

but an impulse has been given to them, and what is now wanted is a greater mass of carefully-authenticated facts. These are the only materials that science can work upon; and whoever assists in the work of collecting them may rest assured that they will be of service, not only to the interests of knowledge, but also to the higher well-being of mankind.

*Muscular Movements in Man, and their Evolution in the Infant: A Study of Movement in Man, and its Evolution, together with Inferences as to the Properties of Nerve-Centres and their Modes of Action in expressing Thought.** By FRANCIS WARNER, M.D., F.R.C.P., Physician to the London Hospital, and Lecturer on Botany in the London Hospital Medical College.

Section I.—Study of Movements in Man.

(1) Movement in man has long been a subject of profitable study. Visible movement in the body is produced by muscular contraction following upon stimulation of the muscles by efferent currents passing from the central nervous system. Modern physiological experiments have demonstrated that when a special brain-area discharges nerve-currents, these are followed by certain visible movements or contraction of certain muscles corresponding. So exact are such reactions, as obtained by experiment upon the brain-areas, that movements similar to those produced by experimental excitation of a certain brain-area may be taken as evidence of action in that area, or as commencing in discharge from that area (see Reinforcement of Movements, 35; Compound Series of Movements, 34).

(2) *As to methods of observing and recording movements.*—Movements are the visible signs of action in certain brain-areas corresponding, they are also the data for the study of brain-action. Most of the observations to be given are the result of simple visual observation noted down when seen; in some cases a graphic method of recording movements has been used (see "Journal of Physiology," Vol. iv., No. 2, and Vol. vii., No. 4).

It is also desirable to record the time of the antecedents of the movement seen, and for this purpose the graphic method

* Paper read before the Royal Society, June 21st, 1888.

is very useful; the sequences and concomitants of the movement should also be noted.

(3) *Attributes of a movement.*—A movement as produced by a nerve-centre has but two intrinsic attributes, Time and Quantity. We may note the sequence of the movement (see 27) as well as its necessary antecedent (see 26), the relation of the time of the antecedent to the time of the sequence, and also the ratio of the quantity of the antecedent stimulus to the quantity of the force of the movement resulting (see 34, 35). Many of the special characters of the movement depend upon its relations to the antecedents, its relations to the sequence, or upon the surroundings of the subject observed.

(4) *Static action in nerve-centres.*—A movement is a sequence and index of efferent nerve-currents. Efferent currents from two or more centres to the muscles may for a time be uniform, in which case we observe their ratios as indicated by the postures resulting.

(5) *Time of a movement.*—We may observe the time, duration, and frequency of a movement. In observing movement of two or more parts we note the combinations, and series of acts. The time of each separate movement determines a special combination and the order of the series of combinations that occur.

(6) *Quantity of a motor action.*—The quantity of motor action is in part observed by noting the frequency of repetition, and the mechanical work done by the movement. It may also in part be described in terms indicating ratios of motor static action as seen in the postures resulting.

(7) *Postures.*—Postures depend upon the ratios of nerve-muscular action, and to some extent they indicate the present ratios of static efferent force proceeding from the centres concerned. Observations show that the postures, when not due to a present stimulus, or when produced by a weak stimulus from without, such as a sound or sight, correspond to and are signs of the general condition of the central nerve-system (see Signs of Fatigue, 38).

Alteration of postures is the same thing as movement. Movement is due to alteration in the ratio of action in the centres. The ratio in equilibrio produces postures.

(8) *Parts of the body.*—In order to describe movement in the body, it is necessary to note and define the part or parts moving, the direction of the movement, and also its time and its quantity. In proceeding to speak of some parts of the

body that can move separately, the more important facts observed as to their movements and postures will be indicated. The following points are mentioned as having specially attracted my attention in recording observations, and are such as appear to be of physiological importance.

(9) *The upper extremity*.—In the upper extremity, the shoulder, elbow, and wrist have the movements described by the anatomist; in making observations, the relative extension of the shoulder, pronation, adduction of the wrist, etc., on either side of the body, can easily be observed and noted.

(10) *The hand*.—In the hand, the metacarpal bones are capable of position all in the same plane, that for the thumb can be separated from the others or approximated to them. All these bones may be approximated so as to contract the metacarpus, as when the hand is made into a cone. The fingers may be flexed at each joint, and extension backwards may occur at the metacarpo-phalangeal joints to a varying angle, greater in children than in adults. The fingers can also move at their junction with the metacarpus, in a lateral direction. It may be noted as an anatomical fact that these lateral movements of the fingers are performed by small muscles, the interossei, while flexion and extension are performed by larger muscles in the fore-arm. Contraction of the metacarpus results from action of the small muscles of the thenar and hypo-thenar groups.

Experience has shown that the following movements, and ratios of action, indicate special conditions or brain-states.

(11) *Metacarpus straight*.—All the bones of the metacarpus may be in the same plane; this appears to be the normal when the hand is held out on request.

(12) *Metacarpus contracted*.—In certain cases the metacarpal bones are approximated, as when the hand is made into a cone. As far as I know, Trousseau, in his article on "Tetany," first pointed out the significance of this posture as a pathological sign.

(13) *Over-extension of knuckles*.—In the normal, the digits are not extended back beyond the plane of the corresponding metacarpal bones, but such over-extension may occur and is commonly associated with lateral movement of the digits. Both this posture and these movements probably result from action of the interossei.

