THE CAVENDISH LECTURE ON THE APPLICATION OF PATHOLOGY TO SURGERY,

*Delivered before the West London Medico-Chirurgical Society, on
Friday, June 22nd, 1900.*

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MR. PRESIDENT AND GENTLEMEN.—A good many years ago, while sitting waiting for practice in my consulting room, my mind was a good deal occupied with the question of a science of applied pathology, which should bear the same kind of relation to pure pathology as mechanics does to physics, or applied mathematics to pure mathematics. I set down various headings on various sheets of paper for the study of the subject, and intended to follow it up. But I got but a little way when my time began to be busily occupied, and the science of applied pathology was placed on the shelf, where it might still be lying, had it not been for the kind invitation of your Council, conveyed to me by Dr. Robinson, to deliver the Cavendish Lecture for 1900. Wondering what should be the subject of the lecture, my memory went back to the question of applied pathology, and I fetched down the dusty sheets and read them through again, and finally decided in their favour. For, although many changes have taken place since they were written, and many fine applications of pathology have been made, there is still no science of applied pathology, as I first thought of it, and as I still would have it.

DISCOVERERS AND INVENTORS.

As an introduction, it is almost necessary, and it certainly is not without interest, to know what pathology has done for surgery, and how and in what manner its applications have been made. In the short space of a single lecture I can, of course, only give certain examples; and if I had more time at my command I should be sorry to drag you through the long and tedious labour which attended my research, and which has forced me to learn more about general *inventors* and *inventions* than I ever thought to know.

First, let me say that I shall use the terms "discovery" and "invention" just as they are used in relation to other sciences and industries, and shall apply the former to surgical principles and the causes and nature of surgical diseases; the latter to the introduction or proposal of new methods of surgical treatment (not instruments). And I shall speak in the same manner of "discoverers" and "inventors" in relation to their work, and shall show, how in pathology and in surgery, as in other sciences and arts, the inventor and the discoverer may be one and the same person; or the discovery of the pathology of a disease and the invention of a method of dealing with it may be the work of different men.

PATHOLOGY THE FOUNTAIN OF SURGERY.

During the time I was house-surgeon at St. Bartholomew's Hospital, my master, Sir James Paget, said one day that he could not understand how men could say that a knowledge of pathology was of no use in surgery. He desired to impress on us, then and always, that pathology is the foundation of surgery; and of course we believed him. We believed everything which Sir James Paget said; and if he had made botany or mathematics the foundation of surgery, we might not improbably have equally accepted the statement. But the foundation of surgery on pathology seemed so reasonable a proposition as to be almost self-evident, and the more I thought of it the more I wondered, too, how surgeons could be blind to the advantages of a knowledge of pathology. When at a later period the science of applied pathology was before my mind, I began to consider the various relations of pathology to surgery, and in what various ways surgery may be indebted to pathology. Three relations instantly occurred to my mind. The knowledge of the pathology of a disease may explain the manner in which an operation acts. Or, it may lead to the development and improvement of an operation which has previously been practised by a kind of rule of thumb. Or, a

thorough knowledge of the pathology of a disease may precede and lead to the deliberate invention of an operation or method of treatment for its relief or cure. The third of these relations is so much higher in its kind than the two first that I determined to collect striking instances of it. And to render the study more easy, I divided it into two periods of time, past and present, and carried the past up to, and the present back to, about thirty-five years ago. The period of the present almost coincides with my own recollections of surgery; but it was not on that account alone that the division was made. About thirty or thirty-five years ago, scientific training and methods began to be slowly appreciated and, in consequence, a great change of method and study gradually took place.

THE PAST.

Both years ago, and again lately, I read old books on surgery, and books on the history of surgery; and as my own time for such reading has of late been limited I obtained the assistance of Mr. Henshaw, who is admirably fitted for this kind of study; and I prepared, not only my mind, but my pen and paper to record the pleasant impressions I should receive from the account of the inventors and discoverers themselves, or of their trusty friends and biographers, of the manner in which new inventions and discoveries in surgery had been made, or in which inventions had been developed and improved. The subject would be likely to derive a special charm, which is seldom felt in the study of general inventions. There is no question here of patents and of large fortunes, only of honour and of the advancement of a noble profession, which performs its work for the benefit of suffering humanity. There would not, therefore, be such an exhibition of human selfishness and greed. And the inventors of surgical methods would but rarely be treated with the same cruelty which has, in all ages, been meted out to the authors of general inventions. What contemplation, then, could be more agreeable than that of the great surgeon of the past sitting in face of some weighty problem, working out slowly and with difficulty the pathology of some serious malady, and then building up his treatment against the disease? or founding a new and admirable operation for the relief of some terrible surgical malady on a knowledge of the pathology which had been worked out by other hands and heads.

Operation for Hernia.

