WAR NURSING

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WHAT EVERY WOMAN SHOULD KNOW

RED CROSS LECTURES

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NEW YORK
ROBERT M. McBRIDE & CO.
1918

Printed in Great Britain

PREFATORY NOTE

The following data of medical physiology, while extremely elementary, will afford the generous women hastening from all sides to the succour of the sick and wounded an opportunity of understanding some of the general laws directing modern therapeutics.

They are not called upon to profess medicine or to practise surgery, but merely to get an insight into the prescriptions of physicians, and the operations of surgeons.

Better knowledge will not only enable them to give more enlightened assistance, but will bring them the intellectual pleasure of fuller comprehension in the accomplishment of their noble task.

TO HOSPITAL NURSES

Before we proceed it must be understood that no distinction whatever is admissible as to either duties or rights between the paid professional nurses of the hospitals and the voluntary nurses—women of society—who have undertaken the hard task of tending the sick and wounded.

The same regularity, the same docility, must be exacted from voluntary nurses as from their sisters. And from the professional nurses we have a right to demand the same devotion and the same self-sacrifice as from the volunteers.

There are not two codes, or two hierarchies. Any sort of inequality would be iniquitous, and the few words I propose addressing here to nurses are directed to professionals and volunteers alike. For each is there an equal share of honours, and an equal share of burthens. Only on pay-days can there be any difference between them, and that for a few minutes a week.

The first virtue in a nurse is *devotion*. Your task must be performed, not as a task, not even as a duty, but as a pleasure. Whether done as a duty or by choice matters nothing. You must bring to all your work ardour, enthusiasm, and—whatever Talleyrand may say—zeal. Believe me, nothing useful can be done if you are in a cavilling, unwilling humour; if you come to your work with lassitude in your gait, weariness on your lips, and indifference in your hands!

The profession of nursing is decidedly not amusing, nor easy, nor elegant. Yet to follow it well you must put your whole soul into it.

This is the truth, ladies. If you are apt to get tired or be disgusted, you must go. Do not cross the threshold of a hospital. Try embroidery, metaphysics, music or cooking. But give up the idea of nursing the sick, for your patients will soon see you take no interest in them, and will not forgive you, however correctly you may perform your duties.

The second virtue is *docility*.

A great friend of mine, an Englishman and a bit of a humorist, once said to me that he considered woman's chief virtue to be docility, but that he never dared to say so before women, because it would make them furious!

So I will only talk of obedience as regards hospital nurses, but from them I ask for docility before everything. They must not treat their patients according to their own medico-surgical ideas, but strictly according to the doctor's orders. In theory, physicians and surgeons are infallible, a false supposition which, while altogether wrong as a matter of fact, must be held sacrosanct by the nurse. When an enema is ordered for No. 23, and painting with iodine for No. 12, the nurse has no business to paint No. 23 with iodine and administer an enema to No. 12. Should the doctor order 15 drops of laudanum, she must not give 10 or 20, but just 15.

And this docility certainly requires much self-sacrifice. Rightly or wrongly, the nurse has personal opinions concerning treatment, operations, and medicines. For instance, she may have noticed, or may think she has, that 15 drops of laudanum are too strong a dose, and so believe herself justified in not following the doctor's orders to the letter. But in this case she has the last resource of speaking to the doctor, and respectfully representing to him that the patient in question cannot stand 15 drops. If she is tactful she will always succeed in getting a hearing. A remark to the doctor himself implies no lack of discipline. On the contrary, it is a proof of deference.

The third virtue is *activity*.

Or, to put it otherwise, no laziness. La Rochefoucauld, who was a great psychologist, declared idleness to be our worst enemy, the one that led us to commit most faults. It was a profound remark. The farther one gets on in life, the more one realizes that negligence is at the bottom of our greatest mistakes.

The hospital nurse ought not to know what laziness means. If she is lazy, the dressing will be badly done, the food ration ill-cooked or served cold, the bed uncomfortable. And the patient will suffer through her negligence. I know only too well that the poor nurses are often tired or worried, but all that matters is that the doctor's orders should be carried out. Fatigue is no excuse. The patients must not suffer from the lassitude of those who tend them.

I could name many other virtues, but I fear by so doing to make this already formidable task appear altogether too difficult. At the same time, I dare not hide from you that to be devoted, docile, and active is not enough. Other qualities are required.

For instance, *gaiety*. The patients, heroic men who have just escaped death, require cheering or consoling by some comforting word.

But such expressions of friendship and sympathy should not overstep certain limits. Too much intimacy between a young patient and his young nurse might have its disadvantages. I have been told, but do not care to believe it, that in the more distant towns there have at times been abuses of this nature.

Good temper. It is silly to be oversensitive, and to be always grumbling about your comrades, about the staff, about the patients themselves, tiresome though they sometimes are. It is not easy to be always in a good humour, even in everyday life, and still less so in a hospital ward, where you are exposed to hearing opinions you do not share, and to little outrages that appear to you to be acts of the grossest turpitude.

Decency of attire: No luxury, please, no jewelry, and (may I hope) no rouge. No ultra-fashionable frocks, but a certain quiet elegance and the most exquisite cleanliness.

Briefly, it requires almost superhuman virtue to be an ideal sick-nurse. In practice one has to be satisfied with less.

I would like to put the case more simply, so as to sum up in one word the true combination of all the requisite qualities. I will say they are all contained in the one quality, *kindness*.

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WHAT EVERY WOMAN SHOULD KNOW

I

ANTISEPSIS

I.

WHAT I propose to give you here is no more than a very simple and rudimentary survey, for I have only a few moments at my disposal in which to summarize facts requiring volumes to explain properly. It will not even be popularized science.

On the other hand, not being a practitioner, I cannot promise you the simplest technical hints. Any other professor will serve your turn there far better than myself.

Still, I think I may be useful to you by taking things from a fresh standpoint. I would like to show you the reason why, the significance, the scope of such medico-surgical technique as you will see employed, perhaps employ yourselves, because doctors, in their need for immediate action, and pressed for time, do not always trouble themselves to explain the fundamental principles underlying their practice.

To-day the point for you to understand is the theory of antisepsis; not to burthen your minds with formulæ, all more or less complex, and uninteresting in themselves, but to get a clear and adequate grasp of things you handle, or see handled.

With such a clue once securely in your possession, you will be able to thread your way through the labyrinth of facts without difficulty. No further effort of memory will be required. Everything will be understood, well and solidly assimilated. To group round a few elementary conceptions the multiple notions of detail, however numerous, will be easy.

You must forgive me if, in order to get you to take firm hold of the interconnection of causes and laws, I make the supposition, doubtless unwarranted, that you know nothing about them, and that I have everything to teach you. If you are ignorant of what you hear here, I am pardoned beforehand for instructing you in it. If, on the contrary, as is quite possible, you are not ignorant, you may still find pleasure and some profit in hearing things you already know well.

To-day I shall speak to you about antiseptics, about disinfectants, and about aseptic surgery, three very modern ideas which are the foundation of contemporary medical science.

II.

The word *antiseptic* means that which *prevents corruption* and *putrefaction*. Antiseptic substances are therefore those which wage war against corruption in wounds and decomposition in the humours of the body.

When a wound divides or a traumatism* lacerates a tissue, the tissue tends normally to cicatrize, to regenerate and heal up immediately. The two lips of the wound join, are soldered one to the other, and cicatriza-

* Any wound from outside.

tion takes place at once. The action is the same in the case of a bone, or of the skin, or a portion of the mucous membrane. An uncontaminated wound heals without suppuration.

But for that to happen no foreign body must intervene. Once let the sore be contaminated by parasites, and the parasites as they develop will produce poisons. The poisons will either be general or local, and will infect the blood, decompose the tissues, bring on fevers, and sometimes cause mortal accidents.

These parasites are microbes, and I must now explain to you what you must understand by this fateful word. As you all know, it was Pasteur who discovered the preponderating function of bacteria in etiology and the development of disease. From 1857 to 1877, in a series of incomparable works, he established certain laws hitherto, for the most part, unsuspected.

A microbe is a vegetable growth which, while extraordinarily small, feeds, grows, and reproduces in the same way as larger vegetables. One of its characteristics is to multiply very rapidly, several generations, capable of existing in a fertilizing culture, and consequently in animal and vegetable bodies, being sometimes born in an hour. Microbes readily infect the blood, the other fluids of the body, the tissues, and any liquids they may fall into.

They can be recognized, their forms studied, their reactions, their vitality, and especially the terrible poisons they secrete, verified, by sowing them in a fertilizing liquid absolutely free from other germs. They will flourish there, just as wheat flourishes in soil sown with wheat. The phenomenon is precisely the same. One does not reap wheat from a field not sown with wheat. No microbe will make its appearance in a culture where no microbe has been cultivated. And when a special microbe has been planted, it is that species that grows, not another.

Pasteur proved that these parasites are universal: they are on the surface of all bodies, in water, in the air; consequently we are surrounded on every side by germs requiring only a favourable soil for development.

To judge of the fearful numbers of these existences for yourselves, you have merely to watch what happens in a darkened room when you allow a ray of light to pass into it. The ray makes a brilliant track through the obscurity, for it lights up in its passage a quantity of dust that you can see dancing gaily in the general gloom of the room, wherever this is traversed by the beam. The ray is invisible, luminous only where it meets solid particles in its path. You could not see it if it were not for the innumerable granulations floating in space.

Bacteria are everywhere. They are on our hands, on our clothes, on every surface. They infest our clothing, our food, our drink, whatever surrounds us. They are the *dust*. And the dust is everywhere!

If, therefore, we had not been endowed by Nature with very remarkable means of defence, we should be invaded and destroyed by these innumerable and implacable foes, always alive, and always a menace.

Fortunately, we have means of defence as powerful as our enemies' means of attack. And our essential protection is the skin. When intact, the skin is absolutely refractory to the action of bacteria. Our fingers can handle the most redoubtable microbes with impunity. They cannot penetrate the epidermis, which presents an insurmountable obstacle.

Our skin, therefore, is immune, but the mucous membrane is not. We have a digestive mucous membrane and a pulmonary mucous membrane, and these can be invaded by microbes, though even there the defences are not to be despised.

To begin with, the lungs can be approached only by organisms from the air. And in general these are inoffensive. Even when attached to the membrane of the air passages, they are soon destroyed by the activity of the lung cells. Not only that, but they reach the lungs with some difficulty, being stopped on their way by the nasal passages, the mouth, the pharynx, so that infection by way of the air passages is probably rare.

The digestive mucous membrane is exposed to a multiplicity of infectious influences. Many diseases, cholera, typhoid, tuberculosis even, are due to digestive infection. Happily, in normal conditions the gastric juices are usually sufficiently vigorous to dissolve, disintegrate, and destroy the microbes penetrating the stomach and intestines.

When, therefore, there is neither incision, laceration, nor ulceration, the skin is never, and the mucous membrane *very seldom*, affected by parasites.

But from the moment that the skin is broken there is a change. For the exposed tissues are then accessible to parasitical invasion. The thick, stubborn barrier of the skin is broken down, and the power of the microbe has full liberty of action. As it is difficult (not to say impossible) to prevent some germ from reaching a wound, all wounds are immediately infected.

The microbes find here the most favourable soil possible. They develop with extraordinary rapidity, like corn in a field, and provoke, by their poisonous secretions, the emigration of the white corpuscles of the blood. Innumerable white corpuscles leave the capillary cells and flock from all parts to bring succour to the contaminated organism.

Now, what causes this general mobilization of the white corpuscles or *leucocytes?* It is admitted that they are attracted to the wound by emanations (odoriferous?) given off by the microbes, or, to put it in another way, by the poisons the microbes secrete.

The white corpuscles constitute the fundamental portion of the pus. A wound suppurates because the microbes, which freely infest this wound, have also freely secreted their poisons, and because these poisons have excited the activity of the *leucocytes.*

We owe to Pasteur the great fundamental discovery that microbes infect wounds, and that uncontaminated wounds are cured quickly and surely. The great Joseph Lister was the first to apply this invaluable and fertile principle to surgery.

