5. Soak hands in a hot saturated solution of potassium permanganate until they are of a deep mahogany color.

6. Decolorize completely in a hot saturated solution of oxalic acid.

7. Soak forearms and hands in a 1 to 1,000 solution of bichloride of mercury for three minutes by the clock, or until the patient is ready for examination.

It should not be forgotten that sterile hands may be contaminated readily at the bedside.

The patient also should be carefully prepared. At the onset of labor she should be bathed and given a rectal enema. The external genitals frequently harbor streptococci and various pathogenic and putrefactive bacteria. They should be carefully washed, before each vaginal examination, first with soap and hot water, and then with a 1 to 2,000 solution of bichloride of mercury; afterward they should be protected, with a towel soaked in the bichloride, until the physician is ready to make his examination.

During the second stage an antiseptic towel should be kept over the vulva and sterile sheets and towels should be arranged in such a manner as to prevent contamination.

In operative procedures rubber gloves may be worn to give added protection. They should be thoroughly boiled and then drawn over the sterilized hands.

Perineal tears offer ready entrance to bacteria and should be repaired. The sutures may be placed during the third stage and tied after the expulsion of the placenta.

Operations for the repair of lacerations of the cervix greatly increase the chance for infection, and should not be done unless imperatively demanded for the control of hemorrhage.

After the birth of the placenta the patient should be cleaned and the vulva covered with an ample sterile dressing, which is held in place by a T-bandage.

Ergot may be used to secure better contraction of the uterus, but should not be given until the placenta has been expelled.

During the puerperium the external genitals should be kept clean by frequent irrigation with a 1 to 4,000 solution of bichloride, and the vulval pads frequently renewed. Vaginal douches should be used only in exceptional cases, and then with the utmost regard for surgical cleanliness. Infections have been caused by the careless use of the vaginal douche, even in the later stages of the purperium.

Treatment.—General treatment alone often gives the best results in the severe streptococcus cases. Strychnine, gr. $\frac{1}{30}$, may be given every two hours with half an ounce of whiskey every hour, but the quantity should be reduced promptly when the pulse shows improvement. The patient should be kept on the verge of strychnine poisoning and a state of drunkenness, if necessary. Mild cases require little medicine. The bowels should be kept open and good food given in all cases.

Antistreptococcus serum has given very unsatisfactory results. Laboratory experiments have shown that serum prepared from a given culture is protective for that particular culture and no other. Recent reports by Labusquière.[13] Savor, Blumberg, and Scharfe show results of doubtful or no value.

The cases of true diphtheritic infection reported by Bumm, Nisot, and Williams showed rapid improvement and recovery following the use of diphtheria antitoxin.

Salt-solution enemata every six hours, given through the long rectal tube, are often of value in relieving symptoms and promoting diuresis. The subcutaneous injection of sterile decinormal salt solution has been of apparent benefit in some cases. Tincture of ferric chloride in large doses is of value.

Local treatment in the streptococcus cases should be limited to douches, preferably of hot sterile decinormal salt solution. These may be repeated every six hours if necessary. Dilute bichloride douches, 1 to 10,000, immediately followed by the salt solution, may be used. But antiseptic douches are dangerous and should be used with great care. Forty cases of death from bichloride poisoning have been reported.

Clots and fragments of the placenta may be removed with the finger or the dull curette. Curetting on the whole is dangerous, especially if streptococci are present, for by it we may break down the protective wall of leucocytes and expose fresh areas to infection, the very thing we wish to avoid.

Hysterectomy has been advocated for severe cases, but the results reported by Rochard, Bazy, Terrier, and Tuffier, with a mortality of from thirty-three to one hundred per cent., hardly justify a resort to the operation. Leopold[14] and Fehling do not favor it. As they show, to be of value it must be done early, before the infection has extended through the uterine wall. But at present we have no means of determining in which cases the infection will extend, and in which it will remain limited to the uterus. Ricard has collected eight hundred and fifty-one cases with fever at 102.2° F. and higher, showing a mortality of thirteen per cent. under general treatment.

Abscesses and dense areas of cellulitis in the parametrium should be opened through the vagina or through the abdominal wall.

Putrefactive cases with abundant foul discharge are greatly helped by cleaning out the masses of necrotic material with the finger or curette, and following this by a large douche of salt solution, the douche to be repeated every six hours. *Otto G. Ramsay.*

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PULLER SPRINGS. — Madison County, Montana. Post-Office.—Puller Springs. Hotel.

This resort is reached by a good wagon-road, and has semi-weekly mails. The location is in a beautiful valley, having an elevation of 5,530 feet above the sea-level. The springs are two in number, the temperature of the water being 95° F. for the larger and 105° F. for the smaller spring. No analysis. The waters have been found beneficial in rheumatism and allied disorders. The beautiful location of these springs, coupled with the potential therapeutic properties of the water, will undoubtedly bring them into extensive use as the State becomes more thickly settled. *James K. Crook.*

PULSATILLA.—U. S. *Pasque Flowers.* The dried herb of *Anemone Pulsatilla* L. and *A. pratensis* L. (fam. *Ranunculaceæ*), collected soon after flowering, carefully preserved and kept not longer than one year. Both are low, hairy herbs and among the earliest and most beloved of spring flowers. For medicinal purposes the plant should be dried in the shade and stored in a cool and dry place. The drug is thus described: Silky-villous; leaves radical, long-petioled, the petioles usually purplish, the blades twice or thrice deeply three-parted or pinnately cleft, the lobes linear and acute; flowers long-peduncled, subtended by an involucre of three pinnately parted sessile leaves; calyx of (usually six) large, dull purple, hairy sepals; petals obsolete; stamens numerous; pistils several, becoming in fruit long, plumose-tailed akenes; inodorous and very acrid.

Constituents.—Pulsatilla yields upon distillation with water a very pungent, volatile, oil-like principle, from which ether or chloroform extracts a peculiar camphor, which has been called *Anemone camphor*, and which possesses the acridity of the oil to such a degree that it is capable of blistering the skin. This camphor is divisible into anemonin and iso-anemonic acid. The former is a colorless, crystalline, neutral substance, of but little taste when cold, but intensely pungent when melted. It is but slightly soluble in cold alcohol, ether, or water, more so in those liquids when hot, and is readily soluble in chloroform. *Iso-anemonic acid* is a white, amorphous, insoluble substance, without odor, taste, or medicinal property.