Take, for instance, the operation for strangulated hernia and the use of ligatures to wounded vessels. Who invented them, how and when was the invention made, and what circumstances led the inventors to turn their attention, at a particular moment, to these admirable methods? Of all curious histories of surgery, that of operations for hernia is perhaps one of the most curious. The nature of hernia must have been ascertained at a very early period of the history of surgery, for operations for its radical cure were devised and practised by the ancients and through the Middle Ages, until they fell into disrepute about the seventeenth century, probably from the danger to life and the frequency with which they failed to effect a cure. The operation had probably always been largely practised by quacks; but, in its decline, it fell almost entirely into their hands; and they were generally itinerant; for a very good reason. Most of them made no attempt to preserve the testicle, in spite of a solemn promise to the patient or his friends. Dionis¹ at the beginning of the eighteenth century, gives an amusing account of the dexterity with which these men removed and concealed the testicle, under careful watching. He says: "We have known one of these operators who fed his dog with nothing but testicles, that animal always lying under the bed, or under the table near his master, waiting for the luscious morsel, with which he was regaled immediately after its extirpation, unknown to the spectators, who would have sworn that the patient had all his parts."

On the other hand, the operation for strangulated hernia was not practised in ancient times or in the Middle Ages; the disease was left to take its course, and the last condition of the patient, vomiting faecal matter and dying with a mortified intestine, was called "*miserere mei*." It is scarcely credible that no operation for its relief was deliberately performed until the latter half of the sixteenth century, when it was recommended about the same time by Pierre Franco² and Ambroise Paré,

and was then only to be employed as a last resource, generally on a dying patient. There has been much discussion regarding the priority of the invention. Some attribute it to Paré, and some to Franco, and some people think it was adopted by both, and invented by neither. There are now no means of settling the dispute, a matter of comparatively some moment to us. Probably, the inventor himself thought but little of his own invention, for nobody claimed to have made it. And as nobody claimed it, so nobody tells what led to the invention of the operation. Yet that is what we should like to know. How came the operation for the relief of strangulated hernia to be recommended, or invented and recommended, by two surgeons who did not know the difference between femoral and inguinal hernia, who were ignorant of the coverings of a hernia and thought it came down through a split in the peritoneum, and who were so ill-informed of the pathology of strangulation that they thought it was due to the descent and condensation of fecal matter and to the escape of ventosity? Their anatomy and pathology was the anatomy and pathology of previous centuries, yet they hit on the means of relief by operation, which nobody had previously suggested, and which they themselves only ventured to employ in desperate need. It was a great disappointment to me not to be able to attribute the invention of the operation to a study of the pathology of the disease.

Ligature of Vessels.

I thought I might be more fortunate in the history of the invention of tying bleeding vessels. It is a matter of common knowledge that we are indebted to Ambroise Paré for the introduction, or the reintroduction, of the ligature into surgery, and I wondered what had made him think of it, and by what process of reasoning or by what series of experiments he had preceded the use of the invention. Let the inventor tell the story. The 26th chapter of the 12th book opens with an apology by the author for ever having used the very horrible and cruel method of arresting hæmorrhage by means of the actual and potential cautery, and he proceeds to counsel the young surgeon to leave such cruelty and inhumanity and rather to follow his fashion of practice, of which it had pleased God to advise him, although he had never seen anyone do it, and had never read of it, unless in the 5th book of Galen, in which he writes that he ties the vessels towards their roots, which are the liver and the heart, in order to staunch great flow of blood. Paré says further that, having many times used this method of closing the veins and arteries in recent wounds, in which there was hæmorrhage, he had thought it might also be practised in the extirpation of a limb. Here is the whole story. Almighty God and the recollection of a passage in Galen inspire the invention, and the experiment is made on the living subject by a man who is absolutely ignorant of the course of the circulation of the blood. Here, again, pathology seems to have had no part in the invention.

It is possible to multiply these curious examples, but they cannot be multiplied indefinitely, on account of the absence of authentic history or even of reasonable romance regarding the origin of new methods of treatment in surgery.

Inventions in surgery have probably been made much in the same manner as general inventions; and have owed more to accident, to observation, to comparison, and to deduction than to pathology. Paré's invention of the ligature may be taken as an example of the influence of accident, if inspiration can be regarded as an accident. Pondering over the brutality of the arrest of hæmorrhage by the cautery, and having dimly in memory a sentence of Galen, his mind is suddenly illuminated with the idea of tying the bleeding ends of the vessels. A less bold surgeon would have shrunk from attempting the experiment on the human subject. Not so Paré. On the first opportunity he applies ligatures to the vessels in a recent wound. The experiment is a success; it is repeated, extended to the vessels cut in amputation, and is then recommended to the world of surgery.

Pott's Treatment of Angular Curvature.

