PHYSICS OF THE BRAIN.

By B. W. RICHARDSON, M.D., F.R.S.

I HAVE recently been carrying out some new researches on the brain, with the view to discover its several seats and places of function, and the Editor of this Review thinks that I may be able to make the nature of the research so simple that all who may read will follow. I do not see why I should not; for, after all the terrible obscurities thrown about it, the brain is an organ not very difficult to understand. It comes sharply enough under the Gladstonian definition of flesh and blood, and when we have the courage to approach it, and look into it, it gives way to inspection with moderate facility.

Thomas Willis, M.D., and his Part.

I find in books of learning and knowledge no glimpse of satisfactory thought, guess thought or real, respecting the brain, up to the time of Thomas Willis. Willis lived in the reign of Charles Mutton, sometimes called Charles the Second, and Willis died in the same reign, his death accelerated, it is said, by a cruel joke of the mutton-king. I have at this moment before me a small portrait of this first physical philosopher of the brain, the man who had the courage scientifically to open the skull-casket and find out what was the nature of that rounded structure which, like a world within a man, takes in all that is outside the man and binds him bodily with the universe. The face of Willis, as it looks up at me through the long gap of two hundred years, is strikingly singular. It is a pensive face with a meaning in it, determinate to a fault, and yet with a modesty of expression that shows a sensitive soul behind:—the face exactly of a man who under the smart of a king's joke resounding everywhere would feel acutely and break his heart in silence rather than reveal the pang.

What nonsense was talked about the brain prior to the time of Willis, I need not stop now to state; except one fact which illustrates many more. There was a notion that a common cold was the phenomenon of the direct distillation of brain-stuff through the nose, and it is worthy of note that men of the

Willis school had as much trouble in disposing of this mild delusion as they had in setting forth positive discovery.

The discoveries of Willis were indeed very grand when measured by what they dispelled and by what they proved. That the brain was an organ of actual flesh and blood; that it was nourished by blood, and was specially well supplied with blood; that it was covered with membranes and divided into distinct parts; that animals had brains built of the same matter as human, but of less magnificent quantity; and that the quality of mind had relation to the quality of brain with varying gradations through the scale of living organic being—these, in the rough, were certain of the gigantic truths taught by the dutiful and right loyal subject of Charles Mutton.

After Willis. Gall, and his Part.

After Willis, the brain became a fine field of study for anatomists of all schools; but, with a few exceptions, anatomists have never been more than industrious men, painstakers, with some hard observance and little insight; and so it happened that the poor brain, cut up after the fashion of cutting up a Dutch cheese, was subjected, long after it was discovered as an organ, to infinite anatomical torture and fearfully insulting misnomer. To this day, the names given to certain parts of the brain are painfully absurd: it is made to have valves and writers' pens, fissures and roads, bridges and canals, beds, curtains and floors, hard bodies which are really soft, and white bodies which are not white, to say nothing of two approximate parts really not mentionable, even in simile, in polite society. At length the physical metaphysical labours of Gall helped somewhat to render the study of the brain less nominal and less obscure. Gall, by his dissections, by his careful tracing out of the diverging fibres, and by his happy and, in many respects, correct and simple divisions of the organ into centres, placed observers on a train of research which was full of promise. Unfortunately his disciples, not excluding the distinguished Spurtzheim, followed in the metaphysical direction to which their master had led them, rather than to the physical. This tendency was in every sense natural. It was the continuous road of enquiry, much widened and more soundly paved, while the physical highway was doubtful from its newness, and especially from the labour demanded for traversing it. The metaphysical path was luxurious, open, and tempting even to fascination; the physical was hard, narrow, and unpromising, nay threatening, to the beholder. Thus sprang up the system of Phrenology, a system in advance of facts, and therefore, though containing many truths, a system based largely on belief, and fluctuating as belief itself.

After Gall. Majendie and others, their Parts.

