Leaming (J. R.)

ACOUSTICS APPLIED TO THE HUMAN CHEST IN PHYSICAL DIAGNOSIS.

BY

J. R. LEAMING, M.D.,

OF NEW YORK.

See pages 19. to 23.

Reprinted from the New York Medical Journal, January 26, 1889, *and Transactions of the New York State Medical Society, February,* 1889.

ACOUSTICS APPLIED TO THE HUMAN CHEST IN PHYSICAL DIAGNOSIS.

BY

J. R. LEAMING, M.D.,

OF NEW YORK.

Reprinted from the New York Medical Journal, January 26, 1889, *and Transactions of the New York State Medical Society, February*, 1889.

PHILADELPHIA:

WM. J. DORNAN, PRINTER.

1889.

ACOUSTICS APPLIED TO THE HUMAN CHEST IN PHYSICAL DIAGNOSIS.

By J. R. LEAMING, M.D.

The interior conditions of that marvellous instrument, the eye, are made known to us with mathematical precision by the application of the laws of light—optics. Any writer or teacher who should reject or neglect to apply these laws in considering the problems of vision would be unscientific and most likely wrong. In fact, since the application of the laws of light to the study of the eye, ophthalmology has become, in the hands of its devoted and learned professors, the one branch of medicine entitled to the distinction of being scientific, and consequently certain.

Optics and acoustics are twin-sister sciences, cognate in origin.

The laws of one, which are familiar, have ever been used in elucidation of the obscure in the other.

Yet, while optics has been successfully applied in the diagnosis of diseases of the eye, acoustics has hardly been thought of as a surely scientific solution of the important and difficult problems of diagnosis of diseases of the chest.

The reason for this is, no doubt, the fact that acoustics has until lately been an unapplied science. Its phenomena in nature have been subjects of wonder and superstition, rather than for education. The ancients placed them all under the dominion of Pan, the mysterious god both of noise and of silence, the unexplainable, the source of sudden fears and panics.

Bacon, the great author of modern philosophy, took the greatest interest in studying echoes, which he never comprehended as mathematical results of natural phenomena in such a way as to make them practical, as he would have done had he been acquainted more fully with the laws of sound. Laennec, who discovered the means of diagnosis by auscultation with the stethoscope, and Louis, who did so much to establish its use and to make it practical, were not learned in acoustics. Therefore it has been said that acoustics is not necessary to any one in order that he may become a good auscultator. The brilliancy of the discovery of Laennec blinded the eyes of the profession to its great possibilities then and since, so that auscultation has just missed perfection by not being based upon eternal law.

Laennec stumbled upon acoustic facts when he placed one end of a roll of paper against a patient's back and applied his ear to the other. Had he been acquainted with the laws of sound, what a grand opening would this have been for the establishment of fact, instead of ingenious theory, in explaining the laws of physical diagnosis! I would not take one leaf from the laurel crown which he so richly won; but rather would add to it that which belongs to discovery—its scientific explanation. Skoda made one more step toward this consummation when he discovered the principle of consonation. That was one more discovery which again pointed out the fact that all auscultation to be most valuable must be based upon the laws of sound, but went no further; the time was not yet.

But in this practical age of the application of the laws of sound to the telegraph, the telephone, the phonograph, and the microphone, it becomes an easy thing to apply acoustic law to the diagnosis of diseases of the chest, which will raise this branch of medicine also from the realm of hypothesis and place it upon a level with ophthalmology.

Mr. Edison, the discoverer of the phonograph, while listening to music and holding his hat in his hand, noticed that the crown vibrated sensibly to the sound, and this suggested the instrument. For, if vibrations in the air-waves could cause this diaphragm to vibrate, why should not vibration in a diaphragm also send sound-waves into the air; these waves, recorded in some penetrable substance by a point, will, on going over the same ground again with the point, reproduce the sound; and thus the discovery was made.

The discovery of the phonograph began and ended with two elements of acoustics—primary vibrations and secondary sound-waves. All sounds originate in vibrations which pass through the universal medium, the air, in waves the same as does light. The rapidity of the vibrations constitutes pitch, and is limited in recognition by the ordinary human ear, practically, between thirty-two and forty thousand in a second. Less than thirty-two vibrations in a second give the idea of distinct sounds, and more than about forty thousand in a second result in silence, too rapid to be taken notice of by the sense of hearing.

Tyndall says that if the vibrations number less than sixteen a second we are conscious only of the separate shocks. If they exceed thirty-eight thousand a second, the consciousness of sound ceases altogether. The range of the best ear covers about eleven octaves, but an auditory range limited to six or seven octaves is not uncommon. Music embraces seven octaves.

Thunder is, in nature, the lowest note which can be heard as continuous sound, and the squeak of an insect the highest in pitch; but it is possible that there are still higher notes of the insect which we do not hear, from their too great rapidity of vibration failing to send out sound-waves that could make an impression upon the tympanum.

These are fundamental principles in acoustics, and are essential in understanding the physical conditions of the chest, as we shall see whenever we make application of these laws in diagnosis.

The chest-chamber is encompassed by walls lined internally with a dense, elastic, smooth membrane—the costal pleura. The walls themselves are formed of the ribs, bone, and cartilage, which are connected by thin muscles which interlace, allowing a very considerable movement; but, whether contracted or distended, they are curved in such a way as ever to present a smooth reflecting surface covered by the pleura. This chamber has slight movement in the superior part, where there is but little cartilage, but expands largely at the base, where cartilages are attached to the ribs, lengthening them in front and attaching them to the sternum, which is itself composed of several pieces attached to each other by cartilage, in order to permit movement, and all are closed in at the base by a diaphragm of muscle with great power of expansion and contraction, so that while ever continuing a perfect acoustic chamber in mathematical form, it may be enlarged or contracted, and consequently its power augmented or diminished with the speed of thought. The upper and unyielding part of this chamber is in the form of a cone; above it, in the trachea, which passes down through it, is placed the larynx or sound-box, where voice vibrations are primarily formed and conducted in tubes in every direction to the chest-wall, where they are reflected again and consonated into a mass of harmonious sound, and, coming back, are emitted through the larynx and mouth into the open air, setting it into vibrations of speech or music for the exquisite enjoyment of all within hearing. The acoustic chamber of the chest in health is a perfect instrument for the formation and reflection of sound-waves, and it has been said that the violin, the most perfect instrument of music, was formed upon its model. As a sound-chamber it is indeed perfect, but it is liable to be altered in shape and its acoustic perfection destroyed by changes of form from intrapleural adhesions, pressure of tumors, or diseases of the spine, etc. Also, the chamber is filled with the lungs and heart and their appendages. All of these interfere with the formation of sound and its passage in waves and reflection from the surfaces of the anterior walls. But the lungs are an independent acoustic instrument, formed of tubes and sacs, for the passage of air and the aëration of the blood of the body, which is brought here and is spread out and exposed in the pulmonary capillaries by the heart and bloodvessels; so that the contents of the chest are of the utmost importance to the breathing, living, pulsating being. The membranes, in which the capillaries are spread out, are in sacs and minute tubes filled with alveoli, thin, diaphanous, and distensible to a wonderful degree, and yet contract upon the contained air with active force in alternate movements in which the air itself is a factor. Constantly renewed by inhalations about sixteen times a minute, or once every three or four seconds, the fresh, cool, pure air is mixed with warm, impure air, and vital interchanges at once commence. The fresh air expands with heat and gives up its oxygen to the greedy blood, and receives in exchange the worn-out material, carbonic and nitrogenic, as filth to be thrown out of the living organism in expiration, while the cooled, freshened, purified blood goes on to the heart to be sent through the systemic circulation, to continue the growth and nutrition of the body.

During this vital act of one respiration in the time of three or four seconds, the heart—a double pump—sends half an ounce of blood about twelve times in each direction: the right to the lungs, venous blood; the left, arterial blood, to the system. These movements of the lungs and the heart are rhythmic, and are accomplished with sound—the heart-beat and respiratory murmurs, contemporaneously. The auscultator must take in both, and give each its due importance, recognizing at the same time that they occur in an acoustic chamber, and are reflected from its walls, consonated, harmonized, and governed by definite law, and then we will appreciate auscultation as scientific. Each little sac is a resonator, distended by air constantly rarefied by heat, upon which it actively contracts, causing vibrations which help to make up the true respiratory murmur. Each sac is connected with a bronchus, and in this way with the outside air at each inspiration and expiration, and consequently sound-waves in the open air pass in and are consonated in each sac, as are also the friction-vibrations of the tidal air pushing in and out through the open bronchi. There are, therefore, three sources of vibrations going to make up the true respiratory murmur, and each one can be distinguished by the organ of hearing placed in audible connection with the chest-wall. Nor does the fact that the chamber, or its contained system of tubes and consonating sacs, may have lost much of their acoustic perfection make it any the less necessary to apply these laws in order to make a correct diagnosis of the location, extent, and condition of the injured part. On the contrary, it increases the necessity, for by the application of these laws we measure the deficiency in the only scientific way.