The more elaborate operations have probably been the work of several or of many men, each of whom has added a little towards the perfection of the operation. A curious instance of this complex manner of invention of a new treatment is afforded in Mr. Pott's tracts on "Palsy of the Lower Limbs, with curvature of the Spine."³ Pott introduced to the profes-

sion the method of treating this affection by means of copious discharge of matter from the adipose tissue at each side of the curvature. He formed a large issue on either side of the spine by means of caustic, filled the grooves left by the separation of the eschars with several peas, and even applied from time to time cantharides, ærugo æris, and other irritants, to maintain or increase the discharge until the patient had completely recovered the use of his legs. Pott was so convinced of the value of this method of treatment, that he wrote a second tract⁴ in favour of it about three years after the first. With his characteristic sincerity he admitted that the idea was not his own, but had been recommended to him by Dr. Cameron, of Worcester, who said "that he remembered some years ago to have noted a passage in Hippocrates, in which he speaks of a paralysis of the lower limbs being cured by an abscess in the back or loins, and that taking the hint from this, he, Dr. Cameron, had, in a case of palsy of the legs and thighs, attended by a curvature of the backbone, endeavoured to imitate this act of Nature, by exciting a discharge near the part, and that it had proved very advantageous." In the same tracts in which he urges the employment of this very doubtful method of treatment, Pott gives an admirable description of the morbid anatomy and pathology of caries of the spine; so that here is an instance of what we should regard as a bad treatment, introduced by Pott, who was thoroughly acquainted with the pathology of the disease, and resting on a false deduction by Cameron, of the effects of the fact observed by Hippocrates!

Morgagni and Hunter.

About the middle of the eighteenth century, the French Academy seems to have appreciated the low condition of surgery, and proposed to raise it from a mere mechanical art to a science, on the basis of clinical observation, physical research, and experiment.⁵ During the course of the century the memoirs of the Academy refer from time to time to experiments on living animals. But of pathology there is little said, for the very sufficient reason that even at that time, there was no science of pathology proper. There were, of course, scattered pathological observations, and there were accounts of *post-mortem* examinations for the most part imperfect. But there was no science of pathology. Professor Virchow assigns the foundation of pathology proper to Morgagni's work *De Sedibus et Causis Morborum*, which did not appear until the latter half of the century; and he pronounces John Hunter to have been one of the first to recognise the value of pathological anatomy, which Morgagni was the first to introduce, and which raised medicine to the rank of a natural science.

From this time the first examples occur of the foundation of surgical treatment on pathology, and of course the Hunterian operation for the cure of aneurysm was present in my mind at the beginning of my research. I intended to use it further as an example of the combination of the discoverer and the inventor in the person of one man; but I did not at first appreciate it at its true value. I regarded it as one example of circumstances connected with surgical invention which I expected to find tolerably frequently repeated. So far as I am aware it is not *one* example, *merely one* example; it is *the one* example, the *only* example, up to that time, of a deliberate surgical invention founded on the study of pathology by the man who made the invention. No wonder our Hunterian orators at the Royal College of Surgeons have referred to it again and again as a marvellous achievement!

In spite of Hunter's example, there are very few surgical inventions during the first half of the nineteenth century which can be shown to be founded on the principles of pathology. One of the best examples is the introduction of subcutaneous surgery by Stromeyer, on the foundation of experiments and observations made by Hunter half a century previously. The idea had occurred to Delpech, but he does not appear to have carried it out. And Astley Cooper had divided the palmar fascia for the relief of Dupuytren's contraction. So that here we have once more an illustration of the influence of several minds in the invention of a new method of treatment. The idea occurs to Delpech, and he suggests it; Cooper applies it in a certain limited sense; Stromeyer puts together the pathology, the suggestion, and the limited application, and introduces to the world an admirable invention.

I confess to a great sense of disappointment at the fruitless result of my research. Nor was I more fortunate in finding examples of the first two relations of pathology to surgery; and I could now more easily understand how, five-and-thirty years ago, men who were disinclined to the study of pathology could make an excellent case in defence of the view that pathology is of no use in surgery.

THE PRESENT.

In the early years of the second half of the nineteenth century there was little change in the relation of pathology to surgery. There was little teaching of pathology; and it would have then seemed very improbable that a new system of surgery would shortly be founded on pathology. I have elsewhere sketched the condition of the study of pathology about the year 1850,⁸ especially in Great Britain, and have shown how small a hold it had yet taken on the minds of teachers or students. Yet there were, even then, signs of approaching change, and the most advanced and enlightened teachers were beginning to found their teaching of medicine and surgery on a more scientific basis. I have little doubt this was part of a general movement in favour of scientific training which began about the Fifties and early Sixties, which questioned the propriety of the old methods of general education, and desired to see them replaced, either in whole or in part, by science teaching; and which has since found its expression in technical and science schools, in laboratories, in science scholarships and prizes. The art of medicine could scarcely fail to feel the influence of this general movement, but the new leaven would probably have been very slowly infused into the teaching of our profession had not an event occurred which revolutionised the practice of surgery, and did more in a few years to lay the foundation of surgery on pathology than had been done in as many previous centuries.

Antisepsis.