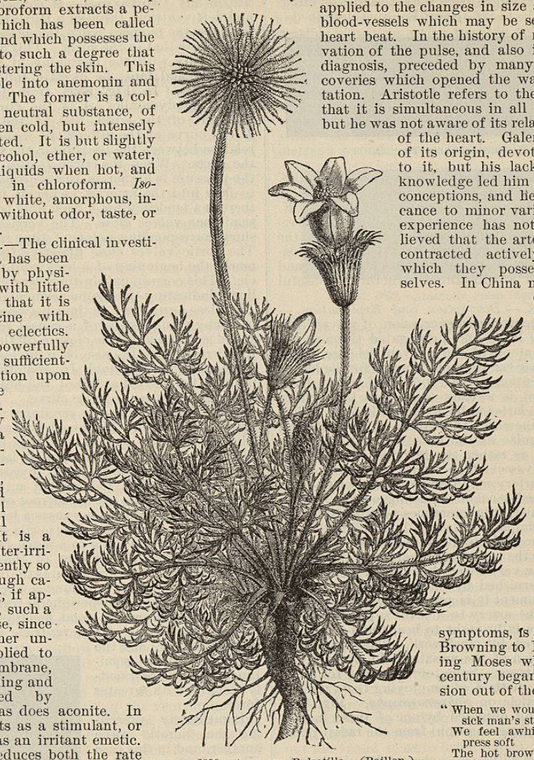

Fig. 3896.—Anemone Pulsatilla. (Baillon.)

Action and Use.—The clinical investigation of pulsatilla has been greatly neglected by physicians, apparently with little better reason than that it is a favorite medicine with homœopaths and eclectics. That it possesses powerfully active properties is sufficiently proven by its action upon the skin and the mucous membrane. Its action is fairly well described in a general way by saying that it resembles that of aconite, but its special field of usefulness is well worthy of careful determination. It is a fairly active counter-irritant, and is frequently so employed. Although capable of blistering, if applied with friction, such a use of it is not wise, since the blister is rather uncontrollable. Applied to the mucous membrane, it produces a burning and tingling, followed by numbness, much as does aconite. In the stomach it acts as a stimulant, or in larger amount as an irritant emetic. Systemically, it reduces both the rate and the force of the heart and of the respiration. It is therefore an antiphlogistic, and is somewhat used as a respiratory sedative. Among the homœopaths and eclectics its sedative action is largely utilized in the treatment of inflammatory conditions of the genitals, although it is also a favorite emmenagogue.

There is no official preparation. The powdered drug may be given in doses of 0.06–0.3 gm. (gr. i.–v.) or the fluid extract in an equal number of minims. The tincture is probably more used than all other of its preparations combined. It is commonly made of twenty-per-cent. strength, and the dose is 0.5–1 c.c. (ɱviij.–xv.). The extract is used in doses of one-half to two grains and anemonin in doses of one-fifth to one-half a grain.

Allied Drugs.—*Anemone nemorosa* L., the common wind-flower, and various other anemones, have a similar composition to that of pulsatilla, and are similarly used. Various species of *Ranunculus* or buttercup, and of *Clematis* or virgin's bower, also exhibit resemblances in the same direction, as does Hepatica or liver-leaf. All these pertain to the family *Ranunculaceæ*. *Henry H. Rusby.*

PULSE, THE.—Introductory and Historical.—The pulse, literally a beating or throbbing, may be broadly defined as periodic movements caused by the rhythmic action of the heart. The term is commonly applied to the changes in size and tension of the blood-vessels which may be seen or felt at each heart beat. In the history of medicine the observation of the pulse, and also its employment in diagnosis, preceded by many centuries the discoveries which opened the way for its interpretation. Aristotle refers to the pulse, and states that it is simultaneous in all parts of the body; but he was not aware of its relation to the activity of the heart. Galen, equally ignorant of its origin, devoted much attention to it, but his lack of physiological knowledge led him to form many false conceptions, and he attached a significance to minor variations which later experience has not justified. He believed that the arteries expanded and contracted actively by some force which they possessed within themselves. In China medical science, like other things, has changed little in thousands of years. The native physicians there have very crude ideas of both anatomy and physiology, and yet they describe and even graphically depict the pulse in great detail. They imagine they find indications in it of the exact seat no less than the nature of nearly every disease.

A more reasonable claim, where the indications given are better supported by other symptoms, is ascribed by the poet Browning to Paracelsus, that erring Moses who in the sixteenth century began to lead the profession out of the Egypt of tradition.

> "When we would thoroughly know the sick man's state
> We feel awhile the fluttering pulse, press soft
> The hot brow, look upon the languid eyes
> And thence divine the rest."

The foundation for the scientific study of the pulse was laid by William Harvey, who discovered and described the circulation early in the seventeenth century. Among his conclusions we find that "the heart is the organ of propulsion for the blood" and that "the pulsation of the arteries is nothing else than the impulse of the blood within them." In 1707 Sir John Floyer states a little more definitely: "The pulse is that sensible motion which is given to the artery by the blood which the heart injects into it." Still fuller is the account given in Haller's "Elements of Physiology," published in 1760: "The arteries are, in a living person, always full of blood, since the jet or stream that starts from an artery is not interrupted by alternate stops, while the heart rests or relaxes itself, but it flows on in a continued thread. . . . Since, therefore, a new wave or column of blood is sent into the arteries already full, although it bears but a small proportion to the whole mass contained in the arterial system throughout the body, . . . yet by its immediate contact with the precedent wave or column, which

moves slower as it gets farther from the heart, it consequently drives the same forward, lengthens the artery, and makes it assume a cylindrical form, augments its diameter, etc. This dilatation of the artery, whereby its light or capacity is changed from a less to a greater circle, is called the pulse." In 1767 Henri Fouquet described in

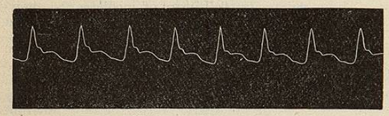

FIG. 3897.—Normal Pulse Tracing.

detail the sensations imparted to his finger by the pulse and was the first in Europe (the Chinese were before him) to represent the pulse by drawings. In 1855 K. Vierordt describes a rough means of recording the movements of the arteries automatically, thus laying the foundation of modern sphygmography. On this foundation a host of modern investigators, both laboratory and clinical, have raised a substantial structure of useful knowledge.