The lungs may originate sound-vibrations in the air-sacs when in perfect condition only — that is, only when the walls of the sacs contract upon the contained air causing muscular sound-vibrations, called muscular susurrus, which is consonated in the compressed air of the sacs into a body of sound.

They may also receive vibrations from without, or from friction of the moving air within the tidal space of the convective system—that is, within the space from the entrance at the mouth and nose into the bronchi, as far as there are developed cartilaginous rings to keep them patent, or until about the fourth division. Here the tidal air meets the residual air and immediately becomes a part of it, or in so short a time as to be practically immediate, by the law of the diffusion of gases, but which is evidently assisted by the contraction of the distensible bronchi, without cartilage, within the true respiratory system. The tidal-air space, where the bronchial tubes have cartilaginous rings to keep them open, is the location of friction-sound—the air moving in and out—and this friction-sound, as well as sound-waves in the open air, are consonated in the air-sacs.

The distance between the tidal-air space and the air-sacs is filled with compressed air, confined in distensible tubes in connection with the air-sacs, and together they form the true respiratory system. These tubes do not originate sound; the residual air does not cause friction. The vibrations from without and the friction in the tidal-air space are not consonated in them, but pass through them silently as the sound in a speaking-tube. It is spoken at one end of the tube and heard at the other, but not along the course of the tube, for the sound-vibrations are only at the ends. This is an acoustic law of importance in diagnosticating diseases of the lungs, for where unusual sounds or noises come from the true respiratory system other than acoustic consonations, or the muscular susurrus of the sacs, it is an evidence of disease, and is caused by conduction by pathological products. Conduction then becomes an acoustic fact of warning; pathological changes have taken place.

The heart, also within the chest acoustic chamber, originates sound; it also obstructs sound, and at the same time conducts sound, which seems paradoxical, but is true. Its particular and useful office is to pump the blood into the great arteries and through their many divisions until it comes within the influence of attraction by affinity—that is, the aërated blood is sent from the left heart with force commensurate with its purpose, and is assisted by the great arteries following in contraction sending the blood on until it is near enough to come under the influence of the attraction tissues eagerly waiting for the coming nutrition.

Without this attraction between the blood and the tissues the circulation could not go on. The physical force of the engine—the heart and arteries—sends it but a certain distance; affinitive attraction does the rest. A power sufficient to send the blood through the capillaries would destroy them. So the forces are divided. The heart, the arteries, and the capillaries act in unison, and their harmony is evidence of health; their want of harmony, of disease. The right heart beats exactly in the same time as the left. In fact, they have the same beat. In sounds and rhythm the right, like the left heart, has three sources of force—the heart, the arteries, and the capillaries in the true respiratory system. There is this slight difference; the right heart is a little weaker, the arteries are not so strong nor are the capillaries as vigorous. This is, no doubt, owing to the fact that the circulation itself is shorter and less force is necessary to complete the circuit, and because of the active affinitive attraction between the air and the blood, and because both are free to move toward each other. Both hearts are indeed but one engine. One power moves both in the same moment of time; there is no such thing as heterosynchronous action. Harvey noticed in his study of the incubation of the hen's egg, that the first appearance of movement in the germinal spot after about two days was a red point which appeared and disappeared rhythmically. This is the first evidence of organic life, or life of the body, and this rhythmic movement commences before there is any heart, or even a rudimentary pulsating tube, which answers in the lowest forms of animals for a heart. The rhythmic movement is *sui generis*. It is the one characteristic, manifest action of organic life in man as well as in animals of a lower order. Rhythmic movement is primary evidence of a commencing independent existence, here it builds its home; first, the simple pulsating tube, which becomes an auricle, and then a ventricle is added, and then in time another auricle and another ventricle, and becomes a double heart, and the arteries are pushed out until finally there is a perfect body—two circulations, a digestive apparatus, a brain and nervous system—a man. But still the rhythmic pulsations of the heart go on counting time until the last one, when life ceases and decay begins—the cycle of human life.

The heart's sounds may be brought into the chest-wall at two different points, from or by either heart, by conduction, and thus give the idea of duplication; but the application of acoustic law corrects the illusion.

In the human chest the heart lies, or is hung, in the middle, obliquely, the apex pointing to the interspace between the fifth and sixth ribs, while the base extends to the right upward and backward, and it is partly in the right and partly in the left chest. It is attached to the mediastinum and to the root of the lungs, and is capable of considerable movement up and down and laterally, outside of the rhythmical beat. It is inclosed in a sac, arising from the bloodvessels, lined upon the inside and covered upon the outside with serous membrane—the pericardium. This sac lies naturally in intimate connection with the heart, conducting sounds perfectly, without adhesion or pathological attachments.

The lungs, separated in the middle by the mediastinum, fill the chest with the exception of the heart, which has a space hollowed out in them for it, only leaving a triangular space in front uncovered—the apex-beat area, where it comes against the chest-wall, and into which is delivered its sound directly, nothing intervening but the close-fitting pericardial sacs.

This, perhaps, tedious description of what you learned so carefully in your student days is only given to remind you how entirely it all agrees with the laws of sound. The lungs press against the inner chest-wall during full inspiration in every space except that of the apex-beat area, which is occupied exclusively by the heart in health. The lungs convey sound through their convective tubes and deliver it into the chest-wall through the air-sacs with diminished intensity during expiration and with increased intensity in inspiration. The lungs are a perfect conductor of sound in the direction of their columns of air in tubes, but are non-conductive in any other direction. The lungs shut off all sound coming from the heart, except by natural direct conduction through the mediastinum, in all parts covered by them; so that whenever the heart-sounds are heard otherwise through the lung-substance it is acoustic evidence of pathological change. Either the lung is condensed by pressure, or there is consolidation or adhesions. The heart delivers its sounds only by indirect conduction through the mediastinum to diagnostic points in and near the sternum; but directly, into the apex-beat area, with diminished intensity during the diastole and increased during the systole, because it is then pressed against the chest-wall. Of course, the heart shuts off all respiratory murmurs within the apex-beat area. It conducts sound when pressed against the chest-wall, or when there is consolidation of the lung, or adhesions attaching the pericardial sac to the lungs and the lungs to the chest-wall.

As said before, the heart is a double pumping-engine, its stimulus of contraction and repose being fundamental in the organic life of the body. The rhythmical heart-beat, commencing before the heart had structure or form, still marks the time of the individual life—seventy to eighty beats per minute ordinarily, sometimes slower and sometimes faster—as if nature had originally intended it should be sixty per minute, and something had disarranged its beat. But any notable change has come to be a sign of danger.

The heart is a hollow muscle divided into two chambers and united by a common wall—the septum ventriculorum—and during the closure of the auriculo-ventricular valves each side is again divided into auricle and ventricle. When the heart is at rest there are two chambers; during contraction there are four. The blood enters the heart on either side through the auricles during the heart's rest after contraction, passively distending it, and floating the auriculo-ventricular valves up to their proper place, dividing each heart into two chambers, with doors not quite closed, when the motion of contraction, commencing in the auricles, instantly passes into the ventricles, closing tightly the auriculo-ventricular valves and forcing the contents of the ventricle into the open aorta and pulmonary artery. Then follows muscular relaxation. The resiliency of the aorta and pulmonary artery, reacting, brings back the blood with force and closes the semilunar valves, and holds them until they are again forced open by the blood, which is again forced into the artery and throws the valves back against their walls for its easy passage.

The heart works and rests, contracts and relaxes. Auricle and ventricle in action are one. And were it not for the closure of the semilunar valves forcibly by the return shock of blood in the arteries, there would be no mystery in the sounds and intervals of silence in the cardiac cycle. It would simply be contraction and relaxation—one sound and one interval of silence. But the return blood, closing the semilunar valves, makes another sound and divides the interval of silence into two parts, one short and the other long, and thus we get the rhythm of the cardiac cycle. The first sound is long, formed entirely by the heart's contraction, occupying about one-third of the cycle, and is emphasized by the apex-beat; the interval from the apex-beat until the "tack" sound of the closure of the semilunar valves is the first interval of silence, short. And this gives us the rhythm; first sound long, first interval of silence short, second sound short, a mere "tack," and then follows the long interval of silence, filling up the cycle.

The study of the heart's rhythm is entirely acoustic, and its right apprehension is of far more importance than all the other signs together, for there can be no alteration of the rhythm without pathological cause. Murmurs may be heard, and in various areas, and mean little or nothing if the rhythm remains correct, but the slightest variation in rhythm means possible danger.