(14) *Anatomical mechanism of the hand*.—Professor Marshall drew my attention to the following fact, which is important as to the significance of certain hand-postures.

Let the forearm be examined when its muscles are all relaxed, the limb resting on a table and the hand hanging free beyond its margin. When supine, the hand falls into extension and the fingers are passively flexed, owing to the mechanical effect of dragging the flexor tendons over the carpus in that position.

(15) *The head.*—Movements and postures of the head may be defined by speaking of flexion, extension, inclination to right or left, and rotation to the right or left; other movements and positions are described by compounding these terms. Head-flexion and extension are its only symmetrical movements and postures, *i.e.*, the only actions due to equal and synchronous action of the corresponding centres on the two sides of the brain.

(16) *The spine.*—The movements and postures of the spine have often been defined. Lateral curvatures and lordosis appear to me specially important, and perhaps are signs of equal value.

(17) *The face.**—The face is so mobile in its parts, its movements and balances of muscular action are so important, that it is convenient to examine each side separately, and then divide it into three horizontal zones, the “frontal” above the level of the orbits, and the “middle,” which is divided from the “lower” zone by a horizontal line at the level of the lower margin of the orbits. The two sides of the face usually act at the same time, and in equal degree in each part respectively. The more common asymmetrical movements are in one orbicular muscle of the eyelids—at one angle of the mouth—or contraction of one levator labii superioris *alæque nasi*, uncovering the canine tooth. The separate mobile features, or facial areas, may act with a certain degree of independence. Slight variations of muscular action may be indicated by slight alterations in the tension of the skin in various parts. In the frontal region it is often useful to use the strong light of a condenser, screening the eyes, and employing a magnifying lens so as to observe slight alterations in the markings on the skin. The muscles of the face generally may be toneless, and void of any spontaneous movements; in extreme conditions the features may fall somewhat, allowing the face to become elongated (see Signs of Fatigue, 38). The tone of the orbicular muscles is in all cases specially worthy of notice.

* See Author's “The Children, how to Study them.” Section IV. F. Hodgson, Farringdon Street.

(18) *Movements of the eyes.*—Under ordinary circumstances the axes of the eye-balls remain parallel to one another in their various movements except upon near vision, when the axes converge and the pupils contract.

(19) *Eyes in coma.*—Under chloroform, in deep alcoholism, and in the deep sleep of infants, this is not so. Then the pupils are minutely contracted and the eyes move, though no other movements are seen in the body but those of respiration; such movements are slow in either eye and quite independent of one another—one eye may be temporarily stationary while the other moves, or they may move in different directions and at different pace.

The greater number of ordinary movements of the eyes are in the horizontal plane of the orbits. Movements of the eyes may be so frequent that they are never at rest; many such movements are not controlled by sight and are usually horizontal in direction. Eye-movements are usually controlled by sight, by sound, and by touch of any part of the body. Movements of the eyes in their orbits may occur without movements of the head. In the adult it is most commonly so, but in young children I think the head and eyes are more frequently moved together. It is much less common for the head to move in one direction and the eyes in the opposite. Dr. Gowers has pointed out some interesting facts with regard to movements of the eyes ("Med. Chi. Trans.," 1879).

(20) *The jaw.*—The muscles of mastication may be relaxed, allowing the jaw to droop and thus elongate the face (see Fatigue, 38). Occasionally, following upon some impression of sight or sound, the muscles contract spasmodically, producing lateral movements of the closed jaws and tooth-grinding. More commonly such action takes place during sleep; such movements, occurring without any immediate impression from without the body, are perhaps the most common spontaneous movements which occur during sleep, except those of the eyeballs already described (see 19). As to what is here meant by "spontaneous movements," see 28.

(21) *Small parts.*—In describing visible movements, it is necessary to note separately movements of small and large parts, or rather movements effected by small muscles as contrasted with those produced by larger muscles. The intrinsic muscles of the hand, the muscles of the eyes, the face, the tongue, and larynx, are here classed among the small muscles. The interossei, whether in the static condition producing over-extension of the metacarpo-phalangeal

joints, or when producing lateral movements of the fingers, may be contrasted with the long flexor muscles; again, the muscles of the thenar and hypo-thenar eminences in contracting the metacarpus may be contrasted with the larger extensors which straighten it transversely.

(22) *Respiratory movements*.—In observing the groups of movements which produce respiration it is usual to find that they are symmetrical on the two sides. The movements of the sternum and epigastrium should be separately recorded. The rhythm of the movements, or character of the series of acts, is usually regular or similar in each act, that is, if not altered by an impression received from without. It has been said that the respiratory movements are usually a regular succession of similar acts, but no set of movements is more liable to alteration of its rhythm than are those of respiration. Sight and sound may readily alter the component movements of the respiratory action.

(23) *Identical and similar movements*.—If on two or more occasions there be movements of the same part of the body, the action being alike in direction, in time, and in quantity on each occasion, then the two series of movements are identical. Identity of movements is thus defined as dependent upon intrinsic attributes, not upon relations to the sequences or antecedents. If the analogy is less perfect, movements may be called similar, though not identical.