ARTERIAL PULSE. — *Description and Explanation.* — The arterial pulse comprises a succession of waves initiated in and near the heart and propagated through the arteries. As the contents of the left ventricle are forced through the semilunar valves, room is made for the blood, partly by the distention of the aorta, and partly by a pushing on of what is already there into the smaller arteries, causing the latter to be distended in turn. This distention slightly increases the calibre of the arteries; but what we recognize as the pulse, when we lay our finger on the wrist, is rather the increase of tension or pressure within the vessel which occurs at the same time. In some cases an artery may become more tortuous as the wave of increased tension is passing over it. With the finger on the pulse, it is sometimes possible to recognize more than one impact or wave. It is difficult, however, and often impossible to be sure of these so-called secondary waves by the sensation imparted to the finger, and we should know very little about them were it not for the assistance furnished by the sphygmograph. By means of this instrument it is possible to communicate the movements of the artery to a lever supplied with a writing point. This is brought to bear upon a piece of smoked paper moved by clockwork. The result is a graphic representation of the variations in pressure occurring within the artery. Some of the many forms of instrument and the method of employing them will be described in the article on *Sphygmography*. Fig. 3897 represents the tracing obtained by one of these instruments (Dudgeon's sphygmograph) from the radial pulse of a healthy man.

If it be examined it will be seen that each pulse beat is represented by a sudden rise followed by a more gradual fall. The sudden rise is known as the *primary or percussion wave* and can be traced to the contraction of the ventricle. The descent is broken by two secondary waves, of which the second, known as the *dicrotic wave*, is in this case the largest and most distinct. This wave is very constant, being found in almost all pulse tracings. It is preceded by a depression known as the *dicrotic notch*. There has been much controversy as to the cause of the dicrotic wave, one view being that it is due to a rebound of the blood from the aortic valves at the moment when they close, and the other that it is a wave reflected back from the small peripheral vessels. While a very few still hold the latter view, it has been discarded by most physiologists as a result of overwhelming evidence that has been advanced in favor of the rebound theory. If the wave were due to a reflection of the percussion wave from the periphery, it would occur earlier in the peripheral than in the central vessels, which is not the case. Moreover, a number of physiologists, notably Karl Hürthle, have shown that the dicrotic notch which marks the beginning of this wave follows immediately the closure of the aortic valves. He has invented the so-called differential manometer to record the time of closure of the valves. This instrument records the relation of the pressure in any two cavities. If connected with the aorta and left ventricle through a Hürthle's heart catheter, it indicates the moment when the pressure in the ventricle falls below that in the aorta. This moment corresponds of necessity with the beginning of a back flow into the ventricle, and must be directly followed by closure of the valves. In Fig. 3898 from Hürthle's "Beiträge zur Hæmodynamik" *A* is the curve of pressure at the root of the aorta, that of the left ventricle, and *D* the curve of the differential manometer showing the relation between the pressure in the ventricle and that in the aorta. When the curve *D* rises above the base line the pressure is higher in the ventricle, and blood begins to flow into the arteries; when it falls below the line, there is a tendency for a back flow to take place and the semilunar valves close. The vertical lines 1, 2, 3, 4, 5 show corresponding points of time in the three tracings. The aortic valves close directly after the line 3, which marks the beginning of a backward flow into the ventricle. This corresponds in time very closely with vertical line 4, indicating the commencement of the dicrotic wave. The close agreement in time between these two events is strongly suggestive of a causal relation. The correspondence between the closure of the aortic valves and the dicrotic wave has also been successfully demonstrated by Martius, Karl Schmid, Jr., and others by marking the time of the second sound of the heart as heard with a stethoscope upon the pulse curve.

The rebound from the semilunar valves may be explained as follows: The blood is thrown out of the ventricle at a certain speed and with a certain momentum. When the ventricle has emptied itself the momentum of the blood in the aorta tends to carry it forward away from the ventricle. This cannot actually take place, or a vacuum would be left at the root of the aorta, but the tendency in that direction causes a low pressure and consequent suction action at the aortic orifice. This lower pressure or suction leads to a wave in a backward direction, completing the closure of the semilunar valves. This is reflected forward again as the dicrotic wave. The dicrotic wave is most pronounced when the smaller arteries are dilated and the peripheral resistance is low. In this case the column of blood, meeting with little opposition, is thrown out of the ventricle with greater speed and momentum, and the recoil against the semilunar valves consequently occurs with greater force.

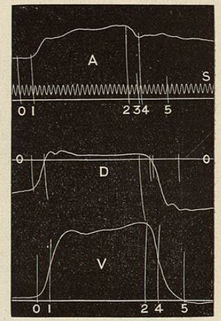

FIG. 3898.—Shows Relationship between the Pressure in the Ventricle and that in the Aorta. (From Hürthle.)

Immediately preceding the dicrotic wave another, and in this case (Fig. 3897) smaller, wave may be seen which is known as the *predicrotic* or *tidal wave*. The cause of this is more doubtful than that of the dicrotic wave. It is found in the curve of intraventricular pressure, and may even be present under certain conditions in the tracing of the transverse diameter of the frog's ventricle (Marey), so that it is frequently ascribed to a peculiarity in the contraction of the ventricular walls, "the systole not being equally sustained" (Foster) or "the outflow remainder wave" (Roy and Adami). There are those who ascribe this wave entirely to inertia and recoil of the instrument

used. The instrument may, and often does, exaggerate it, but there is little doubt of another factor being present. The most plausible explanation is perhaps something like this: both the percussion wave and the predicrotic originate within the ventricle during its systole; the reason of there being a depression or notch dividing them into two is that a slight fall of pressure occurs when the semilunar valves open and afford a passage for the blood into the aorta; the physical laws here exemplified may be studied in the mechanism of the hydraulic ram as has been pointed out by Karl Schmid, father and son. If the pressure in the arteries is low, the ventricle nearly empties itself with one effort, and the predicrotic wave is scarcely seen; but if the pressure is high, only part of the blood is forced out at first, and after a slight fall in pressure at the opening of the semilunar valves, the continued contraction of the ventricle raises it again up to or beyond its original height, forming the predicrotic wave. It is certainly a practical rule that where the predicrotic wave is pronounced and reaches a high level the blood pressure is high relatively to the strength of the ventricle.