At a time when Pasteur's observations of the diffusion of bacteria met with general ridicule and misconception, Lister saw that to prevent these parasitical organisms from developing was to render wounds inoffensive, and to ward off terrible complications: tetanus, gangrene, erysipelas, purulent infection, all horrible disorders which the development of morbid germs infallibly brought in its train.

I need scarcely tell you that tetanus is due to a specific microbe, erysipelas to a specific microbe, gangrene to a specific microbe; without microbes there would be no tetanus, no erysipelas, no gangrene, no septicæmia. There would not even be suppuration. The wound would run its course in a few days, and cicatrization would follow rapidly and promptly.

Very well, then, antisepsis includes the entire process of controlling the growth and development of microbes of all descriptions. Antiseptic substances are substances which kill microbes, substances which, if applied to a wound, prevent parasitical complications from ensuing. Antisepsis is, in a word, the greater part of surgery.

We must, therefore, unite in our common gratitude the names of Pasteur and Lister. Pasteur discovered the primordial law that parasitism is the origin of disease. He pointed out the wide dissemination and noxious nature of bacteria. Lister applied the discoveries of Pasteur's genius to surgery. And the famous English surgeon delighted in recognizing the great French savant as his master and inspirer.

III.

To realize what an antiseptic is, it is enough to know that, in common with all living things, vegetable bacteria—in short, microbes—are susceptible to the action of poisons. A microbe which flourishes in a cultivating liquid develops badly when 1 centigramme to the litre ($\frac{1}{6}$ grain troy to imperial quart) of mercuric chloride is added, and not at all when the dose is increased to a decigramme ($1\frac{2}{3}$ grains troy).

You see at once how it is possible in a general way to judge of the antiseptic value of various substances by studying the behaviour of a microbe in a culture containing a definite quantity of that substance. It has been ascertained in this way that some substances are especially antiseptic—for instance, mercuric chloride, all the salts of mercury, all the salts of the heavy metals, such as platinum, gold, silver, copper, zinc, etc.; that others are strongly antiseptic, such as chemical bodies giving off oxygen, oxygenated water, permanganate of potash, the hypochlorites, chromic acid; also substances containing in their molecular structure phenol, the base of benzene, picric, salicylic, and benzoic acids, etc. Lastly, there are substances feebly antiseptic, such as the majority of the other metallic salts, and a number of organic acids.

But I cannot enter into detail. Remember only that there are an immense number of antiseptics, from which surgery has eliminated all but half a dozen or so, the remainder doing, on the whole, more harm than good. But that also would take too long to go into to-day. I will limit myself to a few simple laws.

1. While acting on micro-organisms, antiseptics act also on the living tissue, and after the same destructive fashion. They injure the wound, and render healing more difficult than if cicatrization had been able to proceed normally and uninterruptedly.

The hot iron and cautery, while certainly destroying all microbes, are the worst antiseptics. They burn and destroy the tissue, making cicatrization slow, perilous, and unnatural.

2. The action of antiseptics becomes more efficacious the higher the temperature at which they are applied.

3. Antiseptics in a certain dose will check the growth of microbes without actually killing them. The dose for preventing the growth of a microbe is therefore different from one that will kill it. The dose that is fatal to bacteria is a *disinfectant;* that is to say, not only are the microbes prevented from developing, but also their spores, rounded shapes which they take when they find themselves in an unfavourable medium, are destroyed and reduced to impotence.

4. Different microbes are not killed by the same dose

of antiseptics. Each resists the action of the poison differently.

Generally speaking, the pathogenic microbes—that is to say, those that are liable to pullulate rapidly and to create disease—offer, fortunately, far less resistance to antiseptic agencies than the non-pathogenic kinds.

5. Antiseptics which coagulate the albuminoids of the body are bad antiseptics. In coagulating they unite, often without annihilating, whole masses of microbes, which remain in the wound with all their virulence unimpaired.

6. Antiseptics are usually less dangerous the more volatile they are. When they are fixed, as it is impossible to avoid their being absorbed, they can, once they are absorbed, only be eliminated from the system with great difficulty.

Not having time to go into the detailed action of various antiseptics, I must be satisfied with indicating the following:

1. *Iodized water*—that is, water containing 5 per cent. tincture of iodine.

2. *Mercurial salts*, at a dose of a thousandth part, are all disinfectants, powerful parasite-killers, but their use is not without risk. Cyanide of mercury is preferable to mercuric chloride. It is active at 1 per 10,000.

3. *Oxygenated water*, the hypochlorites (of soda, potash, or lime), permanganate of potash, picric acid, iodoform, are all substances easy to handle, and excellent antiseptics.

4. At stronger doses, phenol, camphorated alcohol, and boracic acid, offer in special instances very remarkable advantages.

It is for the surgeon operating to decide on the antiseptics he uses. I should recommend in a general way, to people who are not accustomed to write prescriptions and handle poisons, to use boracic acid. It is neither caustic, nor toxic, nor offensive, and so little soluble that it can be employed in as concentrated a form as it is likely to be obtained. More than that, it is solid, easily handled, and cheap. It does not stain linen like permanganate of potash, does not smell unpleasantly like iodoform, and does not affect the functions of the kidneys as do the salts of mercury. With 1 kilogramme (2 pounds 3 ounces) of boracic acid you can have 30 litres (6⅝ gallons) of a feebly but genuinely antiseptic solution, which in any case is harmless.*

IV.

Disinfection and asepsis are produced by the same chemical agents. All disinfectants are antiseptics, though the converse is not true. Moderately antiseptic substances are deficient in disinfecting properties (boracic acid, for instance).

We cannot employ expensive substances like oxygenated water for disinfectants, nor such as stain linen or affect the colour of stuffs, such as lime hypochlorite, iodine, and permanganate of potash, nor any that are too toxic, like the salts of mercury or even of copper. Indeed, the choice of chemical substances for disinfectants which are to be both cheap and non-poisonous is very limited. It is reduced mainly to formol and sulphate of iron.

* Do not forget that to obtain a saturated solution of boracic acid it is necessary to put enough of the substance into boiling water to allow of an insoluble residuum—about 50 grammes per litre (772 grains troy per imperial quart).

V.

But true disinfection, or more properly sterilization, should be carried out by other than chemical means—that is to say by heat.

It is enough to subject dust and germ laden objects to a particular temperature during a certain period for all germs and micro-organisms to be destroyed.

At 70° C. (158° F.) microbes, whether pathogenic or non-pathogenic, can no longer develop, but they are not killed.

At 100° C. (212° F.) the greater portion are dead, but some few escape, if they are in the form of spores; if the heat is a dry heat, not a damp or liquid medium; and especially if the temperature of 100° C. lasts less than an hour.

At 110° C. (230° F.) a single quarter of an hour is enough to destroy the germs definitely.

Lastly, at 118° C. (244° F.) three minutes suffice to annihilate the microbes, whether spores or adult.

Please observe that a dry heat is always less effective than a damp heat, and that in a dry medium the times just given should be doubled.

Of all disinfecting agents, heat is the most effective, the most convenient, and the most reliable. Linen and surgical instruments placed for a few minutes in a stove, the temperature of which is 115° C. (239° F.), will have all germs eradicated. Disinfection (otherwise sterilization) is complete.

And if to the action of heat a chemical antiseptic is added *formol*, for instance—disinfection is still further expedited.

But why apply a chemical? Is it not wiser to place all objects to be sterilized in a well-regulated stove—

excellent ones of all sizes can be obtained—and let them remain there for a quarter of an hour at 110° C. (230° F.)? Nothing is more simple. Nothing gives more absolute security.

VI.

Whatever the power of disinfectants and antiseptics, it is far better not to use them, since, volatile or stable, diluted or concentrated, they are toxic to the cells of the organism and to the parasites alike. It has, therefore, been discovered—and this discovery constitutes the greatest victory of modern surgery—that the surgeon can and should operate without having to fear the presence of microbes.

Antisepsis is the destruction of microbes. *Asepsis* is the absence of microbes!

Let it be made abundantly clear that aseptics cannot be mentioned in the case of wounds and hurts that are the result of accidents. When a bullet or shell splinter penetrates or tears the flesh, neither the skin, nor the clothing, nor the projectile itself, can be held exempt from germ infection, and you can take it as axiomatic that *every wound not of the operating-chamber is infected.*

The first dressing must therefore be antiseptic. In other words, the surgeon must apply to the wound, contaminated of necessity by many and perhaps dangerous microbes, chemical substances to hinder their growth.

If, as is too often the case in the tragic times we live in, the first dressing is not applied for hours (sometimes, alas! for days) after the hurt, the wound must be already deeply infected, and powerful antiseptics required. The wound will be in full process of suppuration; putrid matter will be abundantly present; suppurating fistulas will drain into the tissues. In the presence of long-standing infection of this nature, the very mention of aseptics would be illusory.

But when, instead of treating a wound he has not made, a surgeon has to make a wound himself—that is to say, *operate* by making an incision in the sound skin, and penetrate into a *serous* cavity (pleura, abdomen, articulation) unopened to the air by a previous laceration—it is his duty to eliminate beforehand all danger of bacteria, whether dangerous or not dangerous, pathogenic or not pathogenic, and operate in a sterilized environment.

In this asepsis of the operating-room there are certain precise rules, so precise and so minute that no surgeon can boast of not having offended in some slight fashion against one or more of them.

1. The skin of the patient operated on must be repeatedly washed, sterilized by soap, and later by antiseptic lotions.

2. The instruments, linen, all objects whatsoever destined to come in contact with the wound, must be sterilized in the autoclave (118° C., 244° F., for several minutes), and, after being so treated, not touch any unsterilized object whatsoever.

3. The operating surgeon's hands must be washed and sterilized, or better still, if neither the operator nor his assistant touch the wound with their hands. Thus the use of sterilized gloves has become indispensable.

4. The only germs that then remain to contaminate the wound are the germs from the air, but these are not dangerous. Besides, to prevent dust falling from the walls, furniture, or other objects which may be in

the operating-room, these things (walls, furniture, clothes, etc.) should first be disinfected.

And in this way contact with microbes will be *all but completely prevented.* We cannot say totally prevented, because it is unlikely that there should be no contamination from particles of dust that may have escaped destruction and be floating in the air! But such atoms are rarely of enough importance to propagate disease. Besides, the pathogenic microbes are, relatively to the non-pathogenic, few in number, and do not constitute a practical danger.

VII.

We may sum up this sketch with a few elementary propositions:

1. Antisepsis should be destructive of microbes and harmless to wounds.

2. Any wound not made by the surgeon should be disinfected as soon as possible.

3. The surgeon should operate in aseptic surroundings—that is, should not incise the skin except with sterilized instruments and hands.

4. By means of antisepsis (for wounds) and asepsis (for operations) many thousands of lives have been saved. In this bloody war, more bloody than any in the past, which were mere child's play compared to it, there have been certainly 2,000,000 of wounded on the French side alone. The mortality (in hospitals and ambulances) from wounds in the field, which was formerly 80 per cent., and sometimes more, is now 5 per cent., which means that 75 per cent. of our dear wounded are saved by antisepsis, and that out of 2,000,000 of soldiers, 1,500,000 have been saved by the genius of Pasteur and Lister.

II

ANÆSTHESIA

THE word *anæsthesia* is derived from the Greek. It signifies the loss of sensibility, and the problem of anæsthesia reduces itself to this: *the suppression for a time of the sense of pain.*

There are certain substances which possess this singular property, and are at the same time practically harmless. They are anæsthetics.

I am going to speak to you about these substances, to show you how they act, what are their dangers, and, inferentially, the rules that govern a safe anæsthesia.

I.

A few words to begin with on the history of our subject. We are not dealing here, as in the case of antiseptics, with a discovery due to the labour, perseverance, and ingenuity of great scientists. The discovery of anæsthetics was accidental. It was the work, not of men of science, but of young and inexperienced practitioners—of American dentists.