(24) *Identical and similar postures*.—If in similar parts corresponding joints are equally flexed, extended, etc., then the postures are identical. If in each limb, compared as to postures, corresponding joints are flexed, extended, etc., but not in equal degree, then the postures are similar, but not identical. Thus, when the two upper extremities are held out at request, the left shoulder may be less extended than the right, making an angle of 25 degrees below the horizontal, while on the right side the shoulder is more extended, the humerus being only 10 degrees from the horizontal. The wrist, again, may be more flexed on the left side, and the metacarpo-phalangeal joint, and the internodes of the thumb, may be more extended on the left than on the right. Such ratios of action are common, and such relative postures on the two sides are similar, but not quite identical.

(25) *Asymmetrical postures*.—Asymmetrical postures indicate unequal ratios of action in corresponding centres on the two sides of the brain, hence flexion and extension of the head and spine are their only symmetrical movements or

postures. Rotation and inclination of the head are not symmetrical postures.

(26) *Antecedents of movements*.—Certain movements frequently follow upon a sound or special sight with great uniformity. They may also follow impressions received from any of the organs of sense or any other parts of the body. Sound or sight may be followed by head-rotation, flexion, or extension, but it appears that sight less frequently causes inclination as an immediate sequence. This is more often due to some general condition of the brain-state (see 38), or to previous impressions received. Sight and sound are not known as the usual immediate antecedents of the frequent posture—"wrist-flexion with over-tension of the metacarpophalangeal joints." On the contrary such stimuli may be followed by extension of the wrist, with or without extension of the digits. Sight or sound will not often appear as immediate antecedents of a hand-posture, "all parts flexed with contraction of the metacarpus." Such states of balance appear to depend upon the average condition of the nerve-system, not upon immediate stimulation through the senses. Restless movements of the eyes are due to a want of control of the nerve-centres by surrounding objects.

(27) *Sequence of movements*.—The sequence of certain movements may be very complex, although the movement itself is a simple phenomenon. Given the antecedents we note the sequence. If we use certain stimuli experimentally, as in testing knee-jerk, we observe the sequence as a movement. So if light be allowed suddenly to fall upon the eye we observe the sequential contraction of the pupil.

A muscular movement is always itself a physiological fact, the outcome of nerve-action. The sequence of the movement may not be a physiological fact, but a mechanical one, as lifting a weight or writing.

The terms employed to express the results of movement are almost innumerable, and the supposed antecedents, or causes of actions, are almost as many. The physiologist need do no more than record visible facts and his methods of observation. He may subsequently draw inferences from his observed facts, or look to the relations of his facts. This I shall do in Section III.

(28) *Spontaneous movements*.—Movements are often observed without any known circumstance stimulating them. Examples will be given further on, especially in the cases of young infants (see 42). Probably in all cases such move-

ments, if not really excited by surrounding forces acting at the time, are due to previous impressions received by the individual or inherited by him.

(29) *Controllability of movements*.—Observations on the antecedents of actions show that movements may be controlled as to their time and quantity by physical forces acting from without. If such forces control the time of action of the movements they necessarily determine the combinations and series of movements (see *Impressionability*, 69.)

(30) *Parts free and disengaged*.—It may be found that some stimulus, such as the sight of an object or light, is acting strongly upon a man, and that his movements and postures, or balances of action, are controlled thereby. Observation may further show that the movements and postures are not then readily altered by such other stimulus as sound. If the stimulus of sight be withdrawn, then the sound may control both movements and postures. In a case where stimulation by sight is less strong the sound may act more readily (see 71).

(31) *Movements indicating retentiveness*.—Retentiveness as a property of nerve-centres may be indicated by the movements following from sight. In an individual we may observe a similar series of movements (see 23) follow a certain stimulus on successive occasions. This may be the case when the experiment is repeated at long intervals (see 50, 65, 72).

(32) *Movements indicating delayed expression*.—Series of movements may be observed to follow a long time after some stimulation which was their necessary antecedent. The impression made at one time may not be immediately followed by any visible outcome. The outcome may be long delayed; it may not be visible till certain forces again act upon the subject (see 73).

(33) *Movements indicating double action in nerve-centres*.—It is common to find evidence that an impression received is followed by two results—(a) a movement immediately following the impression; (b) a delayed result, indicated by a subsequent series of movements (see 74).

(34) *Compound series of movements*.—As to the relation of an observed series of movements to its necessary antecedent, it is very common to see a long series of movements, involving many parts, follow upon some slight stimulus, such as the sound of some word of command, or even a gesture seen

in another person. The compound series of movements does not necessarily terminate in a strong act, but in one, as it is commonly said, well adapted to the circumstance. In all such cases, however, it will be found that impressions have been made upon the brain antecedent to the slight stimulus which immediately started the series of actions observed. Such compound action may be in part an example of delayed expression (see 32), or of previous impressions upon the brain, and in part a reinforcement (see 35). Such cases of "compound series of movements" do not occur in the infant at birth, or in very early life (see 43). The cerebral arrangements for such actions must be built up (see 52).

(35) *Reinforcement of movements*—A series of movements may occur sequential to some stimulus, in which the final movement is much stronger than would be expected from the force of the primary stimulus, each group of movements as the series progresses increasing in number and in force. It is the spreading area of movement, or the increasing number of parts moving as the action proceeds, that is here specially indicated, such augmenting series of movements being started by a very slight stimulus. The force expended in such series is out of all proportion to the strength of the original stimulus. The sound of a sharp word to a child may be followed by depression of the angles of the mouth, alternate tonic contraction and relaxation of the orbiculares oculi, altered respiratory movements causing screaming, flushing of the face, and finally clonic contractions in various muscles spreading over the body.