Other secondary waves are sometimes seen upon pulse tracings and are probably due to oscillations taking place within the vessels, or in some cases they may be instrumental in origin. A multiplicity of secondary waves points to high blood pressure and consequent tension of the arterial walls. Elevations or depressions occurring upon the descending limb of a tracing are called katacrotic, those more rarely seen upon the ascending limb are called anacrotic. A tracing with interruptions upon the ascent is called an anacrotic tracing, and we may also speak of an *anacrotic pulse*. Similarly, where there are interruptions on the descent we speak of a katacrotic tracing and *katacrotic pulse*. A pulse may be both anacrotic and katacrotic. The normal tracing in Fig. 3897 is katacrotic only. The tracing shown in Fig. 3899, taken from a case of aortic stenosis, could be classed as both anacrotic and katacrotic. The predicrotic wave forms the summit of the tracing and indicates resistance to the outflow of blood from the ventricle; the primary or percussion wave forms an anacrotic crest or angle on the ascent, and the dicrotic wave is seen as an elevation on the descent (katacrotic).

FACTORS CONTRIBUTING TO THE CHARACTER OF THE PULSE.—The exact character of the pulse depends on three principal factors: the force of the ventricular contraction, the degree of elasticity of the arteries, and the resistance offered to the outflow of blood from the arteries into the capillaries and veins. The quantity of blood in the body naturally occurs to one as a modifying factor, but its influence is difficult to trace, and in any case it probably acts chiefly by modifying the ventricular contraction. An additional factor that does, without doubt, however, exert a modifying influence in special cases is the condition of the aortic and to a much less extent of the mitral valves. Of the three principal factors mentioned *the ventricular contraction* determines the rate and combines with the other two factors to give the pulse its other qualities. *The elasticity of the arteries* modifies the pulse in the direction of less abruptness. The more elastic the larger arteries are, the less sudden is the increase of tension in the smaller ones. The diminished elasticity of age tends to make the rise of the pulse wave steeper. In cases of low blood pressure the same effect is noted, because the elasticity of the arteries is not fully brought into play. *The peripheral resistance* depends largely upon the degree of activity of the muscular coats of the arterioles. When these are relaxed the blood pressure falls, the ventricle empties itself easily, and the pulse is large and soft. When the arterioles are contracted the blood pressure rises, the work of the ventricle is increased, and this is indicated in the pulse by hardness and a prominent predicrotic wave. Advancing age tends to raise the peripheral resistance by the withering of many of the capillaries and consequent narrowing of the channel by which the blood must flow from the arteries into the veins. Age also affects the force of the ventricles and the elasticity of the arteries so that the pulse in old people varies according to the part of their vascular system where degenerative changes have been most active. As the thoughtful observer notes in the pulse the modifications brought about by ventricular activity and peripheral resistance, he will find there suggestions of many possible influences acting through the cardiac and vasomotor nerves.

RATE OF PROPAGATION.—It takes a certain measurable time for the effect of the ventricular contraction to make itself felt in increased tension of the peripheral arteries. In other words, the pulse waves travel at a certain rate. This "rate of propagation" varies somewhat, but is usually given as between three and ten metres a second. It is considerably influenced by varia-

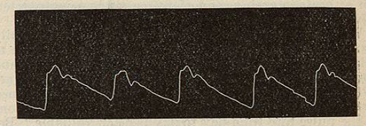

FIG. 3899.—Anacrotic Pulse (aortic stenosis).

tions in blood pressure and by the degree of rigidity or elasticity of the arteries; the more rigid the vessels the more rapid the propagation of the pulse.

Further information on some of the subjects treated of above will be found in the article on *Circulation*.

THE EXAMINATION OF THE PULSE AND WHAT IT SHOWS. —One should not make any direct examination of the radial pulse until he has obtained what information he can by inspection of the visible parts of the body. A glance is often sufficient. In the face one can find indications of the condition of the capillary circulation in the glow of health or in pallor or lividity. In the neck there may be violent throbbing of the arteries or distention and pulsation of the veins. In the fingers one may find lividity and clubbing or a capillary pulse. The pulsation of the temporal and radial arteries may be visible.

It is important to choose for the examination of the pulse a time when the patient is as little excited as possible. It is well to distract his attention by conversation. To obtain the best results the patient should lie or sit in a comfortable position. The observer should be in front of the patient or to his right side. The patient's right arm should be supported with the elbow flexed and the forearm half pronated. Two or three fingers of the observer's right hand should be laid upon the radial artery where it passes over the lower end of the radius between the styloid process and the flexor tendons. The fingers are to be moved up and down the artery and across it, first with light pressure and then with sufficient to flatten out the vessel so as to bring out *the condition of the arterial wall*. If the artery can be felt and rolled beneath the fingers when flattened out it indicates the thickening of arteriosclerosis or the rigidity of atheromatous or calcareous degeneration. If the latter change has taken place to a marked degree, one can often feel the arterial wall to be uneven and ribbed. If the artery can be felt to be tortuous, one is justified in inferring that the patient has been the subject of relatively high blood pressure extending over a long period. In examining the wall, as described above, an impression will often be received of *the calibre or fulness of the artery*. One is very apt to be misled on this point, according to Leonard Hill, by the fact that the venæ comites accompany the artery and contribute to the sensation of size given to the finger.

The arterial pressure may be roughly estimated by the amount of pressure which must be exerted by the finger to obliterate the pulse in the portion below. The artery should be pressed directly backward against the radial bone, and it is well to compress it below as well as above the examining finger so as to exclude any "anastomotic pulse" from a communicating vessel. A correct judg-

ment as to arterial pressure can be acquired only by much practice. One is very liable to confuse the sensation given by high arterial pressure with that of a thickened or calcareous artery.