In 1844 a young man of twenty, Horace Wells, was attending a lecture where experiments were being made on nitrous oxide. Chancing to stumble against a bench, he was surprised to find that he felt no pain. A little while afterwards, when about to have a decayed tooth extracted, it occurred to him to inhale nitrous oxide beforehand. And the same acid that had prevented his feeling the blow also prevented his feeling the extraction of his tooth. Having gone through this painful operation without suffering, he realized, as he said at the time, that a new era had dawned in surgery.

Later, in 1845, two other dentists in America who had heard of Wells's researches, determined to experimentalize with sulphuric ether (ethyl oxide), the ether still used in surgical operations. Their efforts were successful. Pain in surgical operations was abolished.

The wonderful discovery was rapidly perfected. In 1847, thanks to a French physiologist, Flourens, and to the English doctor and obstetric physician Simpson, all surgeons could habitually practise anæsthesia.

Anæsthesia had put an end to the abominable situation, which one cannot think of now without horror, the atrocious moral agony which the long expectation of atrocious physical agony inflicts upon an unhappy patient awaiting an operation.

This torture is at an end. One now knows that one will not suffer during an operation, and when the operation comes there is no pain.

Among all the benefits which medical science has bestowed on the world, none, perhaps, is as great as this.

II.

To explain anæsthesia to you properly I must enter into a few details of anatomic physiology, which I will give you as quickly as possible.

Sensibility lies in the nervous system. All over the surface of the body and the viscera there are nerves connected with the brain, so-called nerves of sensation.

If much disturbed, these arouse in the brain and consciousness a sensation which is pain. Whenever these nerves are violently excited, whether by electricity, heat, a blow, or any sort of wound, pain appears. The nervous centres (conscious brain) become aware of a sensation that cannot be defined otherwise than as *pain*.

Hence, by numbing the brain and paralyzing cerebral sensation pain can be abolished. Hence, also, it follows that there are two means of suppressing pain: either by annulling sensibility in the nerves transmitting excessive vibration, or annulling the sensibility of the nervous centres which register it.

For these two varieties of anæsthesia there are two absolutely different processes: in the first case *local* anæsthesia, when the sensibility of the transmitting nerve is suppressed; and in the second case *general* anæsthesia, when the painful vibration of the nervous centres is prevented.

III.

We will speak first of general anæsthesia—that is to say, of those substances which, introduced into the organism (by respiration), reach the nerve centres and annul the conscious sensibility of those centres. And as a type we will take the commonest form of anæsthetic employed—I mean chloroform.

Chloroform is a volatile liquid which, in evaporating, mixes with the air. Chloroform gas inhaled into the lungs enters the blood, and through the blood reaches the nerve centres, where it so works by a special form of toxic action that anæsthesia by chloroform is tantamount to a temporary poisoning of the nervous system.

What are the different stages of chloroform-poisoning?

I have no doubt that you have seen people under chloroform. Nevertheless, I propose to describe to you the different phenomena presenting themselves during the process.

First there is a period of excitement. Chloroform does not immediately produce insensibility. The person under chloroform continues to move, to be restless, to complain, to see surrounding objects. To use a comprehensive word, he is *delirious*. He is in a state of intoxication.

Intoxication by chloroform is not very different from intoxication by alcohol. In both there is tumult and exaggeration in the ideas. Reason is no longer able to control the thoughts jostling one another chaotically in the brain. The intelligence is in such disorder at this stage that the memory is affected. One cannot remember the incoherencies uttered at the beginning of the chloroformic sleep.

The initial cerebral intoxication may be explained as follows:

The mass of the brain is covered at its periphery with a grey matter, which is the seat of the intelligence, of ideation. This layer of grey matter is made up of the nerve cells of the brain, the most sensitive of the entire organism. A poison entering the blood does not immediately reach the muscles, the nerves of the body, glands, and other tissues. Before affecting these it poisons the nerve cells of the brain, which are exceedingly sensitive to toxic action. A weak dose of chloroform will, while leaving all the other tissues intact, excite, disturb, and later on paralyze the psychic nervous system of the brain—that is to say, the nerve cells which govern ideation, memory, reason, and intelligence.

That is the first period, the period when the poison affects the nerve cells of the grey covering matter of the brain. It is the preliminary stage of chloroform intoxication, but useless for operating purposes.

Patients at this stage are restless and liable to make sudden movements. They are still in a highly excitable condition. They are not motionless and they are not silent, as they have to be. The weak dose that has had full effect on the cerebral surface has not intoxicated the other cells of the nervous system.

But let us come to the second period.

The second period is that when reflex actions of the spinal marrow cease.

The entire surface of the body is furnished with sensitive nerves communicating with the marrow. The excitement there set up is reflected by the motor nerves—by the sciatic nerve and the brachial nerve, for instance, which give movement to the lower and upper limbs. Such transmission of movement to the motor nerves through the irritation of the nerves of sensation can take place without the intervention of the brain or medulla oblongata. This is called *reflex action*. During the first stage of anæsthesia by chloroform, reflex action persists. If the conjunctive nerve of a patient under chloroform is touched at this stage, the eye closes automatically without the patient being aware of it. This is a typical instance of reflex action.

Reflex action disappears during the second period of chloroform intoxication. Activity is then altogether at an end in the nervous system, except in one organ which is still alive, thus permitting the continued administration of chloroform to the patient. This organ is the medulla oblongata, or subarachnoid space, a nerve centre intermediary between the brain and spinal cord.

In the medulla there is a respiratory centre which controls respiration. And this respiratory centre is much more refractory to the action of chloroform than are the cells of the brain or those of the spinal cord. The true chloroformic period, the period to be taken advantage of for operating purposes, is the period during which reflex action has ceased and the intelligence is suspended, but during which respiration continues. Then, though the patients under chloroform are motionless, though they have no reflex actions and no intelligence, though they are unconscious of all that surrounds them, yet they can breathe.

So much for the chloroformic operating period. But let us carry the administration of the drug a little farther. This must not be attempted in surgical operations, but physiologists have made the experiment on animals in order to judge of the dose at which the drug becomes mortal. Now, in this third period the breathing stops. The dose of chloroform administered has been strong enough to paralyze the medulla, the respiratory nerve centre. At the same time certain nerve cells still remain alive and active. They are the ganglionic nerve cells of the heart. In the case of an animal so far chloroformed or chloralized as to be unable to breathe naturally, artificial respiration can be continued as long as the heart beats.

Thanks, therefore, to the use of chloroform, we are able to disconnect the different nerve cells from the cerebro-spinal axis, and to observe that a kind of hierarchy exists between them. First there are the very sensitive nerves, the seat of the intelligence; next those rather less sensitive nerves which preside over reflex action; then those, yet more refractory, of the respiratory centre; and lastly, most refractory of all, the nerve cells of the heart, capable of maintaining the action of the organ when all other nerve cells are profoundly affected.

We can operate in certain cases without waiting for the second period. It is possible to operate with weak doses of chloroform at the moment when pain disappears, while reflex action has not quite ceased. We have no need to carry the administration of chloroform so far as to eliminate reflex action entirely, provided liability to pain is to a large extent removed. This condition is obtained by injecting a small quantity of morphia before administering chloroform, an important discovery due to Claude Bernard. A previous injection of morphia renders the patient exceedingly sensitive to chloroform: perhaps too much so, considering that a whiff or two of chloroform inhaled in these circumstances is enough to render him completely unconscious. Indeed, some surgeons consider the slumber too profound, and reawakening too laborious. Injecting morphia before chloroforming a patient is not generally practised, therefore, in surgery, for serious accidents may result from the double intoxication.

Even during the first period operations have been performed without a previous injection of morphia. A few whiffs of chloroform suffice to produce *analgia*. Analgia means absence of pain. The terms are well devised. Anæsthesia is the absence of sensibility. Analgia is the absence of pain. In the latter condition reflex action and sensibility to touch remain, but there is no pain. There is analgia.

For instance, chloroform can be given in childbirth, for, as the physical phenomena of childbirth are essentially reflex phenomena, the expulsion of the child may still be effected by reflex womb contraction under chloroform. Reflex action is not prevented by the suppression of sensitiveness to pain. It manifests itself till the second period is reached, the period when all activity of the spinal cord disappears.

So the four periods of chloroform intoxication may be summarized in the following manner:

1. Analgia, paralysis of the psychic system.
2. Anæsthesia, cessation of reflex action.
3. Paralysis of the medulla, arrest of respiration.
4. Paralysis of the nerve cells of the heart, syncope, death.

IV.

We come now to the most important part of the matter, which is to know *how people die of chloroform.* I usually tell my pupils in the lesson I give them on the subject, "I am going to show you how to kill your patient by chloroform."

It is also important for you to know how your patients can be killed by chloroform, but to teach you I must enter into certain physiological details. One regrets to be obliged to say that, in spite of their knowledge, of their care, of the very natural fear they have of chloroform, surgeons still have to record fatal accidents during anæsthesia.

How do people die of chloroform? I am telling you once for all, so that no doubt may remain in any one of your minds: *chloroform kills through the heart.* That is an absolutely certain fact. Never does death occur otherwise than through the heart. One dies only when the heart is dead.

You will see at once the practical conclusion to be drawn from this fact. You must watch over the pulse with persistent, I should almost say anxious attention, because the state of the pulse reveals the state of the heart. As long as the pulse beats with strength and regularity, there is nothing to fear.

It is necessary to insist on this, because many surgeons think, or at any rate used to think, that death under chloroform was due to defective respiration—that is, to asphyxia. There could be no greater mistake than this, for nobody ever dies of asphyxia under chloroform.

Death by asphyxia and death by chloroform-poisoning are absolutely different things. It takes three, four, or five minutes to kill a person by asphyxia. It takes three, four, or five seconds to kill a person by arresting the heart's action under chloroform. The stoppage is sudden, unexpected, instantaneous. All at once the face pales and the pulse stops. The heart has ceased to beat and life is suspended—for ever, unfortunately. After a failure of a quarter of a minute little hope remains of restoring the contractions of the heart.

When, on the other hand, breathing stops, which it may do while chloroform is being inhaled, it can be rapidly re-established by artificial respiration, by compressing the thorax, by placing the patient's head down, and by drawing the tongue outwards and downwards. On the score of the breathing there is nothing to fear. After it stops, you have three or four minutes before you in which to resort to artificial respiration, and so long as the pulse beats you may be sure, absolutely sure, that the breathing will return. While, once the heart stops, rarely—so rarely that we may say practically never—can you restore it.

Consequently, never flag in your solicitude for the heart. See that the pulse neither slackens nor weakens. Let somebody always be there to feel the pulse, to note the frequency and strength of its pulsations. *The heart must not give way.*

The breathing may be obstructed, oppressed. It is a minor matter. Even should there be a threatening of asphyxia, it is not dangerous. Or rather the danger is one that can be met. Stop inhalation. Pull the tongue forward with a pair of pincers, so that its root does not obstruct the air passages, place the head low, practise artificial respiration, and you will have avoided all risk of asphyxia.

But how does one avoid the acute poisoning of the heart? That is what I am now going to explain to you.

When a whiff of chloroform is inhaled, the heart receives that chloroform almost at once; because the blood of the lungs, the blood that reaches the heart through the pulmonary veins, is saturated with chloroform. The tension of chloroform vapour in air is greater than in the blood, and this difference of tension forces the chloroform into the blood, which accordingly reaches the heart over-rich in chloroform. Well, *too much must not arrive at a time*, for the heart's ganglia, the nerve cells directing the heart's contractions, are killed when a large amount of blood highly charged with chloroform suddenly arrives in the left ventricle by way of the pulmonary veins. At such a moment the tension of the chloroform in the cardiac blood is too high, and the heart cells are poisoned. There can be no longer question of the three successive stages which occur in the methodic and gradual administration of chloroform. The fourth stage (heart poisoning) is reached at the outset, and is immediately fatal.

Too great a quantity of chloroform will be introduced into the heart if the patient is made to breathe an atmosphere highly charged with chloroformic vapour.