Meanwhile, to a large extent, the old anatomy of the brain has remained but little changed; still exist the absurd names, meaningless, bewildering, and so adhered to, that within the last five years two of the greatest lights in comparative anatomy of this age have been holding desperate contest on one poor nodule, the physiological value of which is altogether unknown, and indeed little cared for, in respect of its function, throughout the controversy. At the same time, it is right to explain that the progress of rational physical discovery, into the nature and function of the brain, has been advancing with some determinate casting-off of the mystical and hypothetical. The classification of the brain into ganglia or centres of power, and into commissures or connecting bands, and the tracing of nerves into the brain-structure, a study which the late Mr. Grainger so admirably and industriously promoted, have all been aids of no mean value to the direct and positive appreciation of function. In the way of minute anatomy, also, a wonderful field of truth has been laid open, especially by the labours of Swan and Lockhart Clarke: while the chemists have been indefatigable in determining the chemical constituents of the organ and their relation to each other. Finally, the pathologists, in a quiet and unassuming research, have added a long array of new facts on this vast subject. Observing the phenomena of disease in instances where the functions of the brain have been disturbed, they have sought, after the death of the subject in whom the symptoms were presented, to find the precise seat of the disease, and so to trace the living phenomena to their true cause. In this direction our accurate and philosophical countryman, Dr. Wilks, of Guy's Hospital, has taken a part which is beyond all commendation. I must linger no longer on these matters, but must proceed to note some purely physiological facts, for the illustration of which this paper is specially intended. To Dr. Philip, Majendie and Fluorens we owe the first real steps in advance for exploring, by physical experiment and analysis, the functions of the brain. It was unfortunate for these observers that their work was laid out before they had the necessary means for conducting it with satisfactory exactitude. Their experiments, often singularly accurate, were, from the mode of their performance, open to criticism. Knowing nothing of any methods for modifying brain-function short of actual removal of portions of the brain of the inferior animals, they proceeded by what is called ablation, or cutting away, of the living structure. The result was that they took what they could not restore, and, as a consequence, left it often doubtful whether the symptoms they

elicited were those of mere shock, injury and pain, or of actual dismemberment of function.

Dr. James Arnott. His Part.

The great leading discovery that the brain of a living animal could be frozen and afterwards could recover was made by Dr. James Arnott, who solidified the brain of a pigeon by exposing it to a freezing mixture. Here research stopped, because with an ordinary freezing mixture it was not possible to act on individual parts of the organ; but the importance of the discovery is not the less on that account. It was a marvellous revealing. Think what it was! Here was a living organ of mind, a centre of power—of all guiding power, of all volition. It took in every motion of the universe to which it was exposed. It took in light and form and colour by the eye; it took in sound by the ear, sensation and substance by the touch, odour by the nostril, and taste by the mouth: it gave out, in return or response, animal motion, expression, all else that demonstrates a living animal. With it the animal was an animal; without it the animal was turned into a mere vegetable. And this organ, the very centre and soul of the organism, was, by mere physical experiment, for a time made dead—all its powers ice-bound. And this organ, again set free, received its functions back again, and, as we know now by further observation, its functions unimpaired. Surely this was the discovery of a new world! The discoverer of such a world needs no praise, for to him comes honour as a birthright, the noble birthright of an interpreter of natural truths deep from the depths of nature in her most sacred treasury.

Recent Research. Freezing the Whole Brain.

Recently, by the advancement in the means of application of extreme cold, we have had laid before us a new line of enquiry; we have been enabled to destroy portions of the brain, as well as the whole organ, temporarily, and we have been also enabled to observe the process of recovery from this form of brief death. Thus we have witnessed death of parts of the brain, and their restoration from death, and by comparing functions lost with functions regained, have traced out, with singular correctness, many facts which by no other means could have been so certainly revealed.

I was myself so favoured as to learn a simple mode of producing an intense cold with volatile fluid in the form of spray, and of so adapting this that even the brain could be

temporarily destroyed in parts or sections. Then I and another physiologist, Dr. Weir Mitchell, of Philadelphia, took up simultaneously and independently the study of brain function by destruction of part. The truths thus learned, in so far as they relate to my own work, I would now record. I put them forward as being yet limited, but not valueless.

I shall begin the narrative best by stating that the brain matter contains two substances which admit of solidification by cold, viz., water and fatty matter. These solidify at different temperatures, but both are entirely frozen by reducing the temperature to 16° Fahr. or 16° below freezing point. At this degree all the water of the nervous structure, amounting to 84 per cent. of the whole, is crystallized as ice; in this condition the structure is for the time dead, it is as though it were removed from the body altogether.