(36) *Movements indicating general conditions of nerve-centres.**—To illustrate what has been said concerning the study of movements, descriptions of certain properties, modes of action, and general conditions of the nerve-system may be given in terms implying movements. Conditions may be indicated by observations as to—(a) *static states* by postures, which are due to ratios of action; (b) *dynamic states* by movements, namely, such as occur upon special stimulation by light, sound, touch, etc., or by reflex movements directly stimulated by impressions made upon certain parts of the body and its surface.

(37) *Movements indicating similar conditions of centres.*—If two individuals do not present similar movements following upon similar stimulation (see 23), we infer that the con-

* See Author's "Physical Expression," Chap. XIII, International Scientific Series.

dition of their centres is not similar. Thus the sight of an object may be followed in one man by the head and eyes turning towards it, while in another man they may turn away from it.*

(38) *Signs of fatigue.*—After ten hours' work a man may present the following signs:—The force expended in movement is small in amount, and the total number of movements is lessened. A certain number of movements may occur not directly stimulated through the senses, and they may not be like the movements ordinarily seen in the man (see *Similar Movements*, 23). Thus the eyes may move horizontally uncontrolled by sight or sound, the fingers may move in flexion or extension, or laterally without effecting any mechanical work; one digit or many may thus move. Under stimulation the movements are not the normal, the eyes are not moved by sight of familiar objects, the head may not move to familiar sounds, speech is not readily stimulated by the sound of familiar words. The head is more readily flexed under the influence of gravity; the knee-jerk phenomenon is less easily elicited (see papers by Dr. Lombard, "*American Journal of Psychology*," November, 1887). Further, the head and eyes may turn away from familiar sights and sounds, an action antithetical to the normal. These reflex actions may be excessive, especially to sharp and sudden noises, or to touch, and compound motor action (see 34) may be either almost absent or different from the normal, as indicated by the movements.

As to the postures in such condition. The postures as well as the movements are often asymmetrical (see 25); the head may be slightly rotated and inclined to one or other side, the shoulders unequal in level, the spine bent to one or other side, and too much bent forward when standing. If the hands are held out they are not on the same level; the wrist is slightly flexed, the fingers partially flexed, the metacarpus somewhat contracted (see 12), or, at least, the thumb is drooped.† This hand-posture is usually seen on either side, but may be more marked on the left (see 25). The face may be slightly elongated and the lower jaw slightly drooped from muscular relaxation, while the loss of tone in the orbicular muscles of the eyelids produces fulness or bagginess

* See Author's "*Physical Expression*," Chap. XIII, *International Scientific Series*.

† See Author's "*Anatomy of Movement*." Kegan Paul & Co. Postures are there classified and named.

about the lower lids. The mouth also may be partially open.

(39) *Sleep*.—We may further observe this individual, and note as follows:—Darkness and quietness are circumstances under which movement may not occur in the limbs while the eyelids close, but the respiratory movements continue. Certain movements, not controlled by present circumstances, may occasionally occur in the limbs and fingers. The orbicular muscles of the eyelids predominate over the elevators, so that the eyeballs are covered. The jaw often falls slightly, the orbicular muscle of the mouth is usually relaxed, and the mouth partially open.

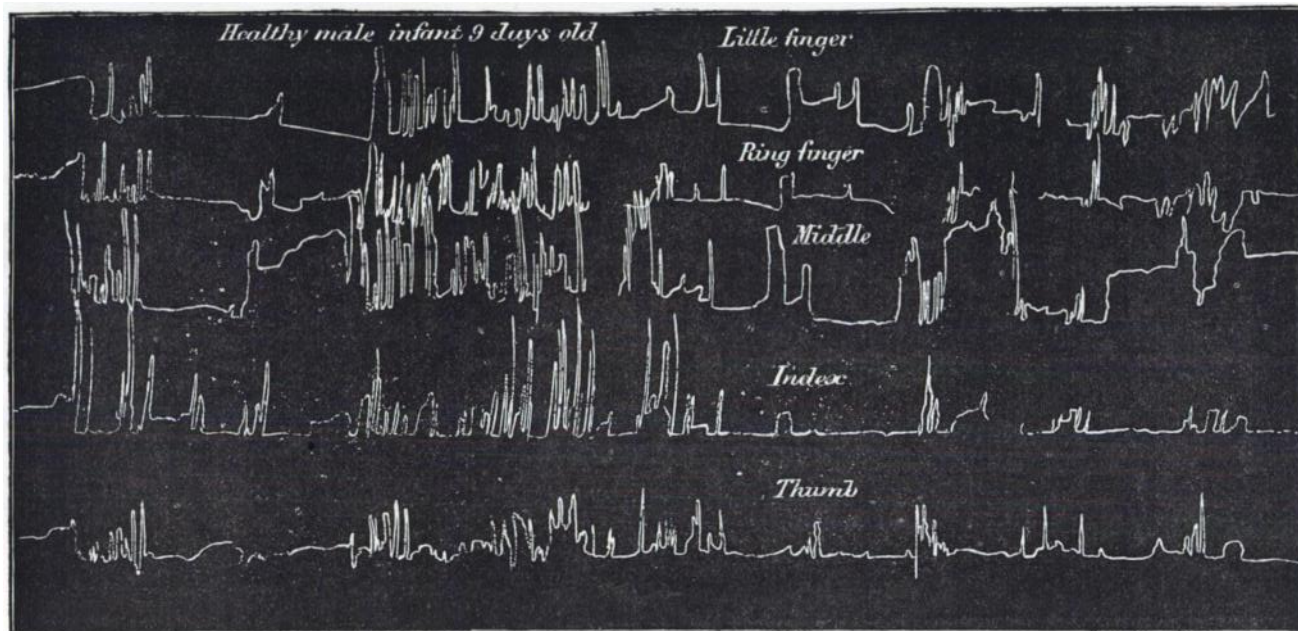
Section II.—The Evolution of Visible Movement in Man.