I make an experiment before my pupils on a dog, which invariably succeeds, and results in death *after a* *single inhalation.* In this experiment the dog is made to breathe air very highly charged with chloroformic vapour, air released from a bottle of chloroform. The animal breathes through a tube placed in the trachea, and by a slight asphyxiation is compelled to draw a long breath. Immediately on drawing this single long breath he falls dead. Why? Because the heart has ceased beating. And the heart has ceased beating because blood very highly charged with chloroform has reached it through the pulmonary veins from the lungs, and has paralyzed the heart ganglia. The heart has ceased to beat, and no human power can restore its rhythmic contractility.

Therefore that dangerous method, which people have dared recommend in the past, and which is known as the method by sideration, should never be resorted to. It consists in at once administering to the patient a very large dose of chloroform. To gain time, a handkerchief soaked in chloroform is laid over the patient's mouth, and he is bidden to "breathe hard"! He breathes hard, and, absorbing an immense quantity of air charged with chloroform, falls inert, motionless. The heart stops, and he is dead. That was the method by sideration. The sideration was so complete that the patient died of it.

Chloroform should be given *gradually*, in small doses. Be deliberate, gentle, so that the system may get accustomed.

More than one apparatus has been invented for regulating the administration of chloroform. I am unable to go into details, important though they may be. I must content myself with giving you a few general hints.

Never give chloroform too quickly or in doses too strong to begin with, or you will make your patients run very serious risks. Of course, some may escape, but only because they are able to protect themselves instinctively against the inhaled poisons. Nature, often wiser than the imprudent doctor, provides defensive reflex movements which, as soon as the air becomes toxic and irritant, attenuate the respiratory powers, and so prevent immediate access to the lungs of a great quantity of intoxicating air, and consequently immediate access to the heart of blood overcharged with chloroform. Death, therefore, is not produced by respiration, but through the heart—that is, through the direct poisoning of the heart cells.

I call the poisoning direct, though there are authors who claim to see reflex action in it, insisting that the inhalation of chloroform determines the stoppage of the heart's action by reflex means (irritation of the air passages). You are aware that, as a matter of fact, there are nerves in the heart able to arrest its action (pneumogastric nerves). So they say: "Chloroform vapour sets up an irritation of the nerves of the periphery, of the larynx, of the face even, and this surface irritation is transmitted to the heart by way of the pneumogastric nerves. The heart then stops through the irritation of these nerves."

Now, such an explanation involves real error, because even direct irritation of the pneumogastric nerves cannot stop the heart long enough to cause death. The arrest of the heart by reflex action of the pneumogastric nerves is always temporary and never fatal.

To conclude, consider this a well-proved fact—and I have no intention of telling you anything but proved and certain facts—*death during chloroformic anæsthesia comes from the arrest of the heart's action, such arrest being due to chloroform-poisoning of the nerve ganglia of the heart.*

V.

This fact being established, I will point out one or two further precautions for you to take. As I am giving you the theory of anæsthetics, I must also mention a few practical matters.

To begin with, the chloroform should be pure. When shaken with a solution of nitrate of silver, it should not yield a white precipitate. A precipitate of chloride of silver formed in this manner indicates the presence of hydrochloric acid in the chloroform. Evaporated on white paper, chloroform should leave no trace.

For chloroform to keep well, without containing hydrochloric acid or other deleterious compounds of chlorine, it must be kept from the light in blue, brown, or black tinted bottles. Under the action of light it decomposes into poisonous chlor-oxy-carbonic products.

Besides these, certain other precautions are indispensable.

Vomiting is of frequent occurrence among patients under chloroform, the reason being that during the first period of cerebral unrest the medulla (the organ presiding over the movements of the stomach) is excited, and this abnormally exaggerated excitement causes nausea. There is no great harm in this. Vomiting is usual and all but unavoidable. All that need be done is to see that no vomited matter falls back into the air passages, where it might cause asphyxia.

It is essential that the air passages should be kept free. I told you just now that death under chloroform is not due to defective breathing. This is true. Still, the breathing must be watched and the orifices of the air channels, the nose and mouth, must not be obstructed by a bandage, a sheet, or anything similar. A patient under anæsthetics must at all costs breathe freely. The air passages must be absolutely clear, because the muscular power of the respiratory organs—especially for expiration—is greatly diminished by the chloroformic poison.

You should also see to the reaction of the eyes. The pupil should remain narrow. When it dilates, there is danger of asphyxia. The tongue should be pink, not purple, livid, or bluish. The face should not be pale. In a word, you should pay the most assiduous attention to the proper functioning of all the organs.

But, above all, it is the heart that needs continual interrogation. And not during anæsthesia only, but also afterwards.

Chloroform may provoke accidents at the time or later, according to circumstances. Sometimes the patient will reawake with difficulty. The heart is weak, and continues to weaken. Death then is the effect, not of an immediate failure, but of a delayed failure. Or perhaps the pulse continues to beat, but very feebly, threatening to stop every moment. In such circumstances, what ought to be done?

In the first place, inhalation must be suspended at once. The patient should be placed head downwards, so as to avoid the danger of cerebral anæmia. Above all, artificial respiration must be energetically applied, and if necessary a stimulation of the heart's action brought about by means of reflex excitement. This can be done in particular by flagellation, by massaging the limbs, by every means capable of strengthening arterial pressure. The tongue must be prevented from falling back on the air orifices, and its energetic traction resorted to. Inhalations of oxygen can be given, and in desperate cases injections of serum. These are all means of restoring strength to the heart, and, in secondary as in primary accidents, it is always the heart that runs the chief risk.

I have frequently made an experiment that proves how sensitive the heart is to chloroform-poisoning. By means of a long, fine needle, I introduce a drop, a single drop of chloroform into a dog's heart. Immediately, two or three seconds after the injection, the animal dies. The heart stops and reflex action ceases.

No death is more painless or more rapid.

If I refer to this classic experiment, it is only that you may all thoroughly understand that when administering chloroform your whole attention must be devoted to the patient's heart.

VI.

To avoid such accidents surgeons employ other anæsthetics besides chloroform: anæsthetics affecting the heart less seriously. It is with this object that they use ether (sulphuric ether, ethyl oxide).

This is a most volatile liquid, anæsthetic only in much larger doses than chloroform. As it does not poison the heart, except in extremely strong doses, it is less dangerous than chloroform.

The process of intoxication is very much the same. It begins with ebriety of an agreeable kind. Indeed, many people have contracted the regrettable habit of getting drunk on ether, just as other unfortunates get drunk on alcohol. In stronger doses ether suspends reflex action just as chloroform suspends it. And it is then that one can operate, the operating period being when the anæsthetic has suspended both intelligence and reflex action.

Ether has both drawbacks and advantages.

Its chief virtue as an anæsthetic is that its use offers hardly any danger of heart failure. Nor is there much to fear from secondary accidents to the heart and kidneys, such as occur twenty-four and even forty-eight hours after inhaling chloroform.

As to the disadvantages of ether, they are the following:

To begin with, it can be handled only with the greatest care. It is very inflammable. It forms an explosive mixture in contact with air, and, its gases being of very high tension, an uncorked bottle of ether will give off vapour that will travel a long way, keeping close to the ground, for it is very heavy. At a distance of three or four yards a lighted lamp or open grate will cause a conflagration. This danger must always be remembered, though it can naturally be avoided by keeping everything in the nature of fire out of the patient's neighbourhood. At any rate, anæsthesia by ether precludes the surgeon from employing thermo-cautery.

Another inconvenience of ether is that it predisposes the patient to hæmorrhage. While chloroform contracts the bloodvessels and gives little to fear from hæmorrhage, ether paralyzes the vasomotor nerves and always makes the flow of blood more abundant.

Other anæsthetics or mixtures of anæsthetics have been employed in surgery. They are numerous, and some are good enough, but scarcely any have been retained in practice, setting aside chloroform and ether, except ethyl chloride. This anæsthetic is used for lighter operations, and it has the advantage over chloroform and ether of being more volatile.

Now, volatility is a very valuable quality in an anæsthetic. The more volatile the gas, the more rapidly it is eliminated by the respiration. No doubt you know that after inhaling ether the breath remains for a long time tainted with the smell. This anæsthetic boils at the exact normal temperature of the blood—37° C. (98½° F.)—so that it can remain in the body only in the form of gas. Chloroform has a very high vapour tension at the temperature of the body, yet at that temperature it is still a liquid, and is eliminated, therefore, less quickly than ether. Ether, in its turn, is eliminated less quickly than ethyl chloride, which boils at 11° C. (52° F.), and which at the temperature of the body is a gas.

The more volatile a substance, the easier it is to eliminate. The toxic nature of an anæsthetic can almost be determined by the rapidity with which it can be eliminated—that is to say, by its volatility.

Now, there is a still more volatile anæsthetic substance than ethyl chloride: still more volatile because it is a gas that liquefies only at an extremely low temperature. I refer to that same nitrous oxide I mentioned to you at the beginning of my lecture. It is an excellent anæsthetic, commonly employed in dentistry, and might certainly be used in general surgery but for its requiring conditions that are very difficult to arrange. Nitrous oxide is not an anæsthetic at the ordinary barometric pressure; but if the patient is put in a room where the air pressure is ⅓ of an atmosphere higher than the normal barometric pressure, then nitrous oxide becomes an admirable anæsthetic. It causes no risks to the heart, and is eliminated as soon as the patient again breathes under normal pressure. Its ready elimination is easy to understand from its being a gas. The patient has only to breathe five or six times in ordinary air to be rid of all the nitrous oxide he has inhaled and passed into his blood. Unfortunately, the special conditions under which the anæsthetic acts require the use of complicated apparatus for compressing the air.

Surgeons also use gaseous mixtures of chloroform and ether, amylene, methyl chloride, methyl bromide. An enumeration of all the various substances scarcely concerns us, inasmuch as they interest the physiologist rather than the surgeon.

VII.

Having studied the substances that react on the nerve centres and abolish pain, we must go on to examine such as have much the same effect, but which, instead of acting on the organs destined to perceive the pain, act on the nerves that transmit it. If a nerve of sensation be cut, pain is no longer felt in the limb or portion of the body served by that nerve. Any locality sensitized by the nerve in question can be manipulated without causing the least sensation. The part has now become insensible. The feeling of pain is abolished.

Hence there are two ways of suppressing pain: *general* anæsthesia, which abolishes pain in the nerve centres; and *localized* anæsthesia, which deprives the transmitting nerve of its sensibility.

Cold used to be the chief means of obtaining the latter condition. If a finger is held in ice, or, better still, in a refrigerating mixture, so that the skin is blanched, the finger is so benumbed as to allow of any operation being performed on it without pain, even amputation.

In 1855 my father recommended the employment of ether as a local anæsthetic. Anæsthesia was obtained by the refrigeration of the ether. The ether no longer acted as ether, but as a substance that produced cold by evaporation. As a matter of fact, every volatile substance absorbs a certain amount of heat while evaporating, and so produces cold. By means of an india-rubber bulb arranged as a pulverizator, ether is sprayed over the part to be operated on, and cold sufficient to cause complete insensibility accompanies the evaporation of the liquid.

But this has been improved upon. In 1884 M. Kocher, a Swiss surgeon, discovered that certain substances were able in relatively weak doses to act upon and paralyze the nerve extremities.

The chief of these substances is cocain, the product of an American plant. It is an alkaloid, employed in the form of a hydrochloride, a salt very soluble in water. A subcutaneous injection of cocain hydrochloride paralyzes the sensitive extremities of the nerves.

The nerves of sensation terminate in the skin and in the tissues, not by filaments, but by little bulbs that are true nerve cells. The whole surface of the cutaneous envelope of the body is carpeted by these tiny and prodigiously sensitive cells, which the slightest touch can affect. Thanks to them, the entire human integument is capable of recording the smallest impressions from outside. The vibrations of these terminal nerve cells give rise to the sense of touch. Whenever the exciting cause is too severe, the feeling becomes one of pain. Now, cocain has the peculiar property of being able to poison and paralyze the terminal nerve cells.