Low arterial pressure is found in fevers, especially the later stages, in most wasting diseases, and in many forms of heart disease. High pressure is seen especially in nephritis, lithæmia, and lead poisoning.

The pulse proper should be examined with reference to its rate, regularity, size, and quickness. The so-called *hardness or softness of the pulse* is practically identical with the arterial pressure which has just been discussed. *The rate of the pulse*, whether frequent or infrequent, is to be determined by counting the pulse beats by a watch for not less than half a minute. It is well to note the number of beats in each period of five seconds so as to determine whether or not the rate is variable.

When the pulse is too frequent to be successfully counted in the ordinary way it is sometimes possible to calculate its rate by counting every second beat and doubling the result. When some or all of the beats are too feeble to be distinguished, the rate can be obtained by auscultation of the heart. A record of the variations in the pulse rate from day to day is often valuable. Before drawing conclusions from the rate of the pulse, due weight must be given to the fact that it may be modified by very slight influences such as the position of the patient or slight mental excitement. If the rate be abnormally high it should be counted again when any excitement has had time to subside. The rate of the pulse varies much within the limits of health. *Age* has a very great influence. The average rate is something over 130 in the first year of life, about 90 in the tenth year, 70 in adult life, and 75 or 80 in those who have passed the allotted span. *Sex* has little influence, the average in females being only a few beats per minute more than in males of the same age. What little difference there is in the two sexes may with reason be attributed to *size*, for, as a rule, the larger the body the less frequent the pulse. Tables showing in more detail the effects of age, sex, and size on the rate are given in the article on *Circulation*. *The time of day* has a slight influence on the pulse rate, which is usually five or ten beats higher in the afternoon and evening than in the morning. *Meals*, especially if hot, may increase the rate for one or two hours. *Change of position* from lying to sitting raises the rate from two to five beats per minute. On standing a further increase of four to eight beats may result. *Exercise* has a still greater influence, very slight exertion sending the pulse up twenty or thirty beats, and violent exercise may more than double the rate. An increased frequency out of all proportion to the effort made is commonly seen in the debilitated and the diseased.

Pathological frequency of the pulse may be conveniently divided into three groups (Mackenzie). First, those in which the heart responds to an extra call upon it by an excessive increase of rate; second, those in which the pulse rate is continuously increased; third, those in which periods of increased rapidity take place in irregular paroxysmal attacks.

To the first group of *abnormal excitability* belong all cases in which the reserve power of the heart is impaired. This may be the result of some general disease or of valvular or other heart affection. When no other sufficient cause can be found, one may suspect a neurotic temperament or the abuse of some stimulant or narcotic (alcohol, tea, or tobacco).

In the second group of *continued frequency* we may place (*a*) most febrile diseases. In fever the pulse usually bears some relation to the temperature. It is commonly increased about ten beats per minute for each degree Fahrenheit of pyrexia. Marked exceptions to this rule are found in typhoid fever where the increase in the pulse rate is usually small for the amount of pyrexia, and in meningitis where the rate is very variable, but may be lower than normal in spite of considerable fever. (*b*) Diseases of the heart. Increased frequency of the pulse is a common but by no means an invariable symptom of valvular disease. In disease of the aortic valves, especially aortic stenosis, the pulse rate is less likely to be increased than in mitral disease. In degeneration of the heart muscle the pulse rate is very variable, and may be either higher or lower than normal. The rate is usually increased in pericarditis and in overstrain from excessive work. (*c*) Exophthalmic goitre. (*d*) Numerous other conditions such as incipient tuberculosis, exhausting diseases, neuroses, pregnancy, hemorrhage, alcoholism, great anxiety, severe pain.

The third group of *paroxysmal attacks* embraces palpitation and paroxysmal tachycardia. In *palpitation* we have a sudden onset of rapid, violent heart action accompanied by throbbing of the larger arteries. This excessive throbbing does not extend to the smaller arteries, "the radial pulse, for instance, being rapid but having no excess of force" (Balfour). True palpitation occurs in weakly anæmic individuals, and is induced by psychical and gastric reflexes of various origins, "never by exercise." The patient is usually painfully conscious of the violent action of his heart.

In *paroxysmal tachycardia* the subjective symptoms are less pronounced. The heart may be beating even more frequently than in palpitation, and yet the patient be unconscious of the fact. The attacks are variable in duration, but may last several days. During the attack the heart frequently dilates as a result of incomplete emptying by the rapid feeble beats. Mackenzie looks upon the disease as caused by some local heart stimulation giving rise to a prolonged series of premature systoles.

Diminished frequency of the pulse must always be carefully distinguished from those cases of missed beat in which only every second pulse is strong enough to be felt at the wrist. It is a safe rule to count the heart sounds before diagnosing an abnormally slow pulse. An infrequent pulse is sometimes present in individuals who show no other signs of disease. It is said that the pulse of Napoleon Bonaparte was never over forty. An infrequent pulse is most common in the latter half of life. It may sometimes be a symptom of degeneration of the myocardium. It is often seen in diseases accompanied by high blood pressure, such as chronic nephritis, and as a result of poisons produced within the body, as in jaundice, or introduced from without, as digitalis. The most marked instances of infrequent pulse, or *bradycardia*, as it is called, are those following injury to the spinal accessory nerve. This nerve arises from the spinal cord as far down as the fifth or sixth cervical vertebra, and may be implicated in fracture of the spine or inflammatory compression of the cord in this region. In such cases the pulse may fall to thirty, twenty, or even lower. A pulse rate of eight per minute has been recorded. In such cases syncopal attacks and epileptiform seizures are common.

Regularity of the Pulse.—In healthy people who are not suffering from any disturbing influences, the pulse beats are usually regular in rhythm and volume. This may be recognized by the examining finger. In some cases, however, we find variation in the intervals between the beats or in their volume or both. Such departures from the normal present themselves in a great variety of types which are often referred to by different names in the various books on the subject, so that considerable confusion of terms exists. The following table is suggested as a classification of the different kinds of irregularity, although I am quite aware of its imperfections and recognize the fact that there is some overlapping so that the same pulse might be put under more than one heading:

Allorrhythmia (Greek, another rhythm).
- P. alternans.
- P. bigeminus.
- P. trigeminus.
- P. paradoxus.