In the years 1867 and 1868 there appeared in the *Lancet* and *BRITISH MEDICAL JOURNAL* the first papers by Professor Lister on the subject of antisepsis, and his is the next great example, after Hunter's, of the discovery of a pathology and the invention of a treatment by one and the same individual. My own recollection of its early application in London is almost ludicrous. In 1868 I was house-surgeon to Mr. Paget (afterwards Sir James Paget). We happened to have in the wards a man, about 40 years of age, with caries of the spine and a large abscess in the back. The results of the treatment of such cases were in those days lamentable, and the man was left for some days in bed untreated. But one afternoon Mr. Paget came down and said he would try a new method of opening and treating the abscess, which had been suggested by a surgeon in Edinburgh called Lister. A few days later we opened the abscess under the direction of Mr. Paget through a piece of lint soaked in some antiseptic, and then applied a little mass of antiseptic putty, about half the size of my fist, over the opening, and a piece of sheet-lead upon the putty. That day and the following days the dressing frequently slipped down and was found half a foot or more below the wound. And in the course of a few days the cavity of the abscess became septic and the patient died, as many of those who were suffering from similar conditions did in those days.

I need not describe in detail the discovery of the causes of sepsis, or the invention of the earlier antiseptic methods; the failures and successes, the opponents and partisans, and the long series of years before the principles of antiseptic surgery were generally accepted. All these things have been described again and again and are common property. I have to do with the effect of the general acceptance of Lister's discoveries on the application of pathology to surgery. The relation of micro-organisms to sepsis naturally led to the suspicion that micro-organisms might be connected with diseases other than sepsis, and this suspicion was quite justified, for it was soon amply proved by Pasteur for some of the diseases of animals. From the investigations which were undertaken in connection with this subject, the vast branch of bacteriology grew up; and as parents sometimes derive new lustre from the achievements of their offspring, so did the parent-science of pathology become the object of greater consideration and of renewed study.

Surgery and Scientific Research.

At the present moment the value of pathology to surgery is no longer in question. The applications of pathology which have been made during the last fifteen years have been so numerous and so important that, from an absolute disbelief in the practical value of pathology, we are veering round to an implicit trust in pathological foundation. As soon as the cause and nature of a disease have been discovered, an appropriate treatment is looked for as a natural and immediate consequence; and if it is not forthcoming, disappointment is experienced both within and outside the ranks of our profession. As such disappointments may occur with some frequency during the next few years, and confidence in the use of pathology may thus be weakened—which would be very undesirable—it may be well to review for a moment the means which are now at our disposal for the application of pathology to surgery, whether those means can be improved, and how the improvement should be made.

In the first instance there are now research laboratories in different parts of the kingdom, and a good deal of money is annually expended on research. Some of this money is found by universities and colleges, some of it by scientific bodies, societies, and associations. In my former capacity of Treasurer of the British Medical Association it was a great pleasure to me to see so much money devoted every year to research, but I am bound to admit that it was not always voted with alacrity. The objects of the various researches often appeared to the members of the Association to have no practical bearing, and it was suggested from time to time that the funds had better have been applied to medical defence and other material purposes. Of course it is always difficult to appreciate the value of researches in pure science which appear at the moment to be of no more use, or likely to be of greater use, than the researches of the professors of Gulliver's Academy of Lagado. And I sometimes wondered myself whether the objects of research might not have been selected with a more direct view to their utility. I was, however, easily consoled by the recollection of the marvellous application of Faraday's discoveries of the relation of magnetism to electricity.⁹ No discoveries could have appeared at the time, and for many years after they were made, less likely to have a great practical bearing. They seemed to belong to the realms of the purest science. Who would have dreamed that at this moment they would be applied to telegraphy, to lighting, to the movement of vehicles, and largely to the use of electricity in medicine? In the face of this brilliant example we have no right to assume that discoveries in pathology, which appear futile or of purely speculative interest, may not at some future time acquire an extraordinary practical importance.

This factor of time is in itself of large importance. It would not be easy to determine with precision the length of time which has elapsed between the invention of certain operations and their habitual performance. In the past this length of time must have been inordinately drawn out, even to centuries. Take once more the example of the operation for the relief of strangulated hernia; invented in the second half of the sixteenth century, it had become a recognised operation in France in the eighteenth century, and Petit had invented and regularly practised the operation without opening the sac in suitable cases. But it appears to have been much longer in gaining a firm foothold in this country. Pott, writing some time after Petit, is well acquainted with the anatomy of hernia, and with the fact that the peritoneum is not ruptured in the descent of the hernia; he is as well versed in the pathology of strangulation as Petit, and both surgeons describe it clearly, and quite differently from the great surgeons 200 years before. Pott describes the operation for the relief of strangulation,¹⁰ and how the intestine and omentum should be dealt with according to their condition; but he would not resort to the operation until such means as bleeding, clysters, purgatives, and manipulation had been tried and failed. About the same time as Pott wrote, Hey began to practise in Leeds,¹¹ where the operation for strangulated hernia had never been performed. By 1814 Hey appears to have operated on five patients, and two of them had survived. To us the percentage of cures may seem very small; but in truth it was 40 per cent., and for a condition which, unrelieved, leads to death in almost 100 per cent. of the

cases. Think what an equal success for all cases of irreducible strangulated hernia during centuries would have meant; and how the principle of early resort to operation would have vastly improved the percentage of cures and have perhaps wiped out the name of "*miserere mei*."