I will give you a characteristic experiment which proves this. It is, I may add, the earliest from an historical point of view. You are aware of the exceedingly delicate susceptibility of the conjunctive nerve of the eye. The tiniest atom of coal-dust coming into contact with the membrane is enough to cause a sharp sense of pain. A few drops of a solution of cocain at 1 per cent. poured into the eye renders the eye perfectly insensible. It can then be touched without producing either feeling or reflex action, and without causing a tremor of the eyelids—in fact, without the patient having a notion of the contact.

And why? Because the conjunctive nerve cells have been poisoned, and all sensibility to contact has disappeared, as well as all reflex action of the eyelids. The reflex action (or blink) of the eye is due to the excitement of the cells of the periphery at the termination of the nerve of sensation—an excitement that is transmitted to the motor nerve of the eyelid.

By the use, then, of cocain paralysis of the nerve extremities has been effected. If touching the eye has no longer any result, if the eye's sensibility is abolished, it does not mean that we have acted on the nerve centres, as in the case of anæsthesia under chloroform, but that we have suspended the irritability of the nerve extremities.

In this same way, by means of cocain, which is a universal intoxicant of the sensitive nerve cells of the periphery, both skin and mucous membrane, as well as parts more remote, can be deprived of feeling.

For instance, there is no longer any necessity for employing chloroform in dental operations. A solution of cocain is injected in the neighbourhood of the diseased tooth, and the nerve extremities are instantaneously paralyzed. The tooth can then be extracted quite painlessly.

Cocain sometimes causes accidents, though these are not really alarming as long as the drug is used prudently, *in a not too highly concentrated solution.*

Solutions of cocain should not be stronger than 1 per cent., while no more than from 5 to 10 cubic centimetres (about $\frac{1}{3}$ to $\frac{2}{3}$ cubic inches) should be injected under the skin at a time. A more powerful dose may bring on cardiac disturbances.

You see, it is the same with cocain as with chloroform: the main, if not the sole, danger is the danger of poisoning the heart.

Many kindred chemical products have been proposed as substitutes for cocain proper. It shows considerable progress in the technique of chemistry to have succeeded in combining ecgonin, the root of cocain, with groups containing methyl, ethyl, and benzoyl, to form a new cocain. A few have found their way into surgical practice under such names as stovain, novocain, etc. I need not trouble you with a complete list of their somewhat arid nomenclature. You have only to remember that all these substances react on the nerve extremities, and are compounded from the same source as cocain.

Serious operations can be undertaken with all of them, the process being to paralyze the extremities of the nerves of sensation by subcutaneous injection of the region operated upon.

It was even suggested some years ago—the method has been abandoned since, and I think justifiably—to inject solutions of cocain into the bony canal enclosing the spinal marrow. Such injections—termed "inter-rachidian injections"—insensibilize, not the brain, but the sensitive cells of the marrow by immediate contact with the nerve cells of the spine. When saturated with cocain solution, the cells of the marrow quickly, one might almost say greedily, absorb the poison. It attaches itself to their protoplasm just as a skein of thread dipped in colouring matter retains the colour held in solution by the liquid. No doubt it is in this way that cocain introduced into the cerebro-rachidian canal insensibilizes the spinal marrow.

Cocain acts on the nerve elements transmitting sensibility, not on the central, conscious organ of the brain. It paralyzes sensibility by preventing the vibration of the nerve cells of the periphery from reaching the brain, where the sensation of pain is perceived.

VIII.

Besides the foregoing general and local anæsthetics, there are other substances deserving of mention which, without absolutely deadening sensibility, so reduce it as practically to abolish pain. In moderate doses they are sedative or merely soothing; in stronger doses they are active agents of analgia.

Among these substances is one which perhaps, from this point of view, is the most beneficent of all the drugs used in medicine: I mean morphia.

Morphia is an alkaloid extracted from the poppy, and is the active part of opium. It has the wonderful gift of assuaging pain—all pain. It does not act on the nerve extremities, but on the nerve centres, rendering them less sensitive to painful vibrations. It is enough to have suffered during long, miserable hours to realize the inestimable benefits of morphia, which relieves the pain at once. It is enough to have experienced the anguish of insomnia to appreciate the sweetness of morphia sleep.

Morphia induces sleep for two reasons. In the first place, it is in itself an hypnotic agent; and secondly it is analgic, possessing the power of stilling pain.

I think we shall do well in this time of war to imitate the English surgeons, who in this awful struggle in which we are both actors and witnesses are in the habit of administering an injection of morphia to every wounded man brought in, quite indiscriminately, as soon as possible after the wound, and without so much as waiting to examine it, their first thought being to alleviate the suffering of the injured men.

But though morphia produces analgia, it is not an anæsthetic. It neither suppresses sensibility to touch nor reflex action. Not being a gas, it has the disadvantage of all non-volatile substances, in that it remains in the organism and is eliminated very slowly. Its effect begins immediately on injection, and lasts for some time. Twenty-four to forty-eight hours after injection elimination is not yet complete.

IX.

We derive from all these facts a few fundamental, elementary lessons.

1. Sensibility can be abolished by acting either on the nerve centres perceiving pain (general anæsthesia), or on the nerves transmitting painful sensations (local anæsthesia).

2. Among ordinary analgic agents, the two most important are chloroform and ether. Both act on the nerve cells, following a hierarchical system of precedence which never varies. They first paralyze the psychic centres (mind, consciousness, memory), then the spinal marrow centres (suspension of reflex action), then the subarachnoid space or medulla oblongata (respiration), and lastly the nerve ganglia of the heart.

3. Death under chloroform is usually, if not invari-

ably, due to heart poisoning (by a sudden rush to the heart of blood overrich in chloroform).

4. The principal agent of localized anæsthesia is cocain hydrochloride. It paralyzes the sensitive extremities of the nerves, and, when (as it occasionally is) introduced into the spinal canal, the nerves of sensation in the marrow.

5. The salts of morphia (likewise laudanum and opium) do not produce unconsciousness, but different degrees of analgia—that is to say, they assuage and annihilate pain.

III.

FOODS

I.

I PROPOSE giving you to-day a few elementary ideas on the value of the different foods, and a rapid summary of what physiologists have discovered and declared essential to the alimentation of the body. The ideas I am laying before you are all the more useful in that they are in the first place positive, incontestable, and uncontested—I will mention only facts which leave no possibility of doubt—and again because no other question, perhaps, has given rise to so many errors and so many ineradicable prejudices as the physiology of food. Some of the opinions you may hear in the course of my statement will most probably appear heretical, or at least strongly opposed to popularly accepted notions. I repeat, many are the errors current as to the relative value of the various foodstuffs.

At the outset it will be as well to define food, and the definition presents, as usual, a difficulty, in that the oxygen which supports organic combustion enters the body through the respiratory system, and cannot be classed as an aliment.

We will take food as comprising all substances *introduced through the alimentary canal, and which cooperate in the nutrition of the tissues.*

It is imperative that I should give you here a few general principles of physiology to show you what you are to understand by the word "nutrition."

Nutrition establishes a fundamental distinction between animate and inanimate objects. A stone is not nourished. It remains always what it was originally, and its substance undergoes no chemical change. Animate objects, on the contrary, without exception, undergo incessant chemical renewal. They are for ever in a condition of chemical instability, and this instability is the characteristic of life. Everything that lives, plant or animal, is in a continual state of chemical flux, of interchange between the living thing and its surroundings: respiratory changes, alimentary changes. In the interior of the cell or *protoplasm* (the essential part of every living thing) molecular and chemical phenomena cease only with life itself. Cellular protoplasm undergoes unceasing chemical transformation: and as the organism is built up of cells, the organism's nutrition is made up of the sum of all the transformations undergone by each individual cell.

Now, if chemical change is continual, there must be wastage. The chemical substances that are in constant conflict one with the other, and which end by forming such products as carbonic acid and urea, are eventually used up, and must be replaced. It is this replenishing of the substances composing the cell that we call alimentation. We need to renew our cells continually because they are being continually used up. Nutrition is chemical change, alimentation the rebuilding of the chemical components of the cells.

So you see that the definition of food is simple enough, after all. Food is the substance that repairs the incessant wear and tear of the cells.

We term "food" those substances that are destined to build up the tissue of our cells.

Now, the essential component of every living cell is a particular chemical substance existing in a multiplicity of forms, called *albumin.* All compounds of albumin have the remarkable quality of being in a continual state of instability and self-renewal. Their instability makes them feel every shock and movement of the outside world, and be perpetually affected and modified by it. Our sensibility is owing to our chemical instability. The irritability of the nerve cells is due to the chemical changes in the albuminous molecule.

The albuminous matters composing the cells are used up by the very fact of their perpetual chemical change or nutrition, and albuminous substances are therefore required to nourish the cell and keep it alive.

Thus we may define life as *the consumption of albumin by the cells.*

II.

Albumin—white of egg—furnishes the type of all albuminous compounds.

These compounds contain carbon, hydrogen, oxygen, and nitrogen, also a small quantity of sulphur. They are designated sometimes as *nitrogenous* compounds. They are also known as *proteins*, from their acquiring different chemical properties under various chemical reactions. They are protean, proteiform.

Each living thing has need of a certain quantity of nitrogenous matter to compensate for the loss of albumin in the tissues. Each living thing, therefore, stands in need of some form of albumin in its aliment.

To give you a clear idea of this, I will at once tell you that the quantity of albuminous matter required by an adult man for his nutrition is 100 grammes a day (about 3½ ounces avdp.). So one of the essential conditions for the nourishment of a human being—that is to say, for the upkeep and renewal of his cells—is the consumption of 100 grammes of albumin a day.

We shall see presently that 100 grammes a day of nitrogenous matter is an insufficient aliment. It is merely an indispensable minimum.

The exact forms in which albuminous matters are absorbed into the system are unimportant. Once they have come under the action of the digestive juices, of the gastric juice, of the pancreatic juice, and the intestinal juice, they are all alike transformed into a substance called *peptone;* and this peptone, when worked upon by the cell chemistry, the molecular reconstruction that takes place in all the cells of the organism, is transformed in turn into urea, which is eliminated in solution by the urine.

Thus the albumin absorbed into the system becomes peptone, and peptone is transformed by nutrition into urea.

These, stated with exactitude, if perhaps a little crudely, are the changes albuminous matter goes through in the organism, and it is this matter that constitutes the most essential, if not the principal, food of each living thing.

III.

Animals of all species are obliged to move about, and must accordingly develop energy. Warm-blooded animals—that is to say, mammals and birds—must, moreover, produce heat.

Besides the nitrogenous food that repairs the waste of his tissues, man requires, therefore, certain other foods furnishing him with heat and muscular power to admit of his maintaining on the one hand a higher temperature than that of the atmosphere in which he lives, and on the other to do mechanical work.

Now, heat and mechanical work are different manifestations of the same force. A particular quantity of heat can be converted into its equivalent in mechanical energy. To lift 1 kilogramme 425 metres (2 pounds 3¼ ounces avdp. 465 yards), or, which is the same thing, to lift 425 kilogrammes 1 metre—that is to say (in one case as in the other), to produce 425 kilogramme-metres*—consumes 1 calorie.

A "calorie" is the amount of heat, otherwise energy, required to raise 1 kilogramme of water 1° C. (1·8° F.), so that in order to raise 1 kilogramme of water at a temperature of 35° C. to a temperature of 36° C., 1 calorie must be applied to the mass of the liquid.

We must consequently arrange to have a sufficient amount of calories in our alimentation. There must be heat enough to maintain the high level of our temperature, and energy enough to permit of our accomplishing systematically certain tasks of external mechanical labour (locomotion and muscular force). The power required is always calculated in calories, because we know that one calorie furnishes 425 kilogramme-metres, and that a demand for a certain number of kilogramme-metres is equivalent to a demand for a certain number of calories.

Let us not forget this. Each living, moving, working being with a temperature higher than that of the surrounding air requires a definite number of calories to enable him (1) to produce heat, and (2) to do work.

* 3,066·8 foot-pounds avoirdupois.

