particular object to the exclusion for the time being of all other objects that solicit its notice."

Those objects will be best remembered, other things being equal, which have been the longest and most frequently before the mind. Recent events are more readily remembered than past occurrences. The greater the strength of the emotion associated with a fact, the more readily will it be remembered, for such occurrences produce a powerful impression on the mind.

Each sense has its images, visual, auditive, tactile, motor, etc. As has been so well said by Shelley:

> "Music, when soft voices die,
> Vibrates in the memory;
> Odors, when sweet violets sicken,
> Live within the sense they quicken."

We may employ all of these sense images or may habitually use only one. Each person has his custom derived from the nature of his organization, and the result of the direction in which it has been developed. Experience has shown that individuals vary in the form of their memories. One remembers sound best, another forms, another color, another numbers.

Accordingly as the mental impressions received by the one sense or by the other are the most vivid, and are the basis of memory, psychologists have set up different forms. The most frequent and at the same time most interesting type is the visual. Probably most of my audience, and especially the female members, belong to this form. If such an individual thinks of a scene viewed before, the image thereof will arise

* Delivered January 30, 1891, as one of the Lane Popular Lectures. From the *Pacific Medical Journal*.