The closure of the valves causes the second sound, and divides the interval of silence.

As to the mechanism of the first sound there are different opinions. More than twenty years ago, before the County Medical Society of New York, I gave a synopsis of the views held by the profession of that time, and presented my own, which I then believed agreed with acoustic law and physics. I feel more sure now than then even that I gave the true philosophical explanation. It is this: The mitral valve (and the tricuspid) are curtains closing the auriculo-ventricular openings. They are floated up to their plane by the inwelling blood during the relaxation of the heart, and are held by tendinous cords attached to the valves and to the fleshy walls of the ventricle through the intervention of fleshy columns or the small muscular elevations arising from the interior walls. These tendinous cords hold the curtains of the valve and prevent them from being forced through the opening. They are strong, take up but little space, and offer a minimum obstruction to the rushing blood. The valve, the ventricle, the columnæ carneæ and the musculi papillares contract in such a nice way that the curtainsof the valves are kept in exact coaptation and resist the forcing blood and turn its stream into the course of the natural exit. When every drop of blood has thus been forced out of the ventricle the heart relaxes and the semilunar valves are closed. To repeat: The curtains of the valves are floated up to the closure of the auriculo-ventricular system, without force, for as yet there is no contraction—then, like a flash of lightning, the contraction commences in the auricle, instantly passes down into the ventricle, and the valves are forcibly closed. Of course, there will be sound. The stretched and vibrating membrane of the valve gives a drum-like sound of low note; the chordæ tendineæ are also thrown into vibrations in harmony with the valve, but of higher pitch.

As the contraction of the heart goes on, the valve-note grows less and less and the higher note of the chordæ increases until the apex strikes the chest-wall and relaxation commences. This is the mechanism of the first sound. It begins in a low note, and gradually increases in pitch until apex-beat. As the whole cycle is about only one second, the time of the first sound is not more than one-third of a second—a very short time in which to make observations of a complicated contraction of a hollow muscle, which suddenly begins to contract upon its contained blood and to expel it from its suddenly formed, bound, girded compartment, rapidly contracting in size until it has ejected all within and the apex is brought against the chest-wall with force. Then as suddenly relaxing, every muscular fibre, the chordæ, and valves lying loosely and without force in the midst of the greater chamber, which fills passively with blood, floating the valves into place for the artificial division when the contraction again binds, girds, and holds the compartment, while it systematically contracts in size, expelling its contents. All of this is done with accompanying sound—first of the valve, then of the valve and vibrating cords, and lastly of the cords alone, and is ended by the stroke against the chest-wall, all in one-third of a second, to be commenced again after two-thirds of a second of relaxation, divided into two unequal parts by closure of the exit valves and the second sound.

The heart does but one thing: it contracts. The relaxation is passive. Whatever else takes place is outside. The muscular susurrus, however, of the heart-muscle is a physical fact; also the blood friction rushing through and among the chordæ and against the tense vibrating valve, which has suddenly divided the right or left heart into two compartments—auricle and ventricle.

The auscultator will become learned in the rhythm of the heart's cycle, the quality of its sounds, and the length cf its intervals of silence. Like the engineer with his engine, or the clock-maker with his time-piece, he becomes intimate with its sounds or murmurs, and they constantly communicate with him in a most intelligent manner. If the engineer is asleep and the rhythm of his engine is disturbed, he instantly awakens. The clock-maker of old used a stick of wood between his ear and the clock to listen long before Laennec was born, and he could detect any change in the regular movement of the works or the tick at once.

The first sound, then, is formed by the vibrations of the tense mitral valve, by the tense chordæ, the sound of muscular contraction, and the friction of the blood. If it loses the valve sound—the low, drum-like note—we know that the vibrating power of the valve is affected. If it has also lost the higher note of the vibrating chordæ, we know that they are affected pathologically. If the valve and chordæ sounds are both gone, then all that is left of the first sound is of blood friction and muscular contraction. If the first sound is increased in energy, and the first interval of silence in length, and the second sound is emphasized with the second interval of silence shortened, we know that there is obstruction at the aortic orifice, or regurgitation, and there will be arterial tension. But regurgitation is practically obstruction, and must soon cause hypertrophy; but hypertrophy is compensation. When compensation is sufficient, arterial tension will have subsided.

In our description of acoustic facts we now come to the organ of hearing in the ausculator, in which we will content ourselves by describing it as inclosed within the temporal bone of the skull, with entrance to it from without by a curved foramen across which is stretched a membrane—the tympanum—which receives the waves of sound, registers them, and communicates them to an interior mechanism of curious and scientific construction, the description of which we will not now indulge ourselves in. The tympanum is supplied with small muscles and bones, which act as machinery to make it tense or relaxed as may be necessary for its acoustic purpose. There is also an entrance for air to the opposite side of the tympanum of great importance to its usefulness.

The methods of auscultation are by placing the ear against the chest-wall so that the drum may receive the vibrations; or by a piece of wood or other sonorous substance placed one end against the external ear and the other against the part to be auscultated; or a tube may enter the external meatus or opening to direct the sound-waves against the drum. The binaural stethoscope of Cammann, conveying twin waves to either drum, is, in mechanism, the most perfect instrument for artificial auscultation invented. But, while stethoscopes have particular advantages and claims for use as a means of avoiding filth and vermin and for direction and limitation of object (and their use must be cultivated), yet for accuracy, delicacy, and freedom from acoustic imperfection or injury from outside causes, nothing equals the temporal bone of the head, placed against the sonorous object, so that the sound vibrations may pass directly into it and to the organ of hearing. One may have occlusions of the Eustachian tube and the hearing will be impaired, or there may be injury of the drum and the person may be deaf, but if he is accustomed to receive sound impressions from vibrating bodies directly into the temporal bone, he will not lose his power of auscultation because he is deaf by injury of the drum. The whole side of the head is sensitive to direct vibrations delivered directly from a sonorous body. But the most sensitive part is in front and just above the external ear. Here, in this way, the nicest discrimination of sound can be made, and, under the laws of acoustics, correct diagnosis. It is not affected by age, by the accumulation of dried wax in the ear, or inflamed throat closing the Eustachian tubes. It measures the time in the heart's cycle with unerring certainty and detects the slightest fault in rhythm, and, of course, detects the earliest evidence of pathological change in the respiratory murmurs—their analysis and cause, their locality and manner of conduction into the chest-wall—are all noted by this perfect acoustic instrument, a microphonometer.

Sound is caused by vibrations which send off sound-waves into the air, the universal sound medium, spreading out in every direction until they finally die away from diminished force. Causes of primary vibrations are readily illustrated by air forced through a tube, by a tense cord over which a bow is drawn, by a bell, or a bar of steel fastened at one end, set in motion by a stroke of a hammer or otherwise.

It is necessary, in order that the vibrations should produce sound-waves, that they should have definite force and frequency. The force of the primary vibrations must be sufficient to send off sound-waves into the air, and of frequency somewhere between thirty-two and forty thousand per second. Less than thirty-two per second produces a sensation of distinct noises, and more than forty thousand ceases to give off sound-waves. The designations of high pitch and low pitch have reference to the frequency of vibrations, and are of practical importance in determining the density of sonorous bodies under examination. High pitch denotes density, low pitch porosity. The pitch enables us to measure the number of vibrations in a second in any body under examination, determining the density; for, with an instrument called the siren, we can measure the number of vibrations in a second in any pitch, which brings acoustics under mathematical demonstration as an exact science, especially including auscultation of the human chest.

There are other limitations of hearing than those of pitch and loudness, which are more readily understood by comparing them with color-blindness in sight, the persons with such deficiency in either case not being themselves aware of it. Engineers and flagmen on railroads are examined in regard to their perceptions of differences in color in the protection of the lives and bodily safety of the travelling public. Why should not also the medical student, before devoting himself to physical diagnosis, test himself, or have himself tested, in regard to clang-deafness[1] before taking upon himself the responsibility of making delicate diagnoses where failure to appreciate the tone differences in the acoustic signs may lead to a plan of management fatal to the patient?

These inquiries approach the domain of æsthetic taste at the same time that they have the solid foundation of practical truth.

The entirely correct ear in auscultation gives its possessor pleasure in listening to natural sounds in the fields, in the forests, on the extended plains, or on the mountain tops—all of which are but dreariness to one who has not that inner sense of the beautiful in nature dependent upon tone appreciation.

In the wonderful music drama of "Siegfried" the natural sounds in the forest—the singing of birds, the drone of insects, the sighing of the wind among the leaves of the trees—are reproduced in music, the "Waldweben." The correct acoustic sense that fits the student for an auscultator will be delighted and appreciative; but the clang-deaf will not hear the melody. It must be noted that this higher quality of tone recognition is entirely different from memory of a tune, which is memory with a sense of time and rhythm only, and enables its possessor to learn and sing "The Marseillaise" or "God Save the Queen" without any thrill of delight in their harmonious chords and spiritual suggestions.