From this it results that if we give the organism, first, a sufficient quantity of nitrogenous matter to meet the expenditure of its cells, and, secondly, the proper number of calories to maintain heat and energy, we provide it with a complete food, one that is both suitable and sufficient.

With the aid of experiment, observation, and much clever analysis, the number of calories required by man has been ascertained. It is something between 2,500 and 3,500 calories. An adult man in cold surroundings needs 3,500 calories, whereas the same individual in warm surroundings needs only 2,500 calories. And besides, the greater the physical exertion and the more the work done, the larger the quantity of food required.

According to the temperature of the air and the energy expended, the number of calories required by man varies from 2,400 to 4,000.

Summer, at rest	2,400
Summer, at work	3,000
Winter, at rest	3,000
Winter, at work	4,000

You are, of course, aware that we need not eat so much in hot weather as in times of great cold. Food being required partly to maintain our animal heat, this can only be because we have less heat to maintain in summer than in winter.

I suppose you have understood by now that the two fundamental necessities of the organism are 100 grammes of nitrogenous matter on the one hand and 2,500 calories on the other. All foods fulfilling these two essential conditions afford a complete and sufficient alimentation.

When we come to examine the different foods, we will be able to judge how to frame a strictly correct food ration—that is to say, bearing in mind the chemical composition of the various usual foods, how the two fundamental conditions I have just mentioned can be arrived at in practice.

For this we must first know the calorimetric value of the different foods.

Albuminous substances	yield	4	calories	to the	gramme.
Carbohydrates	,,	4	,,	,,	,,
Fats	,,	9	,,	,,	,,

Carbohydrates are bodies of which starch is the type. Starch, when introduced into the organism, is converted by the digestive juices into sugar. Starches, sugars, farinaceous compounds, all of which are destitute of nitrogen, are carbohydrates.

All the carbohydrates, whether the starch they contain comes from potatoes, rice, maize, or wheat, are alike converted in the digestive canal into sugar, just as albuminous matters are converted into peptones. The sugars produce, by their combustion, carbonic acid and water, just as the peptones that serve to rebuild the cells are reduced to urea.

The fats or fatty substances we assimilate, and which are chemically composed of carbon, oxygen, and hydrogen, are converted by the blood's alkalinity into soaps—that is to say, bodies composed of fatty acids combined with the soda in the blood.

Thus, by the action of the digestive juices, the albumins become peptones, the carbohydrates become sugars, and the fats become soaps. The peptones, sugars, and soaps, all these different products, are burnt and oxidized in the organism, transformed by the unceasing chemical renewal of the cells, and finally produce—the peptones, urea; the sugars and soaps, carbonic acid and water. Their combustion further gives rise to heat, which can be reckoned in calories, and these calories must be of sufficient quantity to maintain the organism at a proper temperature—generally speaking, higher than that of the surrounding air.

IV.

We will take the essential foods one after the other, and see what proportions they contain of albumins, carbohydrates, and fats. These important points well understood, we shall deduce from them the quantities of various foodstuffs required to constitute a normal food ration.

Our chief food is bread. We will leave the precise composition of wheat flour on one side, and merely remember—what will be fairly exact—that 50 grammes of flour yield 100 grammes of bread. We shall be very near the mark if we say that 1 kilogramme of bread contains 500 grammes of flour and 500 grammes of water.*

Bread contains every alimentary substance required for the support of life.

In the first place it contains albumin: a vegetable albumin, be it understood, called gluten—100 grammes of bread contain 7 grammes of it. But, above all, it contains carbohydrates, the starch or fecula which becomes sugar in the course of digestion. Bread contains in round numbers 50 per cent. of carbohydrates. The remainder is water and a few salts.

You may now estimate for yourselves—I will make the calculation before you—how much bread every

* 1 kilogramme = 1,000 grammes = 2·2 pounds avoirdupois.

person would have to eat if there was no other food available. Knowing the chemical composition of bread, we can get at the number of calories and nitrogenous matter disposable.

We saw just now that every adult man requires 100 grammes of albuminous matters in the day. Well, a kilogramme of bread furnishes him with only 70 grammes of albumins, a quantity that is insufficient. One and a half kilogrammes of bread will provide him with 105 grammes of nitrogenous matter, which is enough. Eating only bread, therefore, and to have a sufficient amount of nitrogenous matter in his food, a man would have to consume at least 1,500 grammes a day.

To determine the number of calories available from bread, we start from the assumption that 1 gramme (15·432 troy grains) of carbohydrate gives 4 calories, and that 1 gramme of albuminous matter equally yields 4 calories. Assuming that bread contains 50 per cent. of carbohydrates and 7 per cent. of albumins, we arrive at a yield from 1 kilogramme of bread of about 2,400 calories, and from 1½ kilogrammes of bread of about 3,600, a quantity more than amply sufficient.

What are we to infer from these figures?

That one can live by eating nothing more than 1,500 grammes of bread a day.

In reality we do not consume so much bread in the day. Statistics show that a Parisian eats on the average 550 grammes a day, so he is obliged to look to other and different foods to supply him with the supplementary energies needed from calories and albuminous matters.

Let us pass on to other foods—to meat, for instance.

The alimentary properties of meat can be summed up in a few words. It contains no starchy matter. When the actual fat is removed it contains very little fatty substance. Meat consists merely of nitrogenous matter and water, in the proportion of 75 per cent. of water and 25 per cent. of albumin.

When you buy 1 kilogramme of meat at the butcher's, you are very likely not aware that you purchase 750 grammes of water, and only 250 grammes of nutritive, albuminous matter.

So it will be at once obvious to you that for his supply of nitrogen a man does not need a kilogramme (2·2 pounds avdp.) of meat a day, since 100 grammes of albuminous matter—that is, 400 grammes (3½ ounces avdp.) of meat—are enough to guarantee the nutrition of his cells.

But to supply the number of calories required for the support of his animal heat, a kilogramme of meat is wholly inadequate. Two hundred and fifty grammes of albuminous matters represent no more than 1,000 calories, whereas 2,500 calories are a minimum for an adult man. Were we, then, to rely exclusively on meat, we should have to eat 3 kilogrammes a day, that amount producing the number of calories that our organism requires to maintain a normal temperature of 37° C. (98½° F.).

In all times men have realized that they could not live on meat alone.

Many countries, especially in Asia, do not use meat at all. Even in Europe there are whole populations for whom it is an almost unknown form of nourishment.

A solely vegetable diet is called *vegetarianism.* And many people claim, not without some show of reason, that vegetarianism is an excellent mode of alimentation.

At the same time, a vegetable diet does not, as is commonly supposed, differ essentially from a meat diet. In reality, living creatures always stand in need of the same essential elements. Whether vegetable or animal, albumin is at all times very much the same substance chemically. Vegetarians take the albumin they need from vegetables instead of taking it from meat. That is all the difference, and the distinction is not fundamental.

Now, in certain cases, should meat be eaten raw rather than cooked? In the treatment of particular illnesses raw meat has indisputable advantages, but the advantages are not of an alimentary order. Cooking or not cooking meat has considerable importance from the point of view of the reconstruction of the organism. Raw meat is of great value to the tuberculous. But from the point of view of the nutrition, properly so called, it matters very little whether meat is cooked or not. Once introduced into the stomach, it is converted, cooked or uncooked, into almost identical substances, which finally resolve themselves first into peptone and then into urea. Its previous condition is of no very great importance. The result is the same. Raw or cooked, meat has an equal nutritive value.

And what shall we say about broth? I am afraid I must take up arms against an inveterate prejudice, according to which broth is a nourishing food. Really this is not so. Broth contains no nutritious principle whatever. All the albuminous substances in the meat have been coagulated by the boiling, leaving none in solution.

Once skimmed of grease, broth contains only colouring matter and aromatic substances, besides the salt added by the cook. I may mention, the better to persuade you of the worthlessness of broth as a food, that physiologists have proved by an incontrovertible argument that, however agreeable it is to the taste and stimulating to the appetite, broth contains no nutritive value. They have found that animals fed exclusively on broth die more quickly of hunger than those from which all food has been withheld.

You can understand this quite easily. Broth, being a stimulant to nutrition, is also a stimulant to denutrition, for it contains salts of potassium, which accelerate and increase chemical change. That is why an animal fed exclusively on broth dies of inanition quicker than one that has eaten nothing at all!

Get rid, therefore, of the very general error according to which broth has a notable food value.

To sum up: Meat affords an excellent aliment, though not one sufficient in itself. We should have to consume too much of it to obtain the number of calories necessary to our welfare.

V.

Farinaceous foods can be classed in two groups.

First there are those containing very little nitrogen, such as potatoes and rice. Potatoes contain a comparatively small quantity of nitrogenous matter, only 2 per cent.; but, on the other hand, they yield 20 per cent. of carbohydrates, thus furnishing a noteworthy number of calories.

Still how great is their inferiority to bread!

For a man to live on potatoes he would have to eat 5 kilogrammes (11 pounds avdp.) a day to obtain 100 grammes of nitrogenous matter.

One can, however, be quite well nourished on a diet of meat and potatoes—say on $2\frac{1}{2}$ kilogrammes of potatoes (2,000 calories) and 500 grammes of meat (500 calories). But $2\frac{1}{2}$ kilogrammes ($5\frac{1}{2}$ pounds avdp.) of potatoes constitute a large mass of food.

Yet this ration provides a sufficiency of calories and a liberal allowance of nitrogenous matter.

Rice contains only a feeble sum of nitrogenous matter (6 per cent.), but it yields 80 per cent. of starch. It makes an excellent food, and deserves to be much more generally used in Europe than it is.

Quite another group of farinaceous products has the advantage of yielding a large proportion both of albumin and starch. Wheat flour comes under this heading, and the meals of maize, oats, and rye. Relatively to their weight and small volume, this class is the richest of all in alimentary products, and if I wanted to describe the most nutritious food to be had at a low weight, I should say meal, especially that of peas, lentils, and beans. All of these contain as much as 60 per cent. of starch, and 30 per cent. of albuminous matter. They are free from everything but an infinitesimal quantity of water; and water only makes food heavy, to the detriment of its worth as a nourishment.

VI.

Another essential food, the composition of which demands our most careful consideration, is milk. Like flour (or seed), which is the food of the young plant, milk, the food of the young animal, is a perfect and complete nourishment.

To make it simpler for you to grasp the chemical composition of milk, I will give you a few well-considered figures, very easy to remember.

Milk, being a complete food, contains albuminous matter, carbohydrates, and fat. We will take it—the amounts are very close to the truth—that milk (I speak especially of cow's milk) contains 4 per cent. of each of these different substances—*i.e.*, 4 per cent. of albumin, 4 per cent. of carbohydrates or sugar—milk contains a special form of sugar called sugar of milk—and lastly, 4 per cent. of fat, or butter. Butter is the fat of milk.

From these figures it is easy to reckon how much milk a man would require a day, assuming that he takes nothing else. We will make the same calculation we made just now in the case of bread and meat. The exercise is worth repeating.

Let us bear in mind that a man needs daily 100 grammes of nitrogenous matter and 2,500 calories. One gramme of fat gives 9 calories, so we shall get, in 100 grammes of milk, 36 calories from the fat, 16 calories from the carbohydrates, and 16 calories from the albumins—in round numbers 70 calories, or 700 calories to the litre. Were milk, therefore, our sole food, it would take 4 litres (about 3½ imperial quarts) a day (2,800 calories) to supply our ration of heat.

Further, a litre of milk contains 40 grammes of albuminous matter, so that 2,500 grammes of milk would be enough to provide the 100 grammes of albumin that are indispensable. But as, in order to have the number of calories he requires, a man must take at least 4 litres of milk a day (2,800 calories), he would be introducing into the organism 160 grammes of nitrogenous matter, an amount which is larger than is necessary.

I do not insist on these various calculations. You must work them out for yourselves if you are to understand properly how to frame a food ration, starting from the fundamental principle that 2,500 calories and 100 grammes of nitrogenous matter are essential to the nourishment of the organism.

VII.