In these days the news of successful treatment travels fast, so fast, indeed, that a new method is sometimes accepted and adopted before it has been proved by the inventor. Such is the progressive spirit of the age, and so abundant and so excellent are the media of communication. Of course, these are great advantages, but there is still no trace of any distinct organisation for the application of pathology to surgery. Indeed, in some respects, things are likely to be worse than they were some twenty years ago. As pathology becomes more specialised, the surgeon and the pathologist must necessarily be more widely separated; and although the surgeon may make great use of the pathologist in his wards, they are no longer one and the same person. Problems in pathology and in the relation of pathology to surgery will arise in the minds of men who have not the time or the knowledge to work them out, and who know not how or by what means to get them worked out. On the other hand, those who work at research may know nothing of the questions which occupy the minds of surgeons. On this account many problems quite worth the working may be wholly neglected or their study long deferred.

If we are to remedy these defects, it can only be by some more perfect organisation, such as may perhaps be supplied by my science of applied pathology. Great attention has been devoted to pure pathology, and pains have been taken to educate and train discoverers. Laboratories for research are provided for them; materials and instruments are furnished; directors of distinguished ability and of approved skill in research are appointed. In consequence, the work of discovery proceeds apace. The more original and the abler workers choose their own subjects of research, and make their discoveries in their own way and in their own time. Those who are not so original and able are assisted in their researches by the directors.

The Making of Discoverers and Inventors.

But while our schools for discoverers are good and are improving, we have no school for inventors, for the men who are to make the applications of pathology in the future. It is on that account I venture to urge the importance of the science of applied pathology, which may prove a fitting school for inventors as the science of pure pathology is for discoverers.

I confess when it dawned upon me that my proposition would lead to a deliberate proposal to breed inventors, I was at first appalled at the daring of the suggestion. Discoverers can, I know, be made, not all equally good or equally able, and great discoverers are rare and priceless. But still, discoverers can be made, and we only discuss the proper means of making them, and of making them well and quickly. But what of the inventor; is it possible to make him too? Is he not, as he was formerly thought to be, heaven-born, a direct off-shoot of divine intelligence, though often poorly equipped for the struggle of life, and too often destined to fall a prey to the greedy maw of the seeker after wealth? Will mere training and education suffice to produce a mind which is not of earthly origin? In order to solve this question, I thought it well to make some inquiry into the lives of inventors, and as our profession can boast but few, I was thrown back on the lives of general inventors with the following result:

In the first place there can be no doubt that many men never would have invented had it not been for a chance (not always a happy chance so far as the inventor was concerned), and therefore might never have been known to the world as inventors. The overturning of a spinning-wheel suggested to James Hargreaves the idea of the spinning-jenny. The idea seems to have entered his mind like an inspiration, just as Paré said that his brain had received the inspiration of the use of ligatures to bleeding vessels. The attention of Cartwright, the country clergyman, was directed to the invention of the power-loom by an after-dinner conversation, and without any knowledge of weaving, and without ever having seen a loom at work, and without any correct notion of the principle or mode of its construction, he is said to have evolved out of

purely mental processes the idea of the power-loom. There must be many such men as Hargreaves and Cartwright, of natural inventive genius, which has never been roused into action by accident or education, and who live their lives through to the end without even themselves being conscious of their talent. In medicine and surgery there are also undoubtedly such men, and if we are to use them we must discover and develop them.

In the second place, when once the inventor has been awakened to the knowledge of his talent for inventing, he seems not only to like to employ it, but to be possessed by a resistless impulse to invent. This has been shown in the lives of many inventors. And in the curious account I have of Cartwright, the book¹⁰ says: "It would seem that the faculty of invention once aroused, its appetite for exercise is constant and insatiable..... An inventor he was, and an inventor he must continue till his eye was glazed, and his brain numbed in death..... Wool-combing machines, bread and biscuit-baking machines, rope-making machines, ploughs and wheel carriages, fire-preventatives, were in turn invented or improved by him."

Invention to Order.