It is an interesting point to determine by trial whether the color-blind are also clang-deaf, which would show, if decided in the affirmative, that the deficiency is not owing to any mechanical fault in the structural formation of the organs of sight or hearing, but is essential in the organic or spiritual life of the body. One fact is demonstrable—that the senses of hearing and sight may be greatly extended in range and accuracy by cultivation. This is seen in experts in music and painting. Culture increases the power of discrimination and delight in color and in tone in the masses, while the exceptionally natural, sensitive sense of sight and hearing will be increased thereby to expert excellence.

Primary vibrations may be conducted, reflected, or consonated. If there is in contact with the vibrating body another body or structure capable of being set into vibrations, the vibrations of both will be in unison; or, as in the case of the lung connected by adhesions to the chest-wall, or by intermediate structures, or by tense cord-like adhesions

[1] Helmholtz uses this term to denote a tone with its accompanying overtones and partial tones.

of any length, then the secondary body—as the chest-wall is when the lung is adherent—may give off sound-waves which will pass into the air the same as if coming from a primary source. The familiar example of direct conduction is the one given of scratching the end of a log with a pin by one person while another listens at the other end, fifty feet away, and hears by illusion the sound under the ear. In such a case there is no solution of continuity, nor is there in the consolidated lung, by which also there is direct conduction. Indirect conduction of sound takes place when there are adhesions of parts to parts adjacent, as of the pericardial sac to the lung, and the lung to the chest-walls, when the heart's sounds will be heard at the site of adhesion of the lung to the chest-wall, although the origin of the murmur may be in another direction and a long way off, and yet will seem to originate directly under the stethoscope, which fact may give rise to false diagnosis. For the natural intraventricular vibrations of a portion of the chordæ are in sound-connection with the pericardial adhesion and are indirectly conducted into the chest-wall, are there heard as if originating under the ear, while there is no fault with the mechanism of the heart as a pump. This shows the fallibility of the stethoscope as an instrument of precision. The locality of the murmur in the chest-wall may be no guide as to the local mechanism or origin of the sound.

Indirect conduction may be illustrated by the violin. The strings are caused to vibrate by the bow primarily, but these vibrations are conducted by the bridge into the front or belly, which is made of straight-grained pine cut so that each fibre may vibrate separately and in unison with the strings. The sound-post conducts these vibrations accumulatingly to and against the back of the violin, which is made of maple or sycamore wood of interlaced fibres which cannot vibrate in unison with the strings, but reflects the vibrations back into the air in the acoustic chamber. The sonorous material corroborates the vibrations at each passage from the strings to the bridge, from the bridge to the front, until they are reflected from the back into the body of pulsating air within the violin, which finally passes them out of the sound-holes into the open air.

Reflection of sound is the opposite of conduction, and in a sound-chamber prevents sound-leakage — in the violin through the back especially. In the human chest the pleural lining reflects equally from all directions. This acoustic fact becomes of diagnostic interest when adhesions connect the internal organs with the wall, or when they press against it, as when swollen, or are hypertrophied, etc. Then sound-leakage takes place. Echoes are reflected sound-waves, either parallel or converging. Reflected sound pertains altogether to sound-waves—not to primary or conducted vibrations.

Consonation also has to do with sound-waves alone. It has nothing to do with primary or conducted vibrations. Let one sing before a sensitive violin, and each string will be made to give sound vibrations whenever its fundamental note is sounded. Consonation is one of the most frequent phenomena of the human chest, and is constantly made use of by auscultators practically in searching for consolidation of the lungs or interplural adhesions or cavities, by sounding the voice in phonation, or whispering, or by the cough. Dr. Holden, of Newark, N. J., introduced a little instrument to the profession a few years ago which illustrated consonation practically. It was an India-rubber tube an inch in diameter, about fourteen inches long, with a metal mouth-piece at either end. The patient would breathe through the tube forcibly so as to create air-friction, while the auscultator would listen to his chest. If there were adhesions or any condensation of lung-tissue, it would be made evident at once by consonation and by the conducted sounds heard through the chest-wall; also, if there were cavities at the same time, it would diagnosticate them from tumors or consolidations, which otherwise may not so easily be done.

When these principles of acoustics are applied—consonation, reflection, and conduction of sound—an interior view of the chest is opened to us as through a window. Much more is this evident in disease when we have previously applied these principles to the conditions of health.

The lungs fill the sound-chamber and envelop the heart, with the exception of the apex-beat area. They are non-sound-conducting except in one direction—in that of the columns of air in the convective or air-conducting tubes.

The little group of air-sacs, six to thirteen in number, developed at the terminal ends of the air-tubes of the true respiratory system, forming a lobulette, do the principal work of aëration of the blood the alveoli of the distensible tubes being but supplementary to those of the air-sacs. The delicate muscular fibres over each alveolus and each air-sac contract upon the contained air, which is constantly expanding under the influence of heat; and sound vibrations are thus caused during inspiration, and especially at its full; individually small, but collectively forming a body of sound of low note. This murmur is significant of the healthful action of the vital process of respiration. If its process is interfered with by paresis of the enveloping muscular fibres, which always takes place in emphysema or in tuberculosis, the muscular susurrus, the true respiratory murmur, will not be heard. But when the disability is but temporary it is interesting to watch the gradual return of the murmur under successful treatment.

In centric pneumonia there is no other physical sign than the true respiratory murmur, except slightly raised pitch under percussion. This acoustic condition may remain scarcely changed for three or four days, but as soon as the pneumonic process has reached the pleural surface, immediately the physical signs show the fact. At once are heard interpleural râles and bronchial breathing, which denote consolidation of the lung and increased conduction of sound from air-friction in the tidal air-tract. The pneumonic condition existed just the same while there was yet no adhesion, but instantly became evident when sound-connection was established.

The early recognition of centric pneumonia gives time to prevent the pleural complications; a very important matter as regards pathological results. The greatly diminished true respiratory murmur over a definite area, corroborated by the slightly raised pitch, fixes the locality, completes the diagnosis.

To those who do not recognize the true respiratory murmur from want of attention or from imperfect sense of hearing, these cases are puzzling, for the rational signs indicate in a doubtful way the pneumonic state, pulse, temperature, and respiration slightly increased, with bloody or rusty sputa.

The recognition of the absence of true respiratory murmur in the centre of the lung will enable the auscultator to make a correct diagnosis and to predict a sudden augmentation of all these signs and symptoms, physical and rational, in a given time—*i. e.*, just as soon as the pleura becomes involved, and the gluey exudation forms sound-connection between its surfaces.

In the normal chest the freedom of movement of the pleural surfaces gives evidence of health. For, as the lungs fill with air and the chest-wall expands, each little lobulette travels a little distance in inspiration and back again in expiration. If the ear or stethoscope is placed against the chest-wall, a multitude of these little resonating air-sacs, each attached to a terminal bronchus—a minute speaking-tube—will pass under review and give sound vibrations: first, of themselves in the true respiratory system; second, of the air-friction in the tidal air-tract—which extends from the entrance into the mouth and nostrils, into the respiratory passages, down as far as to the fourth division of the bronchi—in which the air moves in a body; and, third, outside noises.

Respiratory murmurs are composed of these three elements, which are all intensified by passing rapidly in review in a lively movement of the lungs under the ear in auscultation. Interpleural adhesions fixing the lung in one place are denoted in this way, by the feeble respiratory murmurs, even when the air-sacs are free to contract and dilate as usual.

Every elastic air-sac dilated with compressed air is a resonator, the sounds consonated in which are, first, sounds outside of the body. Auscultators for this reason choose a quiet room in which to make their examinations, and sometimes, too, make the mistake of attempting to exclude outside noises by closing the opposite ear with the finger, which adds unnecessary confusion and shuts off nothing but their fixed attention. Second, the air-friction sounds formed in the tidal air-tract, which are conducted to and consonated in the air-sacs, such as sounds of dryness or of roughness, of mucous râles, and of foreign bodies.

In the first stage of acute bronchitis the mucous membrane is dry and rough and the air-friction gives sounds accordingly, which are conducted to the air-sacs by the bronchial tubes, in which they are consonated with increased intensity. Mucus formed within the bronchia moves forward and backward in inspiration and expiration, causing mucous râles, which also are conducted to and consonated in the air-sacs, especially when adhesions increase the conduction into definite localities. Many times the mucus and the râles are both immediately removed by coughing and expectoration. The mucus is a foreign body, and, like all foreign bodies, should be removed.