(40) *Microkinesis*.—Common observation affords abundant evidence that the various members, and parts, of a healthy infant present constant movement while it is awake. The same thing may be demonstrated by use of the graphic method. These phenomena appear to be of great physiological importance, and as their history, their meaning, and their analogy have not hitherto been fully discussed, I propose to describe this class of movement under the term microkinesis.

(41) *At birth*.—In the infant respiratory movements are established at birth, and continue without interruption. The child cries (see 35) when the skin is wet or cold, and when food has been withheld more than two hours. Contact of an object with the mucous membrane of the lips stimulates the movements of sucking. Cold to the skin is followed by crying, light causes closure of the eye-lids, and if the eye-lids be raised the pupils contract to light. The tone of the sphincter apparatus enables the hollow viscera to retain their contents for a short time. In an infant a few hours' old, the attempt to straighten the elbow when flexed may be strongly resisted.

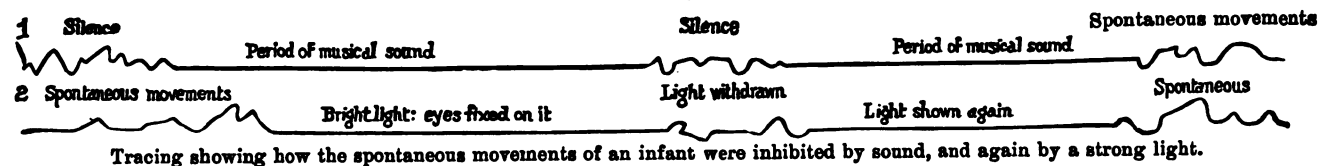
(42) *Movements of microkinesis*.—When the infant is awake spontaneous movements (see 28) may be seen in the limbs, especially in the digits or small parts; they are slower than most of the movements of adults, and are almost constant. They occur in no apparent order, but appear to be quite irregular. A short period of wakefulness is usually followed by sleep, indicated by subsidence of all movements except those of respiration and closure of the eye-lids.

FIG. 1.



Tracings of the spontaneous movements of an infant's hand during fifteen minutes.

FIG. 2.



Tracing showing how the spontaneous movements of an infant were inhibited by sound, and again by a strong light.

(43) *Movements controlled.*—These movements, in the newborn infant, are not controlled through the senses by sight or sound. However, movements of respiration and deglutition are controlled by impressions upon the skin and mucous membrane. At this early stage we do not observe the phenomena of delayed expression (see 32), compound cerebation (see 34), or cerebral inhibition (see 49), but reinforcement of movements appears in the act of crying (see 35).

(44) *Movements of eyes.*—The eye-movements usually maintain parallelism of their axes, but if the organization of the infant is feeble the eyes, as they move, do not maintain a strict parallelism of their axes (see 19). This is most commonly observable when the child is sucking its bottle.

(45) *No signs of mental action.*—It is commonly said that the infant at birth does not give expression to the faculties of mind, because it does not present signs showing that its nerve-centres are impressed, even temporarily, by the sight of surrounding objects; its hands do not move towards objects within the field of vision, and none of its movements indicate that they are controlled by sight or sound.

(46) *At one month.*—Following up our observations through the early weeks of infant life it seems that movements in the face appear first about the mouth, later in the forehead. The limbs are moved with more force, they move through a greater amplitude, and may begin to effect some mechanical results. An object placed in the hands is followed by closure of the fingers, and movements of the elbow may result in the object being carried to the mouth, but soon microkinesis returns in the parts and the object is dropped.

(47) *At three months.*—When about three months old some control of movements through the senses may be observed, and the head may move towards a bright light. Still we do not see the hand move straight towards an object within the field of vision, and when a part of the body is irritated the hand does not move towards it; there is not much capacity for compound cerebation (see 34). I have known a child in whom one leg was irritated, and the hand was not moved to scratch it, but the other leg moved up and did so with the foot. The associated movements of the hands, in such an act as transferring an object from one hand to the other, is not acquired for some months (see Compound Movements, 34). The microkinesis still continues, and when the muscles are strong enough to hold up the head, spontaneous movements of this part as well as of the eyes are

seen. The ever-changing expression of children's faces appears to belong to the same class of movements. In the earliest stages microkinesis produces very little effect upon objects around; it does not supply the child with food or minister to its necessities.