Arrhythmia (without rhythm).
- P. intermittens (dropped beat).
  - P. deficiens.
  - P. pseudo-intermittens (hemisystole).
- P. intercidiens (premature systole).
- P. irregularis.
  - Diastolic.
  - Systolic.

In *allorrhythmia* the variations in rhythm are themselves rhythmical. Thus in the first subdivision, *pulsus alternans*, we have alternately a strong pulse beat and a weak one. This is sometimes ascribed to a strong beat of the left ventricle and a weak beat of the right ventricle alternating with a weak beat of the left side and a strong beat of the right side. In *P. bigeminus* the beats are in pairs, two beats with a short interval between and then a pause. P. bigeminus must be carefully distinguished from *P. bisferiens* which is a pulse where the predicrotic wave is well marked so that each single pulse has a double crest. In *P. trigeminus* there are three beats and then a pause. Cases are reported in which there are two beats and a pause followed by three beats and a pause. *P. paradoxus* is where the pulse becomes extremely feeble or fails altogether at the end of each inspiration. When pronounced this form of pulse usually indicates adhesive pericarditis or great obstruction of the respiratory passages. A slight variation in the pulse at different stages of respiration may be present in healthy people.

Arrhythmia includes those forms of pulse irregularity which have no rhythm of their own. *P. intermittens* is where from time to time the finger misses a beat. It is sometimes spoken of as dropped beat. Where the ventricle misses a contraction altogether we speak of a *P. deficiens*. Where there is a beat of the ventricle which, while it can be heard over the heart, is too weak to propagate a pulse to the wrist, we speak of a *hemisystole*, causing a false intermission. In *P. intercidiens* instead of a beat being dropped out we have one occurring before its proper time. We may refer to this event as a *premature* systole. Such a premature systole is often too feeble to be felt at the wrist, and is then a hemisystole also. At other times it is distinctly felt, and when it occurs at regular intervals may give rise to a pulsus alternans or pulsus bigeminus. Where there are one full beat and two premature systoles regularly repeated we get a pulsus trigeminus. Under the heading simply of *pulsus irregularis* we may put any irregular pulse that cannot be classified in any other group. This and pulses of the other groups as well, may be separated into two divisions of some practical importance. In the first of these the irregularity is due to a variation in the length of the pause (*diastolic*). Such irregularity is frequently found in the healthy, and is of little importance. In the other division the irregularity is due to variation in the force and duration of the ventricular contraction (*systolic*), and the pulse beats are felt to vary in strength. Pulses of this kind are more apt to indicate danger and should be carefully considered after thorough examination of the heart. Diastolic irregularity is frequently seen in children, and Mackenzie proposes to call it *the youthful type* of irregularity, although it is often seen in adults too, especially as the pulse is slowing down during convalescence from a fever. For systolic irregularity Mackenzie proposes the term *adult type* of irregularity. The terms systolic and diastolic seem to the present writer less open to objection.

In looking for the *cause of pulse irregularity* we first turn to the heart and find that sometimes the lack of normal rhythm is due to independent action of the ventricle and sometimes may be traced back to the auricle. To determine which chamber is primarily at fault may best be complished by taking simultaneous tracings from the radial and jugular, as will be further explained shortly in connection with the venous pulse and also in the article on *Sphygmography*. Irregularity is frequently a result of the strain put upon the heart by valvular disease, but is not often seen in pure aortic cases. It is especially in cases of advanced mitral disease in which the auricles are overworked and distended, perhaps paralyzed, that we get the most pronounced forms. Among other causes of irregularity are myocarditis and fatty degeneration, anæmia, strain, and digitalis poisoning. The latter is said to be often characterized by a pulsus trigeminus.

One cause of pulse irregularity that requires special discussion is vagus inhibition. Some writers go so far as to make influences reaching the heart through this nerve almost the sole cause. Such a statement is doubtless an exaggeration, and yet many influences act reflexly through the vagus in such a way as to cause irregularity. Among these we may include emotional shocks, such as sudden joy, sorrow or fear, mental strain and worry, gastro-intestinal disturbance, pain, injury, cold, either external or internal.

Fig. 3900 is a tracing from a patient in whom the heart appeared quite normal. She had suffered much from domestic trouble for several months and it is possible that that was the cause of the irregularity.

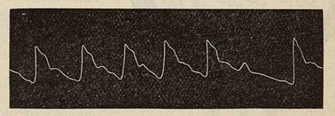

Fig. 3900.—Pulse showing Premature Systole.

To the finger on the wrist it seemed as though there were an occasional intermission. The pulse tracing shows that this was not a pulsus deficiens but merely a weak beat (hemisystole). If careful measurements be made it will be seen that the weak pulse beat comes a little before it is expected (premature systole). One frequently finds irregularities of this kind in people without any other symptoms of disease. An instance which came under my notice recently would suggest that it may sometimes be an hereditary peculiarity. I had the opportunity of examining a father and son, both of whose pulses were irregular. In the father's pulse there was a weak premature systole at intervals varying from a few beats up to thirty or more. In the son they occurred every four or five beats if he kept very quiet, but slight exertion caused the entire disappearance of the irregularity. Both of these men have hearts rather below than above the average size, and neither of them has any symptoms of disease.

As to *prognosis in cases of irregularity*, such cases as those just mentioned in which the heart appears quite sound need not excite any alarm, especially if the irregularity be known to be of long standing. If the heart is dilated the case should receive more consideration. Cases of diastolic irregularity in the young or convalescent need not excite any alarm. It is a totally different thing when an irregularity develops in a case of old heart disease or in the course of a fever. In both of these cases it suggests overloading or paralysis of the auricles, and is a symptom of danger. Cases of pneumonia in which the pulse becomes intermittent before the crisis are usually fatal. As a rule, where people have an intermittent pulse during health the onset of fever causes the intermission to disappear. When this does not occur, it may be taken as a danger signal. Generally speaking, the more rapid the pulse the more serious is the occurrence of intermission or other irregularity. Irregularity can be given its proper importance only when considered with other symptoms. If there are no other serious symptoms and the heart can respond well to extra calls upon it, then irregularity is of little importance. When, on the contrary, there are other symptoms that the heart is laboring under stress of work, then irregularity may be taken as an additional bad sign, and the more so the higher the temperature and the more frequent the pulse.