The following cases are briefly referred to as evidence of the value of acoustic signs in diagnosticating the presence and locality of foreign bodies in the air-passages:

Case I. *A Spanish silver shilling diagnosticated to be in the third division of the right bronchus.*—A man, hurrying to catch a ferry-boat, put the coin in his mouth for convenience, and during a forcible inspiration it passed through the larynx. He came to me in the afternoon of the same day and told me that he had "swallowed" a shilling, and that he thought it was in the lungs. I then believed that it was impossible that a foreign body could pass the epiglottis. Dr. Horace Green had then but lately announced his ability to pass a catheter through the larynx. A committee appointed by the Academy of Medicine, after experiment and inquiry, had reported its impassability. I told the patient so, "but," said he, "I think I can feel and hear it here," placing his hand upon his chest. I listened and heard a "flap" in just about the fifth interspace in the right side. Keeping my ear to the chest, in a few moments there was another "flap," sending the sound in another direction. I soon discovered that after each "flap" a certain area of the chest-wall ceased to transmit respiratory sounds, which only lasted until the next "flap," when another area of the chest-wall became quiet. I was convinced that the coin rested its edge upon the septum of the third division, and, valve-like, turned back and forth as the newly inspired air underneath became rarefied by heat. I directed him to get on his bed and place a cushion on the floor near the bed, and then suddenly to turn down and bump his head upon the cushion, which he did, and the coin was expelled with an explosive cough.

Case II. Through the kindness of Dr. W. W. Jones I saw a man who, three days before, had passed a head of timothy through his larynx. He had placed the stalk between his teeth and was chewing it while giving directions in his stable, and, suddenly attempting to call to some one at a distance, he drew in his breath, and with it the dry head of timothy. One can hardly imagine a more frightful calamity. He coughed some, but did not think it necessary to send for Dr. Jones until the next morning, and even then he did not believe the timothy had passed the larynx, the symptoms were so much less than might have been expected. But they gradually became serious, and on the third day I was called in to auscultate him. There was then no true respiratory murmur and there were interpleural râles over both lungs, but on the right side there was conducted bronchial breathing down so low that I thought it involved the liver. The next day he coughed and vomited up a large amount of muco-pus, and in it was the denuded stalk of the timothy-head, after which there was a cavernous respiration. The autopsy showed abscesses in both lungs and extensive interpleural adhesions.

Case III. *Blood in the right bronchus and lung.*—This occurred in a surgical case in St. Luke's Hospital, New York. A man was operated upon, while under the influence of ether, for the removal of dead bone in the jaw caused by phosphorous poisoning. While unconscious the blood trickled through the larynx and bronchia into the true respiratory system beyond the tidal air-movement, where it speedily putrefied and formed abscesses which caused the patient's death. I saw the patient each day and was able to note the physical signs. The first day there were conductions of bronchial râles, caused by the moving blood within the tidal air-space, and obstruction of the true respiratory murmur. The next day there were interpleural râles over both lungs, although the blood had passed mostly into and through the right bronchus. On the third day there was local peri-bronchitis with consolidation of the surrounding lung. On the fourth day there were moist râles in and around the consolidations. On the fifth there were cavities. On the sixth day there was general acute plastic exudation over both lungs. He died on the seventh day. The post-mortem showed that the pathological processes had been accompanied by the acoustic signs in each particular. The case was an "object lesson" of value to me—full of instruction in regard to the treatment of bronchorrhagic hæmoptysis, and makes plain the danger of attempting to arrest bronchial hemorrhage for fear of getting a clot below the tidal air-tract, where it rapidly causes destructive inflammation and cavities, and the patient dies, as is said, but which is a mistake, of "*acute phthisis.*"

Case IV.—The next case in time was Dr. Gurdon Buck's—a tracheotomy-tube in the right bronchus of a patient at St. Luke's Hospital—an account of which he published.

A man came into the hospital with gummy tumor occluding the larynx, and immediate tracheotomy was necessary. The next day the opening was enlarged and the tumor removed, and a tracheotomy-tube of hard rubber was introduced, corked, and tied with a tape at the back of his neck. This was for safety in case any sudden swelling should obstruct the larynx, and he was allowed to walk about the grounds and corridors. After three or four days, on awakening early in the morning, he discovered that the tube was gone. "The House," Dr. Riggs, and "the Junior," Dr. Lefferts, were at once called, but the tube could not be found. At Dr. Buck's request I auscultated the patient and found acoustic evidence of the tube in the right bronchus. It had dropped down and the lower end was engaged in the very short first division, which is subdivided into two or three bronchia distributed to the apex of the lung. Over this region alone the air friction in the tube could be easily heard. A consultation of all the surgeons and physicians of the hospital was called for the next day, and the tube was removed with a curved forceps.

Case V. *A molar tooth "swallowed" by a man while etherized at St. Luke's Hospital.*—The House Physician, Dr. Lefferts, diagnosticated its presence in the left bronchus, but the patient utterly refused an operation until destructive inflammation had done its work. Dr. Lefferts requested me to auscultate the patient, and I confirmed his diagnosis. The tooth was impacted just above the third division of the left bronchus, and two abscesses in the lung below had resulted. I have a photograph of the tooth in the bronchus, kindly given me by Dr. Lefferts.

Case VI. *A collar-stud in the right bronchus, occurring in the practice of Dr. J. T. Kennedy.*—A boy playing ball, becoming very warm, took off his collar, and put the bone stud between his teeth, but, attempting to shout to another boy at a distance, the stud was carried through the larynx by inhalation into the right bronchus. It caused some irritation and cough, but his discomfort was not great. After some days, perhaps weeks, Dr. Kennedy brought the boy to my office for auscultation. There was acoustic evidence of a foreign body in the right bronchus, just above the third division, the broad button side of the stud being pressed against one side of the bronchus and the cone end against the other side, and the shank extended between. After a time plastic exudation took place in the pleural cavity and in the lung, and the father, who had before refused, consented to an operation, which was tracheotomy, and was performed by Dr. Markoe, who removed the stud with a curved forceps.

Case VII. *Dr. Lefferts's removal of a brass ring from a boy's larynx by operation.*—A brass wire, bent so as to make a nearly closed ring, was in a child's mouth, and a woman, endeavoring to get it out with her fingers, pushed it below the epiglotis. It remained there about two years, although the child had been taken to clinics and to different doctors without relief. By the kindness of Dr. J. L. Smith, the boy was sent to my office, and the ring was traced acoustically to the upper part of the larynx. I sent this patient to Dr. Lefferts for laryngoscopic examination, who confirmed the acoustic diagnosis, and removed the ring by an operation. The case was published by Dr. Lefferts.

Case VIII. *A man with part of a peach-pit in the right lung.*—After several months it was coughed up, but not until it had caused permanent injury to the lung. In the meantime he was frequently examined at my office, the acoustic evidence showing that it had passed beyond the tidal air-tract.

Case IX.—A child, about two years old, "swallowed" a plum-pit, and it passed through the larynx and into the right bronchus, but its exact location was difficult to make out, because the child could not be kept still enough for a careful examination, and also because the true respiratory murmur is not fully developed until after twelve years of age, but it was presumably in the tidal air-tract. It was finally coughed up, being assisted by a blow upon the child's back by its mother.

Case X. *Dr. J. A. Wyeth, at Mount Sinai Hospital. A little dart, made of a pin and yarn, used by children to blow through a tin tube at a target, in the right bronchus.*—The boy inhaled, and the dart passed through the larynx and into the right bronchus. By the kindness of Dr. Wyeth, the late Dr. Elsberg and I were requested to examine the boy. Dr. Elsberg could see its shadow with the laryngoscope, and I had acoustic evidence of its presence just above the third division of the right bronchus, and that it moved up and down in respiration as thickened mucus frequently does. Dr. Wyeth performed tracheotomy, and the dart was removed.

These interesting cases of foreign bodies in the air-passages are summarily alluded to for one purpose only—to show with what certainty their presence can be ascertained by applying the laws of sound in auscultation.

I have already given an explanation of the mechanism of the heart's sounds as agreeing with acoustic law. In studying the philosophy of murmurs we must remember that the heart is inclosed in a sound-chamber, enveloped in a non-sound-conducting medium—the lungs—with the exception of the apex-beat area, in which the heart has sound-conduction into the chest-wall in perfection only while the heart is in contact with it. There is at all times more or less conduction of sound, because of the immediate connection of the pericardium with the heart while in sound-connection with the chest-wall. So that the first sound (and the murmurs connected with it are the only ones formed within the heart) is heard in its entirety from its commencement until it is ended with, and emphasized by, the apex-beat. The second sound is formed by the forcible closure of the semilunar valves by the return blood in the aorta and pulmonary arteries. It is a door forcibly closed, and the sound is conveyed through the cardiac wall to the apex-beat area by conduction. It is also conveyed through the mediastinum into the sternum and adjacent chest-wall of the left side. The closing of the semilunar valves of both the pulmonary artery and of the aorta have the same source of conduction, the mediastinum, and into the same area. The different areas marked out by teachers and writers as the separate localities of these murmurs have existence only in their imagination. Because there are two sets of valves, a very short distance apart, it was imagined that there must be two areas, and so they were marked out.