(48) *At four months.*—When the infant is about four months old we find commencing signs of impressionability to stimulation through the senses, the sight of objects, and sounds around begin to control the microkinesis (see 39). Here is a tracing from an infant about four months old; the microkinesis was temporarily inhibited both by sight and by sound.*

(49) *Inhibition.*—A little later in the history of the cerebral evolution of the infant the sight of an object may not only inhibit the microkinesis, but this may be followed by turning of the head, the eyes, and the hands, towards the source of the light or sound (see Compound Movements, 34, and Reinforcement of Movements, 35). Sometimes the sight is followed by rotation of the head towards the light, then cessation of all movement occurs, shortly followed in its turn by much general movement in the parts of the body. At this stage of development we find that any control of movements by direct stimulation is followed at once by its visible expression (there is no delayed expression, see 32).

(50) *Retentiveness.*—The movements which indicate recollection of names (Retentiveness, 31) are very important; the word is heard and the special movement follows.

(51) *Eye-movements.*—Upward rotation of the eyes, with elevation of the upper lids, and movements of the eyes in their orbits, appear to be later developments than movements of the head.

(52) *At three years.*—At three years old the conditions are markedly changed; many examples of delayed expression and compound cerebration, with or without nerve-reinforcements, may be seen. Microkinesis continues, but it is much more under control through the senses; retentiveness in the centres is illustrated by recurrence of similar actions upon similar stimulation. Actions in other people are now imitated (see 66).

(53) *At ten years old.*—At ten years old but little microkinesis is seen; we see prolonged periods of cerebral inhibition followed by well-marked signs of retentiveness, delayed

* See Fig. 2.

expression, and compound cerebation, the whole being well under command of circumstances.

(54) *The infants' movements.*—The infant at the earliest ages does not show actual signs of mental action; it does not walk or talk, or turn its head and eyes towards objects. Its movements are not modified in any marked degree by the action of light or sound. The infant's brain is in some respects less impressionable than that of the adult, and the impressions are less permanent. During the early months of infant life the signs of brain development are identical with the signs of mental development. Compare the action seen at birth with that seen at five months. Microkinesis still continues, but is capable of control by stimulation through the senses. It may be arrested temporarily by sight or sound, and this, after many repetitions, may be followed by new series of movements occurring upon less and less stimulation, and with increasing quickness and accuracy as time goes on. We infer a corresponding change in the nerve-centres. It appears that at birth they act slowly and independently of one another—as far as we know without any order in their acting—and the time of their action is not determined through the senses. At the age of four months they may be temporarily suspended from action by external stimulation (see 48), and during the time when no efferent currents are passing from them they undergo a change indicated subsequently by special combinations and series of movements (see 65). This appears a great advance in cerebral evolution.

(55) *Kinds of movement seen in infants and children.*—The following kinds of movements may be seen in the infant:—Movements, the outcome of inherited conditions in the nerve-system (microkinesis, see 46); movements following immediately upon stimulation by certain external agencies, as light, sound, etc.; movements resulting from the acquired association of nerve-centres (see 65); movements similar to those previously resulting from a similar cause (see 23); movements in different special areas, such as the small joints in contrast with large joints; asymmetry or symmetry of parts, etc. Action indicating delayed expression (see 32).

(56) *Evolution in nerve-centres.*—We may proceed to consider the evolution of visible movements of the infant as signs of the modes of action of its nerve-centres.

(57) *The infant brain.*—It appears that at birth separate nerve-centres act spontaneously and almost constantly,

except in sleep, and that such action is not controlled by external forces. Certain centres may, however, affect the respiratory centres, and nerve-currents may spread to the centres which produce the movements of crying (see Reinforcements).

Later, impressionability of centres through the senses appears (see 47), and series of movements may be thereby controlled, indicating the spread of nerve-currents among the nerve-cells in a certain order of succession. In advancing stages spontaneous action of centres may be inhibited (see 49), no currents for the time passing to the muscles, and after many such impressions we may see that certain groups of centres tend to act in a certain order (see 65). Retentiveness of impressions is found to exist, and at times an impression may be made and retained with or without coincident visible movement (see Delayed Expression, 32). Among later developments we see evidence that the centres acting in the child are those corresponding to the centres in action in a person speaking to him (see Drilling Lesson, 66).

(58) *Significance of microkinesis*.—Spontaneous movements thus universal at birth must have some important significance. Again, such movements at the earliest ages after birth do not appear, by their sequence, to produce any direct effect upon the body of the infant; they do not assist to supply it with food or minister to its necessities. I here speak of the sequence of the movements of parts, not of the effect of action in the centres.

To understand the significance and analogies of microkinesis it is necessary to look not only to the movements seen, but to the action occurring in the nerve-centres which produce them.

Each movement corresponds to action in a nerve-centre; the mass of movements corresponds to a mass of nerve-centres in action. Further, these movements, as far as we can see, as to their time and the parts moving, are not determined by forces around, that is to say, the nerve-centres are not controlled in their attributes of action as to time by external stimuli acting through the senses (see 43). We conclude that in the infant, in its earliest stages, the nerve-centres act separately and independent of special stimulation.

(59) *Microkinesis: Its corresponding brain action*.—If we want to determine the significance and purposes fulfilled by special phenomena in man, it seems to me that we must

proceed to look at analogous phenomena in other living things.