In the third place, your inventor may invent better and with greater success if his mind has been trained in scientific pursuits. I think one of the best illustrations of this is to be found in the history of the invention of the miners' lamp. By a curious chance the safety lamp was invented during the year 1815 by two men working apart, neither of them knowing that the other was engaged on the invention, and each working out his invention from a wholly different point of view. Both Humphry Davy and George Stephenson were highly endowed by Nature. Both possessed the inventive faculty: Stephenson in a very high degree. But while Stephenson was what may be termed a natural mechanical and inventive genius, his education had, owing to his circumstances, been wholly neglected, and he had only such knowledge as he had been able to gather together in a long struggle against adversity. Humphry Davy, on the other hand, was a highly educated man of science, but his inventive ability was decidedly lower than that of Stephenson. The safety lamps produced by these two men resemble each other in many respects, and a comparison of them in our Museum of Inventions at South Kensington shows how little difference there is between them. Yet one of them was invented on chemical, the other on mechanical principles. Davy,¹¹ at the request of certain gentlemen, undertook to try and invent a lamp for the safety of the men employed in the coal-pits. He commenced his labour by an exhaustive study of the chemical properties of fire-damp (light carburetted hydrogen), the circumstances under which it exploded, and the proportions of air mixed with it which rendered it peculiarly dangerous. By a series of admirably devised experiments he discovered that the surfaces of small tubes prevented the explosion of the fire-damp, and that this depended on the cooling power of the tubes, and he finally found that the greatest hindrance to the inflammation of the gas was afforded by a large number of small tubes or apertures, such as is represented by the numerous tiny openings through a fine wire gauze. Such a covering rendered unnecessary the use of glass or any other fusible or brittle substance, in itself no small recommendation. Stephenson tells his own story¹² of the manner in which he came to his invention. He says he knew nothing of the chemistry at the time he was engaged in setting up some machinery in a coal-pit. In the intervals of work he amused himself with lighting one of the "blowers" in the pit. Holding his candle to the windward of the flame, he observed that it changed its colour. Two candles, drawing the flame towards them at a greater velocity, changed its colour still more, and caused it to grow duller. And when a number of candles were employed, the "blower" ceased to burn. Stephenson rightly attributed this effect to the velocity of the current caused by the heat of the candles to the windward of the "blower."¹³ and came to the conclusion that, if he could produce a current through tubes in a lamp equal in velocity to the current he saw passing along the roof of the pit-gallery, he would be able to make a lamp which might be carried into an explosive mixture without exploding externally. Repeated observation and experiment finally taught him that numerous tiny apertures afforded better protection than a small number of long

and deep tubes, and his third lamp was made by surrounding the flame with a metal plate, perforated by a vast number of tiny holes, so that it differed little from a wire gauze of the same material. Stephenson was so confident of the efficiency of his lamp that he tested it, at the risk of his own life, by entering a coal pit which had been first rendered as foul as possible by preventing the escape of the fire-damp. Davy's lamp was much more generally used than Stephenson's; but Stephenson's lamp was used for very many years in the Killingworth Pit, where he had been colliery enginewright at the time of its invention.

At the first sight it might seem that Stephenson's successful invention is but another proof that your inventor is born, not made; for here is a man without scientific knowledge and without even ordinary education, who invents a lamp almost precisely similar to, and as good against explosions as, that of the philosopher and scientist, Sir Humphry Davy. But, in truth, Davy's proved to be the better lamp. Not only was it lighter and more portable than Stephenson's; but it possessed the great advantage that it was not extinguished in thick fire-damp. Further, the experiments and observations of Davy, in the course of his research, served to render the world richer in the accurate knowledge which it afforded of the nature and chemical properties of fire-damp. If Davy's invention had proved a failure his work as a discoverer of the nature and properties of fire-damp would have far more than repaid the time and labour expended on the attempt to invent.

Again, Davy's invention proves that it is possible to invent "to order," for he deliberately set himself to invent the lamp at the request of a committee of gentlemen interested in the coal mines. I do not know whether we shall ever attain to that with our inventors of surgical methods. Yet a similar instance of a successful investigation and of the invention of a method of treatment, or rather of prevention, at the request of persons interested, may be found in the history of the discovery and prevention of silkworm disease by Pasteur.

Here, then, are found four important indications for the making and perfecting of inventors: That there are certainly many more inventors in the world than the world suspects, but their peculiar talent must be discovered; that when it is discovered they can scarcely help inventing; that scientific training, so far from impairing their inventive powers, will almost certainly improve them; and that men with the proper talent and opportunity may invent "to order." Further, it may be assumed that no man would be likely to make a specific invention unless he were acquainted with the need for such an invention.

Laboratories for Pathological Research.

From these indications it would seem that if we are to make surgical inventors, we must look for inventive minds among our students and young qualified men; that these men must be well-versed in surgical methods at present in use; that they must be thoroughly educated in science and in the methods of science, especially in experimental methods. They must also be well instructed in pathology and acquainted with new discoveries in pathology which may be of use in surgery. And they must either have the opportunity of testing their inventions or of observing and directing the trial of them. They must therefore have free access to the hospital wards and be in frequent or constant communication with them; they must have laboratory accommodation, and must be in touch with those men who are engaged in pathological research.

If these conditions are to be fulfilled in such a town as London, we shall require two species of pathological laboratory for research. The one for research in pure pathology, without any reference to its application, may be of vast size and thoroughly equipped for many workers, and need not be attached, so far as its site is concerned, to any hospital. The other for research in applied pathology, the laboratory for inventors, must needs be attached to the hospital; and those who work in it should have the freest access to the wards, even if they are not in charge of special wards, and should have every opportunity of observing what is done there and in the operating rooms. In order that they may be thoroughly instructed in the science of pathology, they should be taken from among the workers in the laboratory of pure

pathology, and should be selected on account of their special aptitude for the work of research and for the originality they have exhibited. They leave the school of discoverers and the science of pure pathology for the school of inventors and the science of applied pathology.