Both hearts contract in absolute unison, the valves close in the same moment of time, and there is perfect synchronism of the two heart's sounds—the first and the second. And the intervals of silence must remain in exact synchronic proportion so long as the heart remains in perfect mechanism as a pump. The perfect rhythm of the heart's sounds and intervals of silence in the cardial cycle becomes absolute proof of its perfection as a pump. The heart may be weak, irritable, and irregular in its action, but if the rhythm of the sounds and intervals of silence in the cycle is correct, there is no valvular incapacity, no matter what may be the disturbed action of the heart or the number and location of its murmurs. But as soon as the rhythm is altered, its extent will measure the amount of injury the heart has received, and then the murmurs of obstruction and regurgitation will point to the locality and nature of the disease.

Obstruction of the aortic orifice will cause a murmur which, by conduction of the mediastinum, will be heard at its point of attachment in the sternum and to a short distance into the chest-wall of the left side. It will also be heard in the course of the aorta, and especially in the right border of the sternum, through the attachment of the aorta to the chest-wall, for at these points there is indirect conduction of vibrations through the stream of blood into the chest-wall. The aortic and pulmonary signs part company at the first point in sound-convection through the mediastinum into the sternum which they have in common over the aortic valves.

The murmur vibrations at the right border of the sternum come through attachments to the aorta alone, and are conveyed in the stream of blood from their origin at the aortic orifice.

The regurgitant murmur at the aortic orifice will be heard in the sternum through the mediastinum, sometimes extending to the xiphoid cartilage, or in the stream of regurgitated blood against the heart's wall and into the chest-wall about half an inch from the valve, but occasionally to the apex-beat, this depending upon the force of the vibrations. So that the diagnoses of lesions of the aortic orifice and valves are generally easily made out, but the feebleness of the regurgitant murmur at times renders its recognition of difficult appreciation to those who have a limited sense of hearing, or where the acoustic conditions of the chest have been altered by inflammation of the lungs, or by effusion into the pleural cavities, or by hypertrophy of the heart, or contraction of the chest-wall bringing it over a large space into sound-contact with the heart.

Lesions of the mitral valve cause murmurs. The obstructive will be heard at the apex-beat area alone, but the regurgitant almost exclusively over an area at the back near the spine, between the seventh and eighth vertebræ of the left side. The stream of regurgitant blood strikes upon the wall of the left auricle, which lies in sound-contact with the œsophagus, the aorta, and the intervertebral cartilage. Whenever the murmur, the acoustic sign, is absent from this area, it may be safely asserted that there is no regurgitation. If there are no conditions causing intraventricular murmurs—that is, unusual vibrations of the chordæ tendineæ—the true regurgitant murmur *may* be conducted through the cardiac walls backward to the apex-beat area. But this is of rare occurrence, and can only be the case when plastic exudations upon the chordæ prevent their sound vibrations, or where the imperfection of the mitral valve is congenital and does not affect the normal vibrating conditions of the chordæ. Otherwise their excessive sound-vibrations drown those of the mitral lesions. These unnatural vibrations of the chordæ, representing so-called mitral obstructive murmurs, demand special attention, as their frequent misapprehension is the cause of disastrous false prognostications.

We have endeavored, heretofore, to show that the joint sound-vibrations of the chordæ and the mitral valve in health give us the perfect first sound. Any cause, within the heart or without, affecting the natural vibrations of the valve and chordæ, will alter the joint sound and cause an interventricular murmur, so sensitive are they to acoustic law.

If obstruction at the aortic orifice occurs, requiring greater muscular contraction of the ventricular wall, the cardiac muscle, following the universal law, hypertrophies under the increased exertion. Hypertrophied cardiac walls with greater power of contraction increase the tension of the chordæ, multiplying the vibrations, and the raised pitch causes discord in the first sound, and becomes a multiform apex-beat murmur. Plastic deposit on the valves or upon the chordæ, lessening their vibrations, will also cause a murmur. Whenever a murmur is the result of physical change it is properly an organic murmur, even when it may be removed by treatment.

There are other forms of interventricular murmurs: those owing to neurotic conditions outside of the heart, as from chorea, from exhausting hemorrhage, or from nervous excitation of any kind. Another frequent cause is adhesions of the pericardial sac to the lung, and of the lung to the chest-wall, producing an interventricular murmur conducted into the sound area of the adhesions, even when there is no lesion in the heart, which might deceive the very elect were it not for the continuance of perfect rhythm of the heart's cycle. These murmurs are conducted often through a portion of condensed lung, which fact being made out is confirmatory evidence of the general innocuousness of these murmurs—such as are frequently heard in the space around the apex-beat area, where the heart is covered by a thin portion of the lung, and for the same reason over the region of the pulmonary artery. Many times they are merely conducted sound-vibrations of the chordæ, and do not at any time necessarily denote organic disease of the heart.

If the heart were removed from its case and envelopment of lung, still performing its functions, we might hope to arrive with greater certainty at the knowledge of the exact local action of valvular murmurs. We could then place the ear or the stethoscope against the heart itself in search of the evidence of organic change. We could at least eliminate the outside causes of false murmurs by conduction. But the source of vibrations from valvular diseases or relative change in the capacity of the different chambers would still be within the muscular walls of a closed chamber, and absolute certainty could not be arrived at in that way. Is it, then, a wonder that we fail sometimes to make correct diagnoses by the ordinary methods in which we have been taught? But the application of the laws of acoustics is like introducing an electric light into the chambers of the heart and reading their secrets as by the light of day.

I have endeavored for many years past to make auscultation of the human chest scientific and more certain by the application of acoustic law. If I have in any degree succeeded in directing the attention of the profession to the practical application of the laws of sound in diagnosis of the chest, I shall be well satisfied.

INTERPLEURAL PATHOLOGICAL PRODUCTS: THEIR CAUSE, SIGNIFICANCE, AND SPECIFIC RELATIONSHIP TO PULMONARY PHTHISIS.

By J. R. LEAMING, M.D.,
NEW YORK.

Reprinted from the Transactions of the American Climatological Association,
September, 1888.

INTERPLEURAL PATHOLOGICAL PRODUCTS: THEIR CAUSE, SIGNIFICANCE, AND SPECIFIC RELATIONSHIP TO PULMONARY PHTHISIS.

By J. R. LEAMING, M.D.,
NEW YORK.

The normal healthful pleuræ are free in movement. Their surfaces glide over each other in respiration without sound-producing friction. They cover the lungs and their lobes, the inner costal walls of the chest, the outer surface of the pericardial sac, and the mediastinum. Thep are not only smooth of themselves, but they are lubricated by a natural secretion never in excess and never absent.

Unfortunately, the normal healthful condition of the pleuræ is not what is most frequently found in post-mortem examinations, for seldom are they entirely free from pathological results. The early pathologists, finding these conditions of such frequency and without history of illness as cause, looked upon them as normal. It is not yet twenty years since Dr. Flint, standing in the very front of medical renown, whose memory we revere and of whose fame we are proud, in leading the discussion of a paper on pleuritis which I had the honor of reading before the New York Academy of Medicine, said, in effect, and not unkindly, that the profession would not agree with me in my estimation of the causes, pathology, physical signs, or treatment of interpleural adhesions; that they were not discoverable by auscultation, had no effect upon the health of the individual, and could not be reached by medication. There is no doubt that Professor Flint truthfully represented the verdict that would have been given by the profession throughout the world, could it have been taken, at that time. But since then, many advanced pathologists have adopted other views. Sir Andrew Clark, especially in his Lumleian lectures of three years ago last spring, gave a very thorough and clear account of interpleural pathological products, without acknowledgment of any American assistance. My early connection with this subject, if I am not, indeed, the earliest one to draw attention to it, is, I suppose, the reason that I have been invited to bring it before you at this time.

Laennec and Louis refer to saddle-leather creaking sounds as being due to old cartilaginous adhesions within the pleuræ. But all other râles and rhonchi were believed to be interpulmonary or interbronchial. But the application of the laws of sound points out unerringly their location and mechanism, and furnishes the elements of a correct diagnosis.

Pathological products within the pleuræ are foreign elements, whether they are growths, like cancer, or benign tumors, tubercle, or other neoplasms; or whether they are exudates, the result of inflammation, or of depressed vitality—of which I shall have much to say in this article.