(60) *Microkinesis in animals*.—In most animals movements are seen in much greater number in the young than in older members. In the lowest groups free swimmers often become fixed in later life; they lose the power of locomotion.

(61) *Microkinesis analogous to circumnutation in plants*.—Charles Darwin* has shown that circumnutation of the young growing parts of plants is almost a universal law. This circumnutation is due to unequal but regular growth in the cells of bilateral structures, the cells not growing uniformly, but first in one place, then in another, the movements following as a mechanical result.

Microkinesis in infants may be the representative of the movement seen in other young and growing creatures.

In making analogy between the visible modes of movement called microkinesis and circumnutation I do not wish to compare the child and the seedling, but the modes of action in the nerve-centres of the infant brain and in the cells of the seedling plant. In each case it appears that in the early stages of evolution of the individual small groups of cells tend to spontaneous action. There appears to be this difference between the two in the earliest manifestations, that whereas in the seedling plant circumnutation in the earliest stages of germination is controllable by light and gravity, microkinesis is not at birth obviously controlled by forces around. The characters of microkinesis at four months old more exactly correspond to circumnutation than those seen at birth.

If there be this much analogy between the action termed circumnutation and microkinesis, what about the subsequent history of each?

We may try and give a brief description of the significance of this condition in young growing things, and trace its history as evolution of the individual proceeds, showing the history of microkinesis up to its disappearance, when it is replaced by movements controlled by impressions, etc. These properties of brain, as they appear, are the properties which impart to the organism the faculty for the expression of intelligence and thought.

(62) *Outcome of microkinesis in the infant*.—The modes of action termed microkinesis are shown to be replaced by the

* "Movements of Plants," Charles Darwin.

signs of impressionability, retentiveness, inhibition, compound cerebration, delayed expression, double action, and imitation.

(63) *Outcome of circumnutation in the plant.*—Circumnutation as a mode of action is replaced by geotropism, heliotropism, and those special actions in plants which are the most like the intelligent movements of man.

(64) *As to phenomena following subsidence of movement.*—One of the most interesting phenomena that came under my observation in studying movement in infants was the gradual appearance of the faculty for cerebral inhibition (see 48).

Examples may be given where the incidence of light and sound were followed by special series of movements. Inferences as to coincident action in the brain-centres will be given in Section III. (see 79). Two examples must suffice. The movements seen in an infant have been referred to and partially described. Certain movements may be observed as constant during an hour or more. When a red box is held within the field of vision movements stop; when the red box is removed they recur as before.* Clearly, then, the red light reflected from the box was a part of the antecedent of the arrest of movement. Sound, likewise, as produced by a musical box, was followed by arrest of movement (see 48). It will be our concern presently (in Section III.) to study what occurs in the brain during the period of no visible movement.

(65) *Memory.*—We may next observe a child that has had its movements arrested in similar manner by the red box and the musical box on fifty successive days. It is now seen that on presentation of the red box within its field of vision certain combinations and series of movements occur in its hands and face. The fingers open, the movements of shoulders and elbows are such that its hands are carried towards the box, and if this be near enough it is grasped.

An analogous example may be taken among older children. Those in the observation I am about to describe varied from seven to thirteen years of age. Observing about forty children during a drilling lesson I saw the first, second, and third divisions go through the same exercises to the same words of command and took notes.

(66) *Imitation.*—While the children stood motionless in rows in front of the teacher she performed the exercise and

* See Fig. 2.

spoke quietly to the children; then, following the word of command, similar combinations and series of movements were seen in the children. The first division had been similarly drilled about fifty times, the second division thirty times, and the third division only twenty times. In the first division the exercises followed in the detailed series of movements with great uniformity, exact in the time and quantity of action in each part. The word of command was in each child followed quickly and uniformly by the particular series of movements called for. Movements were less exact in the second class. In the third division the movements following the words of command were very uncertain, and varied in the different children.

In teaching the class, the spontaneous movements of the children are arrested as the centres are impressed by the sight of the teacher's movements. After this period of inhibition the children perform series of actions similar to those previously seen in the teacher. It appears that during the period of arrest of all movements the centres were being prepared to perform these special series of movements.

Section III.—Nerve-Centres, their Properties and Modes of Action.

Sections I. and II. were mainly devoted to indicating the kind of observations upon which the views now to be put forward are founded. Facts observed have been defined, classified, and in part explained. Indeed, very little more has been attempted than a description of physical facts, scrupulous care being taken to avoid using any metaphysical terms in such descriptions.

(67) *Terms of descriptions.*—Paragraphs are labelled in some instances with the ordinary name of the condition observed. It is one thing, for the sake of convenience and brevity, to employ such terms in place of description by physical terms; it is another thing to give descriptions which do not connote the facts seen. Physical terms are such as connote what we may observe. Physical science can deal with physical facts, and in many cases give useful explanations concerning them. Hypothesis founded upon facts often guides future observations, thus leading to useful results.

(68) *Properties of nerve-centres and their modes of action.*—Following upon the preceding characters of movements we may draw inferences as to properties and modes of action in nerve-centres.

(69) *Impressionability*.—Impressionability is a main characteristic of nerve-centres. It is opposed to spontaneity, in which condition the centres appear to be but little under control of impressions received through the organs of sense (see 28).