At the time when the idea of a school of applied pathology first presented itself to my mind, the sketch I have made would have appeared to be the dream of an enthusiast. But now, so far from being a dream, it is in some respects actually approaching realisation. There are in this town at the present moment laboratories where researches in pathology are constantly carried out, and some of these laboratories are quite separate from and independent of the hospitals. There is an institution of preventive medicine where pure and applied pathology are studied, but this is also separate from the hospitals. During the last few years several of the hospitals have founded professorships of pathology, and have appointed to them men who devote to the science of pathology not merely the time they can spare from some other pursuit, but their whole time. These men are constantly in touch with the work of the wards, and furnish the greatest assistance to it by bacteriological and histological examinations. Speaking of my own hospital, the assistance rendered to the work of the wards by Dr. Andrewes and his predecessor Dr. Kanthack has been of inestimable value. Indeed, it is difficult to understand how we could have performed our work efficiently before the institution of the pathological laboratory.

But although the last few years have seen a very great improvement, much remains to be done. Money and organisation are necessary if great results are to be secured. The laboratories for research in pure pathology are too small and too scattered, and insufficiently endowed. The laboratories in the hospitals, which ought to be devoted to applied pathology, are used for every kind of microscopical and bacteriological examination and for teaching, so that research is crowded out. And pathological chemistry, from which vast things are to be hoped in future, has taken no proper hold upon the town.

Happily there is reason to hope that the changes which must take place in connection with the new teaching university will be greatly to the advantage of pathological research, especially in connection with the hospitals. The removal of the teaching of the preliminary subjects to large central establishments will afford space for the expansion of the pathological departments. And as the value of applied pathology becomes more evident, funds will easily be found in this rich town for its development.

The question has several times suggested itself to me whether a number of men thrown together in the laboratories for research and for invention are likely to do better or worse for coming into contact. So far as discovery is concerned there is every reason to believe that a community of workers is likely to do more and to do it more quickly than the same men working separately and in ignorance of each other's work. Assistance and suggestion must come from community. But the advantages of community for invention may be contested. We have been so much accustomed to the picture of the inventor working in solitude, and often in secrecy, that the idea of a number of inventors at work openly and in communion with one another seems almost repugnant. But there seems no reason to doubt that the advantages which discoverers might gain from community would be equally gained by the inventors, and there can be little doubt that the solitude and secrecy in which the inventors of methods and machines for industrial purposes have generally worked were imposed on them by the necessity of guarding their inventions from the public eye.

At the present time, I am told that the advantages of the community of workers in research are to be seen in the laboratories attached to some of the great industrial establishments in Germany, particularly to the colour industries. From fifty to a hundred chemists are continually employed in some of these establishments, where they work in magnificent laboratories, furnished with all the apparatus which is needed for original research, and presided over by the most distinguished professors who can be obtained. The laboratories are intended for research, and I understand that the scope of the research need not be restricted to the needs of the par-

ticular industry to which the laboratory belongs, but that original research of every kind in chemistry is encouraged. The cost of such laboratories is extremely large, for the salaries of the workers are said to be on a very liberal scale. And some of the researches (which occupy weeks or months of the time of the workers) and of the space and accessories of the laboratory, are of no direct use to the industry. Yet the industry, which is proprietary, and not the property of the State, or founded for the advancement of chemical science, derives so much advantage from a certain percentage of the discoveries and applications made in the laboratories, that the funds expended on them are well laid out. Those Englishmen who are familiar with these establishments tell me that this investment of funds in scientific research has served to place the German colour industry far ahead of our own.

We want something of the same kind for the advancement of medicine and surgery, a direct and organised scheme for research and the application of pathology to our art. Of the advantage which may be derived from it I have no doubt. And if we fail to obtain it is because our forces are too divided and our views are not sufficiently in harmony. To those who think that the necessary funds would not be forthcoming, the answer must be that very considerable sums of money have, during the last few years, been devoted to medical research, and that the public mind is gradually becoming alive to the advantage to the nation of good health and the preservation of life.

NOTES AND REFERENCES.

- ¹ *Cours d'Opérations de Chirurgie*, Brussels, 1708. ² *Traité des Hernies*, etc., par Pierre Franco de Turriers en Provence, demeurant à présent à Orange. A Lyon, par Thibault Payan, 1561. ³ London, 1779. ⁴ London, 1782. ⁵ *Mémoires de l'Académie Royale de Chirurgie*, t. i, 1743; Préface, p. xlv; "Le plan que se propose l'Académie est d'élever la chirurgie sur les observations, sur les recherches physiques et sur les expériences." ⁶ Address on the Jubilee of the Pathological Society of London, October 20th, 1896, *Pathological Transactions*, vol. xlviii. ⁷ *Faraday as a Discoverer*, by John Tyndall, London, 1870. ⁸ *The Chirurgival Works of Percivall Pott*, a new edition, London, 1779. ⁹ Hey began to practise in Leeds in 1759. ¹⁰ *Triumphs of Invention and Discovery in Art and Science*, London, 1881. ¹¹ *The Collected Works of Sir Humphry Davy, Bart., LL.D., F.R.S.*, vol. vi, London, 1840. ¹² Evidence before the Committee of the House of Commons in 1833, *Smiles's Life of George Stephenson*, fourth edition, 1857. ¹³ The rushing of the fire-damp from fissures in the strata of coal is called a "blower."