To get at a standard of ordinary food consumption for human beings, let us take that of the average Parisian adult. We will study the amount he usually consumes, and see whether we find in a ration consecrated by long habit the fateful figures established by the physiologists, the 100 grammes of nitrogenous matter, and the 2,500 to 3,000 calories.

It is true that the Parisian's ration is confused by his consuming a peculiar food which also yields heat, and which, though a food, is a very perfidious one. I speak of alcohol. Unfortunately, Parisians introduce a very great quantity of wine into their alimentation. It is proved that, owing to the alcohol it contains, wine oxidizes in the body, and accordingly develops heat. It is therefore of the nature of food, innocent enough when half a litre or so is drunk in the day (and when this is real wine, which is rare), but most dangerous when this quantity is exceeded.

But think of the terrible harm it causes! What wonderful progress would be made if its consumption could be restricted and the populace brought to believe that the dealer in drink is its worst enemy. Wine is not so bad, but alcohol! Nothing is more deleterious than the nauseous and poisonous beverages—absinthes, vermouth, brandy, and other pestilential liquors—the fate of which should be prohibition, total and immediate.

VIII.

To return to our Paris ration.

Bread, pastry (to bread we may add macaroni, vermicelli, and other farinaceous pastes): 550 grammes (1 pound 3 ounces avdp.).*

Meat: We may reckon on about 200 grammes of butchers' meat, but the amount must be increased by the addition of pork, ham, fish, fowl, and game, or, say, a total of 280 grammes ($9\frac{4}{5}$ ounces).

Milk: 125 grammes ($4\frac{2}{5}$ ounces).

Potatoes: about 10 grammes ($3\frac{1}{2}$ ounces).

Sugar: 45 grammes ($1\frac{1}{2}$ ounces).

Eggs: 35 grammes ($1\frac{1}{10}$ ounces).

Butter and oils: 40 grammes ($1\frac{2}{5}$ ounces).

Cheese: 25 grammes ($\frac{9}{10}$ ounce).

Lastly, a considerable quantity of fruit and vegetables: 600 grammes (about 1 pound 5 ounces).

I have not mentioned fruit and vegetables, and might almost pass them over in silence. They are of small service to nutrition. To be deprived of them would certainly be a great pity, but their alimentary value is slight.

If you consider their composition, you will see that melons, cherries, apricots, strawberries, as also green vegetables like cabbage, spinach and salads, contain very little nitrogenous matter, in some cases the quite negligible proportion of 4 per cent. If we were to suppose—I make the absurd supposition intentionally, so that you may realize how utterly poor some fruits are in the nitrogenous components of nutrition—that a man existed on nothing but apples, he would need to consume 30 kilogrammes (66 pounds avdp.) a day to be supplied with his necessary ration of albumin.

* 100 grammes = $3\frac{1}{2}$ ounces avoirdupois.

Owing to the overwhelming preponderance of water that exists in them, the other nutritive components are equally scarce in fruit. There is 5 per cent. of sugar, which is not much. Besides, analysis reveals the presence in fair abundance of another substance closely resembling sugar, but which has the drawback as a food for human beings of not provoking the action of man's digestive juices. It is called cellulose. Graminivorous animals and ruminants, which eat and digest grass, have an assimilative mechanism for dissolving cellulose, which our gastric and intestinal juices are powerless to attack. Man's system does not possess the special microbes which in the case of the horse, for instance, make the cellulose ferment, and cause it to be easily assimilable. Consequently, in man the cellulose from fruit and green vegetables passes through the digestive canal in an inert mass, and leaves it intact. It is without any sort of nutritive value.

We may conclude that, the sugar and starch in fruit and green vegetables being extremely small in quantity, these products have but the feeblest value as foods.

We eat still other things, such as fats, oil, and butter. While green vegetables stand for 1,000 grammes in a Parisian food ration, butter accounts for only 50 grammes.

Rice is not in great favour among the population of Paris. In our daily ration it stands for no more than 50 grammes. Its very limited use is to be regretted, as it is a cheap and healthy food.

Cheese, too, is an excellent food, rich in fat and albuminous matter. After peas and lentils, it is the aliment that contains the largest proportion of calorific energy and nitrogenous ingredients in the smallest volume.

It would take too long to work out in detail the sum total in calories and albumins of an average Parisian food ration, computed on the quantities absorbed. You will, I hope, take my word for it when I tell you that the foodstuffs we have examined yield the calories and nitrogenous substances that are required for the maintenance of human life.

But while the foregoing alimentary ration, which we have taken from a general average, is as a whole admirably composed, its components can be altered at will and with impunity. It is, as I say, an average, and obviously each individual has his own particular tastes in food. Nothing is easier or more permissible than to vary the quantities of the different aliments that we have been reviewing. Our physical constitution is so flexible that each one of us consumes this or that food in this or that quantity as we choose, always provided we conform in the result to the two fateful figures I so frequently name—*i.e.*, 100 grammes ($3\frac{1}{2}$ ounces avdp.) of nitrogenous matter and 2,500 calories. So long as we do not overload our digestions (for instance, by absorbing too much fat, a difficult substance to digest), and so long, too, as we give a preference to starchy materials over nitrogenous materials and oils in the matter of heat-giving foods, we shall arrive at a very satisfactory alimentation.

IX.

I will take the liberty now of throwing into a few apposite propositions the very rudimentary statement, claiming no more authority than a sketch, that I have put before you to-day. I shall be repeating what I have said already, but one must sometimes repeat things.

1. The life of the organism and the perpetual renewal of the living cells require a constant and definite supply of nitrogenous matter, a supply amounting in the case of man to 100 grammes ($3\frac{1}{2}$ ounces avdp.) every twenty-four hours. Under penalty of dying of hunger, we must introduce 100 grammes of nitrogenous matter into the alimentary canal every twenty-four hours.

2. To provide the muscular energy dependent on the consumption of sugar in the organism, a certain quantity of starchy matter (or, what comes to the same thing, sugar) is required, and all the more so as muscular work is increased (labour ration). Whether in order to provide for the oxidization of the tissues (cells), for muscular exertion, or for maintaining our temperature at a level normally higher than that of the atmosphere, it is incumbent on us to develop at least 2,500 calories—3,500 for a man at work in winter, and 2,500 for one at rest in summer.

3. We may vary our different foods, and, provided the digestion is not interfered with, these rations will give the same result. That is to say, the fundamental quantity of essential food is the same in whatever shape we take it, and provided (be it well understood) that our digestive juices are able to assimilate it.

When you have leisure at home, you should take the figures I have given you and draw up different bills of fare, each providing in the food set down the number of calories and quantity of nitrogenous matters required per day to maintain life. I am sure you will have the curiosity to look for (and find) in your own home fare, the figures given by the physiologists.

The human body as a whole can be likened roughly to a steam-engine burning coal. To repair the wear and tear of fire-bars and furnace, 100 grammes of nitrogenous substances are required. To provide for combustion—that is, to yield heat and energy—you want 250 grammes ($8\frac{3}{4}$ ounces avdp.) of coal. These will be supplied you by 625 grammes (1 pound 6 ounces avdp.) of starchy food.

IV

HÆMORRHAGE

My subject to-day is hæmorrhage, and I propose treating it neither from the point of view of surgery nor of medicine—for one should know one's limitations—but from that of physiology. It is as a physiologist that I will go with you into the causes, phenomena, symptoms, and treatment of hæmorrhage.

But first I must give you a few general ideas in rudimentary physiology.

Hæmorrhage is loss of blood. And it is necessary to know the use, otherwise the function, of blood.

You are all aware that the blood serves to maintain life in the tissues by transporting to each cell the oxygen of which it stands in peremptory and unceasing need. To effect this an immense number of tiny red corpuscles of seven-thousandths of a millimetre* in diameter circulate in the blood, which, in virtue of their particular chemical composition, have the remarkable property of absorbing oxygen. When, in the lungs, the blood comes in contact with atmospheric air containing oxygen, a process of chemical combination occurs. A portion of the oxygen of the air unites with the corpuscles, while a part of the carbonic acid which was dissolved in the blood quits the blood, and is diffused in the air contained in the lungs, to be afterwards driven out by

* 1,000 to the metre of 39·37 inches.

expiration. This phenomenon is known as the "respiratory exchange." The blood absorbs oxygen from the air and returns carbonic acid.

The function of the blood, therefore, is twofold. It has to rid the tissues of carbonic acid (a waste product), and, more important still, to carry oxygen to the cells of the body.

When there is no oxygen in contact with the living cells they die. The cells, as Pasteur told us, are aerobic, which means that they have need of oxygen (or vital air) to live.

On a final analysis, asphyxia and loss of blood come to much the same thing. In asphyxia blood still circulates in abundance in the arteries, but no longer contains oxygen. After mortal hæmorrhage there is no longer enough blood—that is to say, the corpuscles are not numerous enough to carry sufficient oxygen to the cells. In each case it is the deprivation of oxygen that determines the death of the cells, either by asphyxiation or anæmia.

The blood has yet another function, less urgent than that of furnishing the cells with oxygen. The blood brings the tissues their nutritive elements. When, however, the animal (or cell) dies of hæmorrhage, the cell does not succumb to the absence of the chemical substances required to prolong life, but solely to the absence of oxygen; for nutrition by nitrogen and carbon is not the most pressing demand of the cells. The demand for oxygen is immediate, and that of other nutritive substances merely secondary.

Coagulation is the earliest phenomenon in the death of the blood. As you know, blood is liquid during life. It circulates in the bloodvessels without any sort of interruption or coagulation even in the smallest capillary veins. But once out of the veins, a very remarkable change takes place, and one that is still very mysterious, notwithstanding all the attempts that have been made to ascertain its cause. The blood coagulates.

The phenomenon appears after varying periods: In the case of man in from six to seven minutes; in the case of some animals, notably the rat and squirrel, at once, in a few seconds; in that of the greater number of birds and mammals in about the same time as in man, or perhaps a little sooner. The exception is the horse. By a singular anomaly the blood of the horse takes a long time coagulating. In a test-tube it will not coagulate for three, four, or five hours.

The blood does not owe this property of coagulating to the red corpuscles. The blood of animals not containing red corpuscles also coagulates, from which it may be inferred that coagulation is a property common to all bloods, whether to the red blood of vertebrates or the white blood of invertebrates.

So now you can yourselves set about discovering the final cause of this property. And you will find it. It is a good thing in physiology to look for the ultimate reasons of phenomena, if only to use the so-called explanations as *memoria technica.* If the blood coagulates, it is in order to stop hæmorrhage. The clot* that is formed plugs the little wound, and prevents hæmorrhage from continuing.

There are children born with a certain malady of the blood, which may be hereditary, called hæmophilia (a word derived from the Greek signifying "the love of blood"). It is an unsatisfactory sort of word, but one consecrated by long usage. The blood of individuals

* Do not use the term "clot of blood." Every clot is a clot of blood.

suffering from this weakness is incapable of coagulation. They scarcely ever reach advanced age, because from childhood the slightest wound that breaks the skin of such individuals has caused a hæmorrhage nothing could stop. Some have been known to die of uncontrollable hæmorrhage after a single puncture by a leech.

The normal condition of blood, therefore, is to coagulate. Though why it coagulates is what we must find out, the matter being interesting both from the point of view of physiology, and from that of therapeutics.

Instead of the fluid it was, the blood in a few minutes becomes muddy, viscous, after which it separates into two portions, named the *clot* and the *serum*. Blood is composed in its liquid state of a *plasma*, in which float red and white corpuscles. At the moment of coagulation the blood separates into two layers, one quite liquid that rises to the top and is the serum; the other, composed of red corpuscles and fibrin, which stiffens into a jelly, and is the clot.

No red corpuscles remain in the serum. After coagulation the serum is limpid and slightly yellow, while the clot is very red. The corpuscles forming the red portion of the blood have been held imprisoned in the meshes of the fibrin.

We are able to give, therefore, I will not say an explanation of the phenomenon, but at least its mechanism. Let us imagine a substance (fibrin) appearing in the blood. This fibrin forms a sort of net when precipitating, in which it collects the red corpuscles, and the result is a *fibrino-corpuscular clot*.