Suppose, then, that we bring into this state of temporary death the front part of the brain, the two lobes or hemispheres of the cerebrum or larger brain, which mainly fill the skull. The phenomena produced are those indicating entire loss of volition, of sensation, of all that may be considered intelligence. To appearance the animal profoundly sleeps, it is as if it were under the influence of chloroform or ether, and an operation of any kind may be performed upon it without pain. It may, nevertheless, move when handled, and it may show a kind of involuntary life due to what is called spinal action, to some power resident in the spinal cord. A frog thus circumstanced will sometimes leap; but warm-blooded animals, as a general rule, will remain like as in catalepsy, always retaining the position in which they last were left.

In cold-blooded animals, as in the frog, when the functions of the brain are entirely suspended, the freezing process may be carried to and through the spinal cord, and every portion of the nervous system may thus be deprived of force, the animal remaining motionless, rigid, and indeed like stone. In this state it would remain, I believe, for an unlimited period of time if it were kept under the same condition of temperature; but from this extreme condition of shrunk death it will, nevertheless, recover on gradual restoration of warmth. In some warm-blooded animals we see an approach to this same state, naturally brought about in the period when they are hybernating, in the profound sleep of the cold season; but there is this difference, the animal, during hybernation, still breathes, and still takes in some air for respiration, without which it could not recover with the return of warmth. And we find by experiment that if the process of freezing artificially be carried on in a warm-blooded animal, from the brain into the spinal system, so as to stop

the function of respiration, the living action is put an end to for good.

The statement of this fact will naturally suggest the question, Why is there this difference between warm and cold-blooded animals; between a frog, for instance, and a pigeon? The answer to the question is simple; the frog requires only, for its best life, a comparatively low temperature, and its outer covering or skin is a fair conductor of heat. Hence the frog, after being entirely frozen, can take up sufficient caloric from a warm air to become recharged directly with force throughout all its nervous organism; but the warm-blooded animal, living always by the heat it developes in its own body, is protected by a skin covered also with a good *non*-conducting surface of feathers, or fur, or hair: it cannot, therefore, so receive heat from without as to be able to recharge its nervous centres from any external source of heat; it dies outright whenever its internal and radiating force is cut off.

To return to our animal made lethargic and insensible by the direct abstraction of caloric from the cerebrum. I have said that it resembles an animal sleeping after the inhalation of chloroform, and this is indeed what is observed. A pigeon will lie motionless and insensible for long periods of time, breathing slowly, but regularly, and with the heart beating in even time. By allowing the temperature to be gradually raised to 60° or 65° Fahr. there follows steady recovery and return of living function; but the order of recovery is not always the same, variations being introduced dependent upon the parts in which restoration begins. Usually, however, when the whole mass of the cerebrum, or larger brain, is frozen, recovery of intelligence is the first sign exhibited; then there are attempts at motion, which are propulsive forwards, and soon afterwards there is sensation. I have, however, seen this order reversed, the sensation returning before the return of motion. Finally, the animal entirely recovers, and with the recovery memory and all the spell-bound faculties return into active play. The brain has been crystallised, and it has been loosened back to the fluid state, but it has lost as little as it has gained; all impressions it held it has retained, and the light, and the sound, and the touch, and the odour, strike again to reach and endow the now impressionable matter.

Freezing Sections of Brain.

So far we have seen the effect of removing force from the cerebral part of the brain substance as a whole; let us next enquire what is the effect of removing force from special parts of the organ. As preliminary to this description I should explain, that the brain substance being a bad conductor of

caloric it is quite possible, by using a fine ether jet and a low boiling fluid, to isolate parts with great minuteness. Thus we can remove the force from the two large front cerebral hemispheres without removing it from the smaller hemispheres which lie behind, and which form the little brain or cerebellum; it is possible again to remove the force from one hemisphere without removing it from the other, or from the spinal cord without interfering either with the large or the small brain.

In the superior and front part of each hemisphere of the cerebrum there lies a mass of nerve matter very distinct in form, and, as it would seem, very distinct in function. The older anatomists called this the striated body (*corpus striatum*), because in section it appears to be marked by faint lines of grey and white colour. It is now more correctly called the superior cerebral ganglion. With very little difficulty, and without pain, we can expose this ganglion in one or both hemispheres, and remove the force from one or from both. When we have removed the force from both—when, that is to say, we have solidified them, and, for the time, destroyed their function—there is presented this singular phenomenon: the animal falls forward, or sometimes rushes forward with unmeaning impetuosity, and these symptoms will last until the relaxation and restoration of the ganglia is complete.