THE LIFE-SAVING SOCIETY.—We have received the annual report of the Life-Saving Society, which is now in the ninth year of its existence, and are pleased to see that it is in a flourishing condition, and extending its useful work. It is, we believe, the only Society that organises systematic teaching of the various methods of rescuing the drowning and resuscitating those who are apparently drowned, and it has been the means of inducing many swimming organisations to make life saving an important element in their courses of instruction. By its instrumentality the subject has been introduced and successfully carried on by the aid of honorary teachers into many public and elementary schools and other educational bodies, and classes have also been formed in connection with the police, dock labourers, and Her Majesty's forces, the instruction given being theoretical and practical, on land and in the water. Another important branch of its work is arranging public demonstrations in various baths and docks, when large numbers of people, sometimes amounting to thousands, witness the graceful swimming and diving exercises practised, as well as the various modes of succouring and bringing safely to land the apparently drowning. This has perhaps done more than anything else to awaken a general interest in the work, and increase the demand for information and instruction. The Society, which has its central office at 8, Bayley Street, Bedford Square, London, W.C., is supported by voluntary subscriptions, and is well worthy of being brought into greater prominence.

REGISTERED MEDICAL PRACTITIONERS IN THE UNITED STATES.

—According to the *Medical Record*, the average number of registered physicians in the United States to the whole population is about 1 to 647. The proportion in the States varies greatly; California appears to be the State which is most liberally supplied, the proportion there being 1 physician to 420 inhabitants, while in Iowa nearly the same conditions prevail. On the other hand, in North and South Dakota and New Mexico, the proportion was respectively 1 to 1,285, 1,296, and 1,391 inhabitants.

THE CROONIAN LECTURES ON DEGENERATION OF THE NEURONE.

Delivered at the Royal College of Physicians of London

By FREDERICK W. MOTT, M.D. LOND., F.R.S.,

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LECTURE II.

MR. PRESIDENT AND GENTLEMEN,—In my last lecture I briefly referred to the present position of the neurone theory. I gave some examples of its practical application, and I dwelt at some length upon a method which has been used for studying the bio-chemical changes which occur in the protoplasm of the nerve cell. Moreover, I pointed out the important evidence afforded by the development of the myelin sheath in proving correlation of structure and function: and that the formation of myelin depends upon three fundamental biological principles:

1. An acquired inherent tendency the result of evolutionary differentiation of structure and function for certain systems, groups, and communities of neurones at successive periods of time to ensheath their axis-cylinders with an insulating and protecting structure, the myelin sheath, which in the case of the peripheral nerves is contained within, and partially formed by a chain of tubular mesoblastic cells.
2. Phylogenetically and ontogenetically stimulus from without is the determining factor in the bio-chemical change associated with the deposition of myelin.
3. Absence of stimulus as occurs from long disuse occasions a regressive metamorphosis back to the embryonic type.

THE EFFECTS OF INJURY OF THE NEURONE.

Section of the axis cylinder or destruction of the nerve cell (speaking collectively), whether produced by direct trauma or by morbid processes occurring in the vascular and supporting structures of the nervous system, causes a simultaneous death change of a characteristic chemical nature affecting the myelin sheath and axon extending from the point of injury to its terminal fibrils. This is Wallerian degeneration, or secondary degeneration of Waller and Türk. Ranvier showed that the sheath of Schwann consists of a series of tubular mesoblastic cells wrapped round the axon, and that when a nerve is cut there is degeneration of the myelin and axon above the lesion as far as the next node. Each internode, therefore, represents a cell; and the fact that the degeneration does not extend upwards beyond the node allows the presumption that these tubular cells have some metabolic interaction with the contained axon and its surrounding myelin. But whatever that reciprocal metabolic interaction of the axon and its ensheathing structures may be, secondary Wallerian degeneration conclusively proves that it is controlled and determined by the nerve cell and its contained nucleus; indeed, it is possible to conceive that the metabolic activity of the nucleus is the mainspring of this trophic influence, by the production of some bio-chemical or biophysical stimulus which pervades the whole complex neurone even to its far distant prolongations. The Nissl method has shown that section of an axon causes changes in the nucleus and cell protoplasm; these may be temporary and recoverable or permanent and irrecoverable, the result apparently depends very much upon the degree and extent of the injury. When a peripheral nerve fibre is cut through, the trophic influence of the cell is removed from the axon and myelin sheath which it generated. These die; not so, however, the independent tubular cells of the sheath of Schwann, for these, soon after the death change has commenced in the myelin, show signs of active proliferation; whether, as some authorities would have us believe, they can lead to regeneration of the nerve, or whether, as seems much more probable, they prepare the way for the down-growing axon, I shall not here enter into; but that they have an important function in regeneration is undoubted, seeing that regeneration in the central nervous system, where the sheath of Schwann is absent, does not occur. Tuckett has shown that when a non-medullated sympathetic nerve is cut, the nuclei and sheath