Of tumors or neoplasms, benign or malignant, I shall not discourse, not intending to be exhaustive of the subject of intrapleural pathology, but shall confine myself to the two forms of exudates—sthenic and asthenic, which may influence or cause phthisis pulmonalis.

The interpleural exudates which interest us in this discussion are of two kinds: First, those which are the result of active inflammation, such as pleuritis or pleuro-pneumonia; second, those which result from depressed organic life. The first is the one generally had reference to when the subject is under consideration.

At the discussion which followed the very able papers before the New York Academy of Medicine, led by Dr. Westbrook, on the subject of interpleural exudations as causes of consumption, the sthenic was the only form considered. That lowers the organic life by its mechanical pressure upon the organs, shutting off the circulation by closing the capillaries for nutrition and for aëration of the blood in the lungs. There is more or less natural tendency to remove this foreign factor by the absorbents, and the effort is successful or not according to the degree of vigor of the organic life in the body.

There is no question that they depress the vital force mechanically; but they have no other phthisical tendency. Such seemed to be the apprehension of this subject by the New York Academy of Medicine. But there is another cause producing exudation within the pleuræ which is not preceded by inflammation or rise of temperature. Indeed, many times the temperature is subnormal before and at the time of its exudation, which soon commences to contract, and the temperature to rise, or to vacillate from below to above the normal. This cause is within the life of the individual, is a part of it, and is immaterial; while the first causes are exterior to the life and are material.

There is a trinity of life in man: The organic; the intellectual; the moral or responsible.

Life, like heat and electricity, is known only by its manifestations. Let us study the beginning of these manifestations of organic life, as Harvey did with the eggs of the hen during incubation. After the first day, upon opening the shell, it was found that the relative positions of the yolk, the white, and the germinal spot or eye were changed, and that the white began to be a little turbid. This was the first manifestation, and proved that the hen had been with the cock, for the eggs of the hen which had not been with the cock did not show these changes. In them were no manifestations of life, and there was no life, for an unfertilized egg is dead. In the fertilized egg before incubation the life is inchoate, and by incubation it is warmed into manifestations. At the end of the second day the changes are still more marked, and at about the beginning of the third day a little point of red appears in the germinal spot, pulsating. This is the beginning of the circulation of the blood before there is a heart, proving that the rhythm and pulsations are primal manifestations of organic life, which then commences to build—first the right auricle and ventricle, and afterward the left heart. Finally, the arteries still shooting out, the whole body is formed in completeness. This organic life—the builder, is immaterial. It uses the prepared organism of the egg as the mason does the brick and mortar, the stones and cement provided for him. It shapes the building in form and for use.

The immaterial essence which results from sexual congress, and which builds the material body, preserves its identity as an individual from the moment of conception until its final death, or until its manifestations cease in the material world. But as organic life always manifests itself in form as well as in motion, we see the spermatozoa of the male with its distinctive form and locomotion by which it reaches the ovum of the female and is destroyed and a new creature begun.

In the fable of Dionysius or creation, representing in Greek mythology desire or love—"Semele, Jupiter's paramour, made him take an inviolable oath to grant her one wish, whatever it might be, and then prayed that he would come to her in the same shape in which he was used to come to Juno. The consequence was that she was scorched to death in his embrace."

The form of the individual continues during life, modified by age, accident, or disease—also the form of the organs, the members, and the constituent parts, the blood-disks, the cells of all the tissues, and the secretions. Everything that has life has inherited its form, its limit of age, and transmits the same to its children—not only the essential inherent qualities of the individual but, many times, acquired peculiarities. So that disease forms and tendencies may also be inherited—not the material, but the immaterial.

The building material in each individual is introduced into the blood from the digestive organs, and is vivified and used to build or repair the form, which, as it grows old and dies, is thrown out of the system, and fresh, new material takes its place. The life and form continue, and are continually modified by time until the limit of the age of the individual is reached, when formation ceases and form decays. The most absolute proof of the immateriality of life is its death; because the dead body is proof of its former life. The excellence of Lord Byron's beautiful simile in "The Giaour," in the description of "Greece, but living Greece no more," depends upon the appearance of form simulating life:

> Before decay's effacing fingers
> Have swept the lines where beauty lingers.

Bone is the evidence of the once living animal. Hamlet, with Yorick's skull in his hand, reasons upon the former life of its occupant until his "gorge rises," and he puts it down in disgust, but goes on in his illustration by citing the dust of Alexander and that of Cæsar in decay, and suggests the vile uses to which they might come. Wood is the evidence of the life of the tree, and of its growth from the seed; the identity of the life remaining ever, for the wood was always cedar, mahogany, or oak, as was the seed from which it sprang. The life remained, although it often changed particles—the particles which it took up from the ground and assimilated always making cedar, mahogany, or oak, never losing identity, for a thousand years or more, a continual evidence of the immateriality of life in the tree as in the animal. And the wood remains the death-evidence of the life of the tree for thousands of years afterward.

The diamond, the ruby, or the sapphire are evidence of the immaterial Creator. "The earth was without form and void." Divine creative energy flashed through these elements and crystallized them into gems of particular form, brilliancy, and hardness, or of rocks enduring, or of ores of precious metals, where they ever remain evidence of the eternal immaterial existence of the Creator. The crystal, the tree, the animal, represent the primal creation.

Man is mortal—the race immortal. There is an endless succession of individuals, each filling his allotted time and then giving way for his successor. Each constituent molecule is mortal, like the individual man. It has its limited time of existence, and then passes away and gives place to a new one—and the succession goes on during the existence of the individual. It has its predecessor and successor, and with them its acquired tendencies to disease. These are laws impressed upon all organic life—heredity and endless succession. The organic life, besides pervading every constituent part of the body, has its particular home in the great sympathetic nerve. A connected series of ganglia near vital regions massed together in plexuses are reservoirs; each ganglia, however, is in a measure, independent, yet all are joined in sympathy with each other and with the unity of the individual. Filaments accompany each artery, vein, and capillary. The organs of special sense, the heart, lungs, kidneys, liver, stomach; of digestion, of secretion, of generation; even the brain, which itself was created for the home of the intellectual life, is in every part of it supplied with organic life. The brain could not emit a single thought or emotion without the active assistance of organic life. We learn of the intellectual life through its manifestations. The feeblest brain-effort of the newt to its highest development in man is recognized only by its manifestations. Both the newt and the man seek their food, defend themselves from danger and attack, and propagate their kind. Their intelligence differs with corresponding differences of brain-development. The chief manifestations of the lower animals are locomotion with definite purpose. In man the manifestations are of greater extent and greater power, with the capacity for improvement by education. But what distinguishes man from all other animals is a manifestation of another kind of life—a moral life, or conscience. The manifestations of this new life may be very feeble, but they are distinct, and the power admits of education, like that of the intelligence. It is quite certain that each may be educated separately or in unison; but, if separately, resulting in a moral monstrosity. The trinity of life in man may be thus stated: First, the organic (the builder)—the life of the body; second, the intelligence—the life of the soul; third, the conscience—the life of the spirit; body, soul, and spirit all immaterial—each known by its manifestations only. The evidence of the immateriality of the life of the body is in its manifestations as builder. We could know nothing of them but by building the form of the material body in all its parts, and as a whole; its mysterious conception—intra-uterine existence and birth, and independent life through the periods of infancy, childhood, youth, manhood, old age, and natural death. Intellectual life commences after birth, noticing outside objects, learning its relationship to the outside world, feeling pain, showing pleasure, fear, or joy. The manifestations increase with the growth of the body and the successive stages of periods of age, until decline and death. The soul, too, grows old. Its habitation, the brain, is part of the body; and as the body grows feeble by age, the intellect must give feebler manifestations, according to the waning power of the body, and the brain, its instrument.