We change the line of experiment; we turn from these front cerebral ganglia to the lower large ganglia which lie at the back of the skull, and form the smaller brain or cerebellum. We lock up these, by taking from them their force by cold, and at once the animal marches backwards, and turns backward summersaults, and in the most determinate manner shows that it has no control over these movements until its cerebellum is set at liberty by the restoration of caloric.

If the anterior cerebral ganglia, together with the cerebellum, be simultaneously deprived of force, there is neither backward nor forward movement, but prostration of movement for the time, with equal restoration of power consequent on equal restoration of force.

Throughout all these induced changes on the great centres of nervous power, it is observed that however much the volition, the perception, and the sensibility of the animal are reduced, the semi-voluntary and involuntary acts, the acts of respiration and the motions of the heart, are not prevented. To say they are not affected is not strictly true, for they are rendered slower after a time and feebler; but this is an indirect retardation of function, and would occur if any other large surface of the body were for a long period deprived of caloric; but we may say, confidently, that the removal of force from the large and small brain does not seriously interfere with the functions named.

When, however, we pass beyond the great and little brain and approach that part of the spinal column which is in immediate connection with them, we are introduced to new phenomena. The part immediately leading from the brain is called the medulla oblongata, and as we subject that part to the influence of the extreme cold we instantly interfere with, and even stop, respiration, so that the animal, if it be a warm-blooded animal, will die, as suddenly as dies the Spanish bull from the short sword-thrust of the skilled Torero; but the heart still continues in action, and, if the breathing be sustained by artificial means, the heart will remain in action even though the influence of the cold be made to extend to the whole of the spinal cord.

When only the upper surface of the cerebrum or large brain is superficially frozen, the power to move remains, although the perception and sensation are entirely destroyed. Indeed, in this condition there is often active movement of the body, but altogether without will or desire. The motion in this case is not motion of one particular and exaggerated type, but general, uncontrollable motion, such as is seen in some forms of insanity in man.

I might extend these observations respecting the removal of force from the brain, but I see I am already trespassing on the pages of the Review, and I feel that I have given enough of experimental fact to illustrate as much as I can this time put down upon paper.

Deductions.—The Force and the Matter.

On reviewing the facts disclosed in the experiments that have been described, we learn that the force by which all the manifestations of brain function are sustained is the force we call caloric, or commonly, and by incorrect speech, heat. Two evidences lead to this truth: the first, that all the manifestations are withheld when caloric is withdrawn; and the second, that all the manifestations return when the caloric is restored. But inasmuch as with the restoration of action, there is continuance of the impressions which were made on the brain before any force was drawn out of it, it follows that the extant force in the brain at any given moment, is not the seat of the impression, nor the cause of it, but the means by which the matter of the brain is held ready for the reception of the impression, and for the production of those manifestations which we denominate functions. We are bound, therefore, to infer that impressions are physical realities, stamped as it were on brain matter, each distinct and perfect when the matter on which it is set is in condition for motion. Everything we remember is, I doubt not, thus imprinted on the brain, on infinite points of brain

substance, each independent, free, and capable of motion when the whole mass is charged with force. The brain, in fact, is a world within of the world without, a camera of all from the world without that it has received in the course of its waking life. Until recently the idea of such a physical microcosm could not have been conceived; now it comes forward strengthened by physical truths of human invention so called. I hold a piece of transparent glass in my hand and see nothing upon it. Nay, says my friend the micro-photographer, look again. Still nothing there? No! Then he slides the glass under his lenses and adjusts, and repeats, "Look again." I obey, and lo! before me on an infinitesimal space of matter is the Pater Noster, as legible as it used to be in an old church I well remember, where it covered half a wall, and, with the ten commandments to balance it, enframed the Lion and the Unicorn, and Georgius Rex, and the Garter, like a holy family.