Size or Excursion of the Pulse.—Pulsus magnus or parvus, large or small pulse. These terms are used to describe the sensation that the finger has of being lifted as the pulse wave passes. When the sensation is very considerable we speak of a large pulse, when it is slight of a small pulse. One naturally explains this sensation by supposing that the artery expands as the result of increased tension. Many writers, however, among whom

Sir William Broadbent is prominent, minimize the effect of arterial expansion or deny its occurrence. According to them the finger pressing upon the wrist pushes in or flattens the artery between the beats, but feels a tendency of the vessel to resume its cylindrical shape under the increased tension of the pulse wave. This latter view seems very reasonable, but some slight expansion must certainly take place.

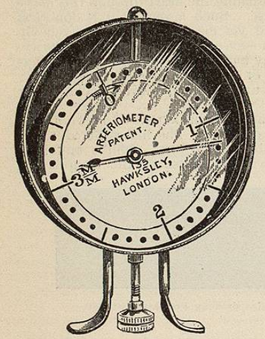

FIG. 3901.—Oliver's Arteriometer.

A large pulse means that a large quantity of blood is being forced into the arterial system at each heart beat and points to a powerfully acting ventricle and unobstructed vessels.

A small pulse may be present in a variety of conditions. It may be from the presence of some disease of the valves of the heart putting the ventricle at a disadvantage. It may be from some obstruction between the ventricle and the wrist, such as aortic stenosis, aneurism, or tumor. Or the artery being examined may be abnormally small on account of some other artery like the ulnar being larger than usual. The most obvious cause of all is a heart beating feebly.

If we get a small pulse in a contracted artery we call it a wiry pulse, if the arterial tension is still considerable; if the tension is low and the pulse very small, we speak of a thready pulse, which is seen in cases of severe shock or where a patient is in extremis. A small pulse in a relaxed vessel is sometimes spoken of as a trembling or a running pulse.

Quickness of the Pulse.—Pulsus celer or tardus, quick or slow pulse. These terms are properly applied not to the rate of the pulse, but to the suddenness with which the expansion of the vessel takes place. In the quick pulse the sensation imparted to the finger is that of a sudden tap. In the slow pulse there is a sensation of more gradual lifting or heaving, and the feeling of pressure lasts for an appreciable time. A quick pulse is seen when the ventricle empties itself easily. It is usually present when the blood pressure is low, but not in aortic stenosis, for then there is obstruction to the work of the ventricle. The most characteristic form of quick pulse is the Corrigan's or water-hammer pulse of aortic regurgitation. The character of a slow pulse differs according to the position where the obstruction to the outflow of blood from the ventricle may be. If the obstruction is at the aortic valves the pulse is slow and of low tension, as in aortic stenosis. If the obstruction be in contracted peripheral vessels, then the pulse is slow and of high tension, as in chronic nephritis.

A dicrotic pulse is one where the dicrotic wave can be felt as well as the primary wave It is characteristic of relaxed vessels with a fairly strong heart action. It is most common in fever where the arterial tension is usually rather low. When the blood pressure falls very low, as in a failing heart, the dicrotic wave tends to disappear. It will be more fully discussed in connection with pulse tracings.

Symmetry of the Pulse.—An examination of the pulse is not complete without comparing the corresponding arteries on the two sides of the body. When there is a difference on the two sides, it is necessary to trace up the course of the vessel on the side where the pulse is weakest. Somewhere in its course from the heart to the wrist one may find a tumor or aneurism or deformity causing pressure and partial obstruction. Dr. Allison, of Edinburgh, made the claim in a clinical lecture some seventy years ago that he had observed in a severe case of fever that the pulse had a fuller character on the side on which the patient was lying. He ascribed this to the influence of gravity acting on weakened relaxed vessels much as it would do after death. I do not think there is anything in Oliver's recent experiments to render this unlikely.

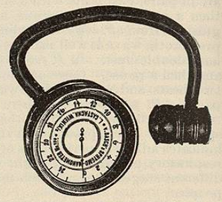
FIG. 3902.—Von Basch's Sphygmomanometer.

Field of Response.—This is a term suggested by Mackenzie for the ability of the heart to rise to occasions. We may also speak figuratively of the heart's "bank account." This may be investigated by noting the effect upon the pulse of various degrees of exertion. Sometimes a pulse which seems good when the patient is resting changes its rate and character to such an extent on slight exertion as to indicate serious weakness. The breathing should be noted and may furnish confirmation of the opinion formed from the pulse. This is a method of considerable value in estimating the seriousness of an irregular pulse. The less dangerous forms of irregularity tend to disappear on slight exertion, whereas cases due to a failing heart may be expected to show increase of irregularity and breathlessness.

INSTRUMENTAL AIDS in the examination of the pulse. *The calibre of the vessel* may be approximately measured by *Oliver's arteriometer* of which an illustration is given in Fig. 3901. The principle is that a pointer on the graduated dial marks the distance which the central foot has to be pushed down from the time it begins to press on the artery till it quite obliterates it. The readings of this instrument may not be absolutely reliable, but it is sufficiently accurate for comparing the size of the same artery under different circumstances. In this way it has been used by the in-

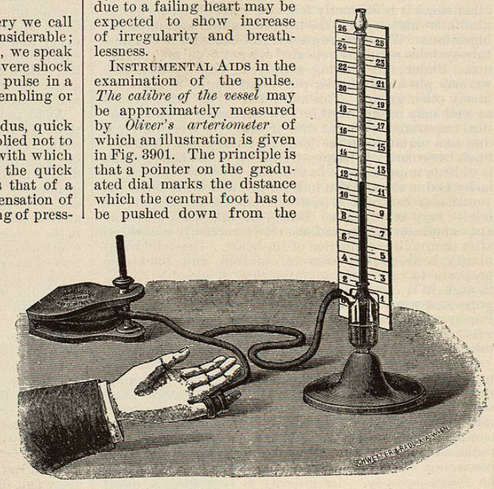
FIG. 3903.—Gaertner's Tonometer.

ventor for working out the effect of various influences on the vaso-motor tone and the distribution of the blood in the body.