The manifestations of the spirit commence only when the soul upon which it depends has arrived at some degree of capacity for intelligence. All human laws recognize this fundamental truth, for the child is not held responsible for its acts until it has arrived at the age of discretion. Responsibility is measured by intelligence. Intelligence is limited by the development of the body. This delicate interdependence may become deranged at any time during the life of the individual. It is frequently temporary, as in fevers, or in intoxication from medical agents, or commonly by alcohol; or may be more or less permanent, as in pathological conditions of the brain, or reflex, in sympathy with organic disease in some other part of the system of organic life. This higher development of the animal in body and soul, with the added form of spirit or moral life, belongs alone to man. "Conscience makes cowards of us all," is an appreciation by the poet of the spirit's power, for good or evil, over the physical organism. It dominates with controlling force in nutrition, in pathological conditions of atoms as observed in the intimate structure and in the blood. This power is in contradistinction with the outside agents which affect the life of the body—such as poison of different varieties brought in contact with the organic life, externally or within; or miasma, which is simply another form of poison; or microbe, especially the bacillus tuberculosis. The *modus operandi* of these agents is difficult of explanation, but the practical fact remains that tartarized antimony will cause emesis, or that croton oil will produce catharsis, and that other agents the same or similar effects or different ones, and that we make use of our experimental knowledge of them in the treatment of diseases. Again, it is just as difficult to explain how the *materies morbi* which may come to us in the air which we breathe or in the food we eat—miasmatic or microbic—should always produce in the organism the same diseases. There is nothing *a priori* in the constitution of the *materies medicatrix* or of the *materies morbi* which will explain their peculiar and characteristic effects upon the living organism. We are forced to the conclusion that the peculiarity of the invariable effects of these exterior agents is not in the agents themselves, but in the organic life—for if the life has gone out of the body, these agents have no similar effect. Calomel or other preparations of mercury applied to the dead body produce no characteristic effects, as they invariably do when applied to the living organism. And so with all other medical agents or poisons, or disease-germs. They are exterior causes which have power to influence the interior life of the body for health or for disease. But the spirit is a potent factor in preserving health or in causing disease, and its action is not less mysterious upon the organic life than is that of the *materies morbi* or the *materies medicatrix.*

This interior cause which dominates the life of the body through the life of the soul, although depending upon them for its life, controls their healthful manifestations when benign, or of disease and death when malign. It may cause death of the body by first causing death of the atoms, instantly or successively. When malignly influencing the atoms, causing their immediate or successive death, it gives rise to diseases of the body similar to those produced by the *materies medicatrix* or *materies morbi.* With the tissues and circulation filled with these dead and diseased atoms, the organic life attempts their expulsion by crowding them through the walls of capillaries into the natural cavities of the body, notably the pleuræ and the cellular tissues. They are not all dead atoms, but diseased, and when thrown out of the systemic circulation they still have enough vitality left for organization, imperfect though it be. The immediate action of this pseudo and imperfect organization is to contract, and in this manner to cripple the functions and manifestations of the organic life in local areas of the physical body. The pleural cavities are the great dumping-ground of the organic life. Here pathological products are more frequently found, and when of much extent their contraction mechanically closes the capillaries of the lungs upon their surfaces, preventing largely the aëration of the blood, and, all of the malign causes continuing to operate, the disease becomes progressive fibroid phthisis. The temperature, perhaps, always is subnormal in the earliest stages of exudation. But when contraction commences after adhesions, the local irritation causes the temperature to rise at irregular times, and vacillates from below to above normal. It is frequently a sign of organic feebleness and a losing struggle in the battle of life.

Physical and pathological conditions similar to these followed the severe storm of last March in New England and New York, known as the blizzard. It will be remembered that the temperature was low—about zero—and that the winds were very high and the atmosphere loaded with fine particles of ice. The result was, many times, disastrous to those obliged to travel on foot for any length of distance.

The exertion was constant and violent; breathing very much interfered with, on account of the fine snow or frost filling the air. This, with the vital depression consequent upon the intense cold, immediately lowered the organic life of the atoms in the circulation, and death or partial death of these constituent parts of the body took place. Soon after the storm—two or three weeks, in some cases—violent efforts of the organic life to expel these dying and dead constituents became demonstrative. Slight or limited attacks of pleuro-pneumonia of a low type, with hemorrhages, became frequent. These were generally amenable to treatment, but the interpleural pathological products increased *pari passu* afterward with vital depression, and many of the sufferers died shortly—that is, within three or four months—with the genuine conditions of fibroid phthisis as from depressed organic life. The method of death was the same as in that of fibroid phthisis from immaterial interior causes; the spirit acting upon the intelligence causing the disease and death of the atoms of the body in the tissues and in the circulation. Great and prolonged sorrow, deep disappointment, worry, and anxiety—the loss of friends and property, of position, reputation—always cause death of molecules, which being crowded out of the circulation, interpleural pathological products occur which may finally result in progressive fibroid phthisis. When this happens to a wife or husband who has unduly and inordinately mourned the other's loss, it has been ascribed, without sufficient reason, to contagion. The known cause of immaterial vital depression through the conscience is enough to account for the morbid phenomena, without referring to the principle of contagion, of which we know so little.

I have not known of a case of fibroid phthisis in which a distinct history of vital depression could not be elicited by getting the history of the mental conditions of the patient during the preceding years. Sometimes it comes from great sorrows and anxious worry of a few months. Again, it is the result of years of continual unsuccessful struggle in the battle of life—the inability to cope with its great difficulties. Morbid products accumulate in living organisms. The organic life thrusts them out of its dominion, into the pleural cavity, for instance, where a feeble reorganization takes place, which contracts upon the lungs, shutting off a portion of its circulation and crippling its life-power. Here we may notice the great difference between these pathological products and those which result from the sthenic inflammation. These are characteristic in their morbific results, and in this are distinctive of phthisis pulmonalis. It is progressive—the products are constantly being thrown out into the pleural cavity, until the end. One has an inherent tendency to get well, the other to die, and needs all the assistance of the physician, or of climate, or of food, to arrest its progress.

Management of fibroid phthisis from interior immaterial causation of molecular death, must be rational in order to be successful. The organic life expels the diseased and dead particles, crowding them out of the circulation. The pleural cavities are generally an ample and the most convenient receptacle. The crowded capillaries of the true respiratory system are separated from them only by the thin membrane of the pleuræ. As might be expected, the pleural cavities give the earliest evidence of morbid impressions upon the individual life of the particles or blood-disks. When not overwhelming they are thrown out, ejected from the circulation, until the organic life has recovered from the attack, and the mass of débris is taken up by absorbents and carried out of the system. But if the morbific cause continues to operate, more of the waste is expelled from the blood, and the pathological products become too much for the absorbents to remove; which are soon organized, and commence an independent existence. The diseased atoms in this parasitic mass become not only mechanically obstructing and depressing, but vitally also, by their morbid effect upon the life of the body. Under these great and overwhelming difficulties, the mucous membranes of the bronchia become exuents through which these dead and dying atoms are expelled in the form of mucus, and the broken-down, dying, red corpuscles being added to the diseased white ones, a "hemorrhage" results. If we look at this state of things wisely and calmly, what are we to do? Attempt to resist nature by arresting the "hemorrhage" with ergot, or leave this agent to the gynecologist? For it has no power to arrest a bronchial hemorrhage, but rather to increase it; and, if it were possible, it were undesirable, for then would be retained in the circulation the morbific products which the organic life is endeavoring to expel.

The most rational, as well as the most successful, remedy, is spirits of turpentine applied by frequent washings of the chest externally. This has the tendency to prevent or relieve pulmonary stasis: First, to remove the interpleural morbific exudates before organization has commenced; and, second, to revivify the sick corpuscles, both white and red.

The emergency having passed, we have to deal with organized products which, by continual contraction, are lessening the area for blood-aëration, and progressive emaciation results—consumption.

Spirits of turpentine is still a valuable agent, stimulating the absorbents and dissipating local congestion, and promoting the health of the blood-corpuscles in active circulation. But, above all things else, it is important to maintain and increase the area of blood-aëration. This is best done by simply breathing rightly, taking in as full respiration as is comfortable, and then holding the breath in for a short moment until the newly inspired air has mixed with the residual air, and has expanded under the rarefaction of the blood-heat. This must be continuous. It must be the all-time breathing; spasmodic or stated periods of correct breathing, of forced inspiration, will not succeed so well, for if the expansion is intermittent, the pseudo-membrane will recontract at every intermission, and the fable of Sisyphus will be illustrated. For this reason, all mechanical methods of expanding the chest, although undoubtedly useful when not violent, are less beneficial than correct breathing which is continual. Change of locality, pine-woods, and mountain-climbing, may all be beneficial.

Interpleural pathology has but a casual or accidental connection with tubercle. Tubercular inflammation, extending to the pleuræ, may cause plastic exudation within the pleuræ, and occasionally tubercle may come independently to the pleural membrane in general tuberculosis. And in this connection only will we refer to the bacillus tuberculosis, which has come to represent the disease. One thing is certain, that wherever a tubercular cavity in the lungs is found, there, in the cavity and in the tissues surrounding it, we expect to find in great abundance the bacillus. Wherever tubercular concretions or aggregations are found, there will the bacilli be also. But sometimes as well, but in far less proportion, where there are dead or dying atoms from mental anxiety or sorrow, scattered through the body, and, of course, in greatest abundance in the lungs, there, too, will be found bacilli. In regard to the question of contagion, or specific causation, of tubercle, I shall not enter. But in regard to its connection with the dead and dying elements within the tissues of the body or in the circulation of the blood, I have come to no conclusion, except that the connection is casual, just as mould comes to decaying animal tissues by natural selection. And mould and the bacillus tuberculosis are suggestive of each other.