When we see what the micro-photographer can thus do in putting physical impressions on what seem infinitesimal points of matter, and when we know that there is no assignable limit to his art, it is no crude inference that in the vast surface of the grey matter of the brain, in those cerebral lobes of which I have spoken, myriads of points of matter are thus impressed—points of matter floating in that eighty-four per cent. of water of which the brain is made up. I call up to remembrance a ridge of hills which were often before me in childhood. I see them in all the distinctness of that time, their height, their breadth, their length, their divisions, the structures upon them, all their belongings. Why do I see them? Because they are actualities still in my brain, imprints on points of matter there. But twenty years elapse, and I look on those hills again, and they are and yet are not what they were. They seem to my present view smaller, that is certain; and one of them was barren, and now it is cultivated; and one had a mill on its summit, and the mill is gone; and one had two or three trees on its side, which in the distance looked like the flint and steel of an old-fashioned gun, but now in place of those trees is a copse. These are not the hills, in fact, which I have carried so many years, for now as I take them in once more my capacity for taking has changed and the hills have changed. I must have therefore a new picture altogether; and from this time forward I must carry two pictures of those hills, the child's picture and the man's picture; for the old is not put out by the new, nor the new by the old.

Physical points of brain for physical impressions are then essential; but to reveal their impressions they must have force and condition for motion. Let us remove that force, abstract it, as it comes to the part, by cold, or crush it out by firm mechanical pressure, or cut it off at its source by putting out

the animal fire, and then the impressed molecules, losing condition for activity, and coming to rest, cease, functionally to exist.

But they do not cease actually to exist; because, whether they be bound in ice or bound by pressure, we see that when they are unloosed they can return, if the body can supply them with caloric, to full vigour. Indeed, the images of the brain, once well developed and fixed, can only be obscured by derangement of brain matter, and can only be destroyed by disintegration of brain matter. Cases have occurred in which, under pressure of brain, a man has been for months dead to the outer world, and, on recovery has remembered what preceded his accident, showing thus that the imagery of his brain remained intact; and, as I have said already, an animal with a frozen brain, when it is restored, will not show an evidence of a lost faculty. By disintegration of brain matter the world within of the world without only dissolves. This disintegration is, in all men and animals, going on slowly, and thus memory becomes defective. In second childishness this gradual metamorphosis, this natural mode of removing the world and its past from the man, is completed; it is the dissolving view of nature. In the vigorous the imagery of the brain is finally destroyed by death alone, and by death not of necessity immediately, but with the after disintegration of structure. A brain frozen in a living animal, and with the animal crystallised in ice, would retain, in that condition, the imagery with which it was replete for any grasp of time; for time is no element when there is no change, nor is it recognisable by aught except change of matter by force. When I wind up my watch I put into it so much force, which force is expended in moving so much matter, and the measure of that movement is the measure of motion,—time.

The force called caloric, then—the force we liberate in the combustion of blood—is the sustaining force of the brain, but it is not the only form of force to which the brain is impressionable when its natural condition is maintained. Through the eye calorific force does not pass to the brain but is cut off, yet the form of force called light, and probably the actinic force, make way; while through the ear and tactile skin common mechanical force finds ingress. We see, we hear, we feel, in fine, by the direct action of forces other than caloric, but without caloric as the base these are unavailing, for an animal with a frozen brain cannot be awakened neither by light, nor by noise, nor by touch; if it could a dead animal could be awakened by the same means.

Sleep and Dreams.

The course of our research leads us, as we have seen, to contemplate the condition of the brain in its active state, and under

artificial states in which its functions have been suppressed. But we are led also to another subject, I mean the natural inertia or rest of the brain, which we call sleep. Physically the brain asleep is the brain exhausted of its force—force expended during waking hours in the production of its equivalent of animal motion. As the sleep creeps on, the natural imagery of brain rests. During sleep, motion being suspended, the brain and nervous centres altogether are recharged, and natural awaking is the index of the fact.

But it is not always that the brain centres rest as a whole, or work as a whole. Sometimes one part of the brain works while the rest sleeps, and then we dream in sleep, sleep being the major phenomenon. Carmichael, many years ago, well taught that there are seven distinct stages of waking and sleeping. 1. *When the entire brain and nervous system are buried in sleep*, then there is total exemption from dreaming. 2. *When some of the mental organs are awake, and all the senses are asleep*, then dreams occur and seem to be realities. 3. *When the above condition exists, and the centres of voluntary motion are also awake*, then may occur the rare phenomenon of somnambulism. 4. *When one of the senses is awake with some of the mental organs*, then, during our dream, we may be conscious of its illusory nature. 5. *When some of the mental organs are asleep, and two or more senses awake*, then we can attend to external impressions, and notice the gradual departure of our slumbers. 6. *When we are totally awake and in full possession of our faculties and powers.* 7. *When, under these circumstances, we are so occupied with mental operations as not to attend to the impressions of external objects*, then our reverie deludes us like a dream. These are faithful observations, and define with exactitude the fluctuations of force in the brain under different conditions. In experimental research, and in disease, we have the same phenomena brought before us, and they all accord as to cause.