Arterial Pressure.—A number of instruments are on the market for measuring the arterial pressure in man and several different principles are represented. The best known instrument for the purpose is perhaps the *sphygmomanometer of von Basch*. This is shown in Fig. 3902. It consists of a capsule which is pressed upon the radial artery until the pulse is obliterated below, and a dial and pointer which indicate how much pressure has been exerted. It is only moderately accurate. Leonard Hill claims that errors as great as from 30–70 mm. of mercury are made with it. Much would doubtless depend upon the man using it. *The tonometer of Gaertner* (Fig. 3903) seems to be a very good instrument. Dr. Orr, of Montreal, reported at a recent meeting of the Canadian Medical Association an exhaustive study of the pressure in different diseases in which this instrument was used. The most striking results were the high pressures obtained in many cases of nephritis, and the fact that in cases of valvular disease of the heart the pressure average was not very different from that found with sound hearts. With this instrument we measure the amount of pressure which must be exerted around a finger to prevent the blood flowing through its vessels. The instrument as shown is well adapted for the office, and a more portable modification may be obtained for carrying about.

Other instruments for measuring blood pressure depend upon the principle that the excursion of the pulse is greatest when the pressures inside and outside the artery are equal. The *sphygmometers of Hill and Barnard*, the *sphygmomanometer of Riva Rocci*, and the modification of it used in the Johns Hopkins Hospital, and the *hæmodynamometer of Oliver* are all of this type. Of all these the simplest is one of the two forms invented by Hill and Barnard (Fig. 3904). It consists of a vertical glass tube five inches in length which expands above into a small bulb and is closed at the top by a glass top. A small india-rubber bag partly protected by a metal cup is fixed to the tube below. The bag is filled with colored fluid, and on pressing it down upon an artery the fluid rises in the tube and compresses the air in the bulb. The more one presses the more the fluid rises; at a certain height the meniscus of the fluid exhibits more pulsation than at any other height. At this point the top of the meniscus indicates the arterial pressure. This instrument has been described at length because it is cheap, simple, and fairly accurate if carefully used.

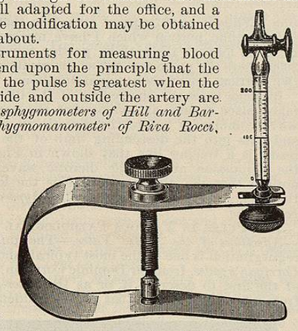
FIG. 3904.—Sphygmometer of Hill and Barnard.

The pulse waves may be made to record themselves automatically by one of the various forms of *sphygmographs*. These instruments, as already said, are contrivances by which movements of a blood-vessel are transmitted to a lever, which records them on smoked paper. For the various forms of instrument and the method of using them the reader is referred to the article on *Sphygmography*. The product is a tracing, of which a normal example has already been given in Fig. 3897.

Criticism and Appreciation of the Sphygmograph.—It was thought for a time that the sphygmograph would indicate, so that he who ran might read, the pressure, size, and quickness of the pulse, as well as the peculiarities incident to various diseases; these hopes have proved vain, and we now know that the sphygmograph is inferior to the finger in most of these points. One great difficulty in the interpretation of the sphygmogram is that a great variety of tracings may be obtained from the same pulse by simply varying the pressure of the instrument or by employing different makes. Fig. 3905 shows three pulse tracings taken within a few seconds of each other from the radial artery of the writer. The differences are due to the pad being pressed down upon the artery with varying force. Fig. 3906 shows tracings taken, the upper from the carotid, and the lower from the radial of the same subject, within a few minutes of one another. In this case the carotid was recorded by air transmission and the radial by transmission through a spring. Features are sometimes found in pulse tracings which do not represent anything in the pulse at all, but are dependent on inertia or rebound of the instrument.

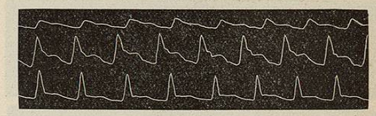
FIG. 3905.—Pulse Tracings which show Effect of Varying Pressure.

In spite of all these pitfalls that beset us, however, it is possible to take sphygmograms that will afford us much information about the pulse and the conditions which determine its character. In tracings we can see the principal events of the pulse in their proper time relations. They show us what to feel for, and corroborate or controvert the opinions we have formed of the pulse from our tactile examination. The sphygmograph is very useful as a guide to those who are learning to feel the pulse and in whose finger tips the tactile sense is not fully educated. There are points about the pulse, too, that even the most highly trained "thumb and finger fail to plumb" which are shown with ease by this instrument. The dicrotic wave and the predicrotic wave usually belong to this category. In irregular pulses we often have premature systoles or other weak heart beats causing pulse waves too weak to be felt by the finger, but not too weak to be shown by the instrument. Then tracings enable us to compare the time relations of the waves in different arteries or to compare the time of the arterial pulse with the heart beat or with the venous pulse. Such tracings are of value in working out the rate of propagation of the pulse and the direction in which the waves travel. The venous pulse very often can only be safely interpreted in the light of such simultaneous tracings.

It is doubtful whether sphygmography will ever be a routine method in general practice, but for the specialist, the teacher, and the investigator it is very valuable, and, when the elements are mastered, becomes an interesting and instructive practice.

Normal Pulse Tracings—High and Low Pressure.—The four tracings shown in Fig. 3907 are all taken from people in good health without any circulatory or general disease.

As far as tracings can do so, the first of these four sphygmograms indicates rather high blood pressure and the last one low pressure, while the two between represent intermediate conditions. One is safer in trusting the finger for indications of the arterial pressure than in

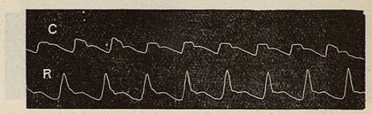

FIG. 3906.—Pulse Tracings Taken from the Carotid (*C*) and the Radial (*R*).