In certain cases, as in the drilling lesson described (see 66), the series of actions in the observer are similar (see 23) to those of the individual observed (see 29).

(70) *Imitation*.—Here it appears that the sight of certain movements in another individual is followed in the observer by action in the nerve-centres which correspond to those whose action in the man observed produced the visible movements imitated (see 66).

(71) *Nerve-centres free*.—Nerve-centres, when only slightly stimulated, appear more impressionable than when under the influence of a strong stimulus (see 30).

(72) *Retentiveness*.—Retentiveness in nerve-centres is the tendency to repetition of similar action under similar stimulation, as in a common reflex action. This property appears comparable to inertia in mechanics (see 31).

(73) *Delayed expression*.—This character is a relation in time between the impression produced in the centres and its visible expression. That some impression was produced by the antecedent of the delayed expression may be fairly assumed. Retentiveness preserves the impression till it is expressed in visible movement (see 32).

(74) *Double action in nerve-centres*.—It seems that the nerve-centres affected by an impression may undergo some local molecular change, and also send efferent currents to muscles producing visible movements (see 33).

(75) *Compound cerebration*.—A primary stimulus may be followed by currents passing from certain cells to other groups of cells, to be finally succeeded by movements well adapted to the circumstance which produced the primary stimulus. The causes of such action do not appear manifest (see Compound Series of Movements, 34).

(76) *Reinforcement*.—It appears that a nerve-centre may be stimulated by an afferent impulse, and may then discharge its efferent impulse to more than one centre, so that the nerve-currents become reinforced or strengthened as they proceed finally to the muscles which produce visible movement.

Such reinforcements occur at the earliest stages of existence, whereas "compound cerebral action" occurs only as a later development (see 35).

(77) *Diatactic action*.—Diatactic action is the term here used to signify the getting ready of the nerve-cells for combined action (see 66).

(78) *Psychosis*.—Psychosis is the term used to signify those physical changes in the brain, which corresponds to “a thought,” and which are known to us only by subsequent expression in movement.

(79) *Cerebral inhibition*.—Cerebral inhibition and its sequences suggest the hypothesis that unions may be formed among nerve-cells, preparing them for combined action and series of actions, as expressed by definite series of visible movements. Definite series of movements, which had not previously been observed, seem to follow such impressions as produce a period of inhibition of movement; combinations and series of movements are due to efferent currents from centres. The hypothesis is “that during the period of inhibition functional unions are formed among nerve-cells,” the evidence being that new combinations and series of movements follow.

(80) *Diatactic action and thought*.—As deductions from such hypothesis it is suggested that “thought” or an act of psychosis—which is known only by a combination or series of movements—is physically represented or corresponds to the formation of a union among cells (Diatactic Action). If the union thus formed discharges efferent currents to muscles, then the act of psychosis is expressed by movement. The passage of currents from the union formed may be long delayed after its formation. The union may be followed by currents passing not directly to muscles, but to other cells forming them into other unions, and so on through a long series till at last currents passing from the last union to muscles are expressed by visible movements.

To give further illustration let A, B, C, D, E, etc., represent certain nerve-centres, and a, b, c, d, e, etc., the muscles stimulated by these respectively. An incident force—say, the sight of some object—may be followed by union ADF, which, sending currents to D and E, is followed by union DE, and this sending currents to muscles d and e, is followed by movement de, the formation of ADF and DE corresponding to intermediate thoughts or acts of psychosis.

(81) *Theory of psychosis*.—In the expression of psychosis by its sequential movements we see a series of actions having complex relations. They may effect but a slight amount of

mechanical work, but they may have special antecedents and sequents of much interest.

The movements which indicate intelligence appear not to be distinguished by any special intrinsic characters, but by certain relations in the time and quantity of action in relation to antecedents, to surroundings, and to their sequences.

(82) *Intelligence*.—Intelligence is not a property of the brain *per se*. Intelligence is a physical fact capable of observation, but not capable of correlation with modes of force. According to the views put forward the physiological conditions of the brain giving it aptness for the display of the signs of intelligence are indicated by—

1. Action in many small parts, not necessarily directly stimulated by any present or immediate antecedent forces.

2. Retentiveness and capacity for delayed expression upon a subsequent stimulation.

3. Capacity for the formation of functional unions among cells upon slight stimulation, such unions sending efferent currents to certain centres or muscles, with exactness, upon their stimulation.

(83) *Note as to quantity of brain-wear in mental action*.—The display of intelligence does not depend upon the amount of brain-wear, but upon its susceptibility for control by the environment and its relation to past impressions.

(84) *Conclusion*.—In conclusion I would suggest that new physical signs are here presented for the clinical observer; postures and movements in the body are signs produced by action of the nerve-centres, and they are capable of exact record. It has been my endeavour for some years to render such observations more exact by graphic records.* The attempt has also been made to enumerate these movements and their special combinations, hitherto with only partial success.

In the study of microkinesis we see the earliest manifestations of the faculty for the expression of the action of mind. The gradually increasing sensibility of nerve-centres for immediate and delayed action, as controlled by surrounding forces, appears to produce the signs of active intelligence.

Certain properties and modes of action among nerve-centres appear to be demonstrated by the observation and analysis of movements.

* "Journal of Physiology," Vol. iv, part 2.