Intoxication.

There are various modes of producing insensibility artificially. The insensibility of intoxication from alcohol is an illustration at hand. The insensibility thus produced is the same as that from cold; the agent taken, that is to say, interferes with the distribution of force through the brain substance, and is carried away at the expenditure of so much force as shall be required for its elimination. At the late meeting of the British Association for the Advancement of Science at Dundee, I showed that the period of action of alcohols of different kinds could be determined by the force required to lift them out of the organism. Moreover, various of these intoxicating substances,

which all act in the same manner as cold, pressure, or exhaustion, affect differently sections of the brain matter, producing various phenomena analogous to dreams.

Lastly, some other external influences, by causing concentration of force on one particular part of brain, may so reduce other parts to rest as to cause that inertia which Carmichael calls reverie. This is a disturbance of the equilibrium of force in the brain which can be intensified by practice; and there is no difficulty in tracing the phenomena of mesmerism, such as they are, to their physical source when the nature of reverie, or waking dream, is explained and understood.

Balance of Power in the Brain.

One more fact relating to the physics of the brain, as taught by experiment, and I have done. We have seen that when the anterior cerebral ganglia are destroyed for a time, an animal moves impulsively forward, and that, when the cerebellum is destroyed, the animal moves impulsively backwards. This indicates the existence of a balance of power between these centres —a balance which is also detectable between other centres. It is therefore a fair inference, that every centre of power in the brain is, during healthy states, physically balanced, and that what is called a well-balanced mind is really a properly balanced brain. By this reading we explain many phenomena of living action otherwise inexplicable.

By constant overaction one centre of the brain may gain undue power, which shall be so persistent as to distinguish the man throughout life. Or a centre of power may be suddenly prostrated, and the balancing centre, no longer controlled, may overcome all for the moment, and produce phenomena not before observed in the same organism. Impulses—sudden, vehement, propulsive, onward, under the influence of any impression which for a moment paralyses the cerebrum, are thus explained. Whenever the cerebrum alone is overcome with sudden shock, it fails in power the same as when its structure is deprived of force by the direct action of cold or by pressure: then the propulsive cerebellum unaffected shows its force unchecked, and there is forward rush. In some stages of disease of the cerebrum and specially of disease induced by alcohol, there is this break of balance. I lately pulled out from under a railway train the headless trunk of a man. Passing into a tunnel out of which the train had emerged, I found the brain of this man entire, and while the servants of the company were fetching the police, I read in the brain his physical history, and interpreted it to the Inspector by my side. I discovered that while the cerebellum was quite sound the anterior lobes of the cerebrum were intensely con-

gested with blood, and had undergone previous disease. I found the anterior cerebral ganglia specially involved, and from the whole of this dumb but forcible evidence, I learned that the man was insane, that he had been insane before this time, that his insanity had taken the impulsive character, and that in a fit of extreme and uncontrollable impulse, he had committed suicide by throwing himself under the train. When the facts of this man's life were brought out before the coroner, Dr. Lankester, they gave the same evidence to the letter, nor less nor more.

In the heat of battle it is not the cerebrum but the cerebellum which propels the man on; in the chase in the race it is the same. The vehement tendency to rush forward, which nearly all persons feel when they look over a deep precipice, is of the same nature. The cerebral ganglia, overcome by the impression made upon them, are, for the moment, deprived of power, and the cerebellum, acting with sudden and uncontrolled force, gives the initiative propulsive start towards what is sometimes a deadly fall. But I must cease. If in the physics of the brain I have shown that some things, deeply interesting in their social as well as their physiological meanings, are known, what have I not unintentionally shadowed forth of that which has yet to be discovered, by the bold, the diligent, the truthful disciple of nature? Who shall show how the imagery of the brain is physically cast; who shall disclose that imagery as a world to be visibly seen? Yet in the days to come even these things, simple as known as wonderful when unknown, shall be revealed.