If we pour a little liquid blood into a test-tube, we see after a few minutes that its appearance has altogether changed. The red corpuscles have, owing to their density, settled at the bottom of the tube. Above them is a layer of white corpuscles. Fibrin forms more slowly. Finally, on the surface is a layer of serum. All these phenomena are very clearly observed in the blood of a horse, where coagulation is slow.

In the case of the blood of other animals the different layers are not given time to deposit separately. The fibrin in precipitating carries with it the red and white corpuscles, so that instead of four successive layers we have only two—viz., a solid mass below, which is the clot, and a layer of liquid floating on the top, which is the serum.

The problem of the blood's coagulation has at all times excited the curiosity and genius of physiology. For a long while only negative solutions were arrived at. It was proved that neither temperature, nor oxygen, nor pressure, nor atmospheric dust, had any influence in the matter.

The sole factor playing a predominant rôle—a fact quite well established to-day—is the chemical activity of the leucocytes, or white corpuscles of the blood. The white corpuscles, which in normal conditions, and so long as they remain in contact with the epithelial wall of the bloodvessels, secrete nothing, become irritated when separated from it. Then they all at once secrete a substance that precipitates fibrin—*i.e.*, the fibrin solidifies under the influence of the ferment secreted by the white corpuscles.

We can consider the white corpuscles as tiny creatures independent of ourselves, which, while the blood is in circulation, explore the walls of the bloodvessels unceasingly in order to make sure that they are in order. As long as the walls are normal, they are satisfied. But if they chance to find one that is abnormal and out of order, they immediately secrete a special fermenting agent which brings about coagulation.

The fact has been all but proved by a pretty experiment. Coat a vase internally with paraffin, so that contact is prevented between blood and the sides of the vase; for, as paraffin will not mix with water, it emits a vapour which interposes between the blood and the receptacle. In this paraffined vessel blood coagulates very slowly, but if something be dropped into the vase we may see the blood immediately coagulating round the foreign body.

Here is another proof. Take a big vein full of blood, and tie it in two places without introducing any foreign body into its cavity. The blood it contains will remain liquid for an indefinite period. Directly, however, the vessel is punctured, the blood, liquid till then, will flow out and coagulate, the reason being that, having come in contact with other substances than the vascular walls of the vessel, the white corpuscles have secreted the substance that coagulates the fibrin.

The coagulation of the blood is due, therefore, to the activity of the white corpuscles.

Many other experiments have been made relating to the coagulation of the blood. They are obscure and contradictory, and their consideration would take us into the domain of somewhat complex physiological problems.

I will limit myself to telling you that there are substances that have the property of hastening coagulation, and others which retard and even prevent it.

Among the former I will mention the salts of calcium. Gelatin, which is often injected in order to hasten coagulation, probably acts through the salts of calcium it contains. All the soluble salts of lime, calcium chloride, acetate, lactate, nitrate, accelerate coagulation. Arthus has proved that coagulation cannot take place if the blood (which in its normal state contains salts of calcium) is treated with substances like the soluble sodium fluorides, oxalates or stearates, which in the presence of these salts of calcium form insoluble precipitates of calcium fluorides, oxalates, or stearates.

On the other hand are substances which prevent the blood from coagulating. Among them is a singular one. I mention it to you as a physiological curiosity, for it is of no therapeutic value whatsoever. It is an extract of leeches' heads. The blood sucked by a leech remains in the creature's digestive tube for an indefinite period in a liquid state, owing to the leech's salivary glands secreting a ferment which prevents the blood from coagulating. The extract of leeches' heads contains this ferment.

Another substance having the same power is peptone. Whenever physiologists desire to keep blood in a state of liquefaction for a long period in a glass or indiarubber tube, as is sometimes necessary in the case of experiments on arterial pressure, they inject 1* or 2 grammes of peptone per kilogramme into the blood. This prevents coagulation.

We have now to consider the quantity of blood in the human organism, in order to learn the quantity a man can lose without jeopardizing his life.

A number of experiments have been made with this object on different species of animals. Here is a description of the highly ingenious processes used to ascertain the quantity of blood that circulates in the body.

A precise quantity of some known substance easily

* 15·432 troy grains.

discerned and measured in the blood is injected into a vein. At the end of a minute or two, when the substance injected is thoroughly well diffused in the mass of the blood, an exact quantity of the blood is drawn, and the proportion of the injected substance contained in it measured. This proportion enables us to calculate the whole quantity of blood circulating in the organism without further trouble. As an example, say we inject into a bloodvessel a gramme (15·432 troy grains) of potassium ferrocyanide, and that we find in 10 cubic centimetres ($\frac{16}{25}$ cubic inches) of the blood drawn 1 centigramme (·115 troy grain). Evidently, if the ferrocyanide was uniformly diffused, and if the 10 cubic centimetres of blood drawn contained 1 centigramme of it, there must be a hundred times 10 cubic centimetres, or 1 litre ($\frac{8}{9}$ imperial quart) of blood in the organism.

Another process, possibly more acccurate, consists in sacrificing an animal by hæmorrhage, and measuring the blood drawn. Only, all the blood is not drawn. A considerable amount remains in the tissues. A means (called "hydrotomy") for withdrawing all the liquid remaining in the body is then resorted to. A current of water is passed through the bloodvessels until the escaping fluid is quite colourless. The whole quantity of this fluid is then put together, and its colour determines approximately the degree of dilution of the blood that had remained in the veins, and was obtained by hydrotomy.

Thus, in one way or another the quantity of blood an organism contains can be measured with considerable exactitude. In the case of man the quantity is about 5 litres ($4\frac{4}{9}$ imperial quarts), or in weight (for a man of average size) 5 kilogrammes (11 pounds avdp.). The amount of blood in the body is taken at one-twelfth the whole weight, such being the classic figure, so that an animal weighing 12 kilogrammes has 1 kilogramme of blood. Man, weighing on an average 60 kilogrammes (132 pounds avdp.), has 5 kilogrammes (11 pounds avdp.) of blood.

But the allowance varies considerably according to species. Cold-blooded animals have proportionally less blood than the warm-blooded varieties by one-twentieth or one twenty-fourth.

Another thing every medical man ought to know is that the quantity of blood in the newly-born is only one-twentieth the weight of their bodies, and not one-twelfth, as in the case of adults. A newborn infant, a tiny baby, cannot afford to lose blood, because its organism has none too much to spare. Hæmorrhage must be very particularly avoided in its case, more especially by way of the umbilical cord at birth.

Now, how much blood can be drawn from an animal without causing death? It is hard to give an exact figure. In a general way it may be accepted that man, being more susceptible to hæmorrhage than many other animals, must not lose more than a third of his blood. At the same time, a third is a huge quantity. A continuous hæmorrhage of 1500 grammes (3 pounds 5 ounces avdp.) is most serious, and generally, though not invariably, mortal.

But exact figures cannot be given. The minimum quantity of blood compatible with existence may vary enormously according to the different physiological and pathological conditions of each case. So much, however, you must remember, because it is important that you should have a few principles on which to base your ideas. Man can lose about 30 per cent. of the total quantity of his blood without running grave danger—say about 1200 grammes ($1\frac{1}{5}$ imperial quarts).

I am speaking of continuous hæmorrhage. In the case of successive bleedings, much more blood can be spared.

Formerly, even as late as the beginning of the nineteenth century, doctors used to subject their patients to frequent and copious bleedings. Some bled the same patient three or four times a week, or even oftener. Cases are on record of persons who were bled 3,000 times in the course of their lives.

The quantity of blood taken in this way may be very considerable, the nourishing fluid recovering its bulk pretty quickly in the intervals of cupping. The flexibility of the organism is such as to allow the organs generating the blood corpuscles, the liver and perhaps the spleen in the case of the red corpuscles, and in that of the white corpuscles the lymphatic ganglia, to make good the losses in corpuscles caused by hæmorrhage very rapidly. The water in the muscles and tissues, and especially the water imbibed, furnishes the necessary liquid in such generous measure as to enable an individual who has lost 500 grammes* of blood to lose another 500 grammes after a few hours, as much again after twenty-four hours, and as much again next day. He certainly could not have stood a continuous hæmorrhage of such copiousness, but his blood was able to recoup its lost volume in the interval.

By replacing the blood lost with artificial serum, one can enable animals to stand the strain of a very profuse hæmorrhage. By injecting a horse serum the life of dogs has been maintained after a withdrawal of as much as 85 per cent. of their blood. The experiment can only

* Approximately 1 pint.

succeed if the hæmorrhage on the one hand and the transfusion of artificial serum on the other are both managed with the utmost care.

Hæmorrhage is arrested, then, by the coagulation of the blood, but it is also arrested by another admirable mechanism of Nature, the contraction of the walls of the arteries. In both the large and small arteries are several successive membranes; first a membrane composed of cells in which pass the nerves and veins which nourish the arterial walls; next a membrane of *muscular tissue;* and lastly a membrane of elastic fibres. These two last-named tissues, the muscular and elastic, are so devised as to contract and obliterate any small puncture that may be made in the artery.

Let us imagine an artery cut completely across. By the action of the elastic fibres, by the contraction also of its muscles, the two ends of the artery fly widely apart, and coming back on themselves close the orifices of the artery. The outpour of blood then ceases mechanically. It is curious to note that hæmorrhage is more easily stopped when the vein has been completely cut through than when only slit, for in the case of a partial cut the elasticity of the walls tends to enlarge the orifice of the wound, and to make it yawn wider, while if the cut is completely through, the two ends fly apart and blood stops flowing.

Why does hæmorrhage cause death? I told you just now that the main reason is want of oxygen; but, granting this, what particular elements and cells suffer from want of oxygen?

You may have heard that Bichat used to speak of the tripod of life, consisting, according to him, of the heart, the brain, and the lungs. Now is death in a case of hæmorrhage due to the heart, to the brain, or to the lungs?

Death is really due to the brain. That is to say, it is the nervous system which is the first to be affected by the deprivation of oxygen which follows the loss of blood.

Of all the multiple mechanism of the body, the nervous system is by far the most delicate. The nerve cells are the first to feel the effects of toxic action. It is they that stand most in need of oxygen. Directly they are deprived of it they die. Thus, after profuse hæmorrhage death is due to the brain's inability to withstand the loss of oxygen. The brain must have oxygen. It is resolutely aerobic, and dies as soon as deprived of the oxygen-bearing blood.

But oxygen is indispensable to all nerve cells, not only to those of the brain, but also to those of the heart. Whether it concerns the heart, the brain, or the medulla oblongata, the nerve cell is the element most sensitive to a privation of oxygen.

I must mention here a fundamental experiment to which I attach the greatest importance, and to which I invite your most particular attention. Were I to teach you nothing else than this in the course of my very rudimentary lecture, I should still have done you a real service.

If an animal—for instance, a rabbit—is placed in an upright position by attaching it to a board head upwards, the animal is found after ten minutes or a quarter of an hour, and after a few transient convulsions, to be dead. Death is due to its having been placed in a vertical position, in which it has succumbed to acute anæmia of the brain. This singular experiment proves that if the mechanical conditions of the circulation of the blood in the brain are sufficiently interfered with, the cerebral anæmia so produced is enough to cause death.

The same experiment can be made on a dog, though the experiment will fail on a dog in its normal state. A partial anæmia must first be brought about by drawing a considerable quantity of blood—33 per cent., a loss the animal can support without dying. If when weakened in this way by hæmorrhage, the dog is held in a vertical position, it dies after two or three minutes. If, again, a few seconds before death ensues, it is replaced in a horizontal position, it regains its senses and returns to life. The experiment may be renewed at will, and the dog killed again or brought to life again, according as the blood's circulation in the brain is aided or impeded.

The definite conclusion to be drawn from this experiment will be obvious to you. In the case of hæmorrhage, do not waste a moment. Do not try anything fanciful, far-fetched, or complicated. Employ the simplest method available at the moment. Place the patient, ill or wounded, head downwards. That is the one vital, easy, and essentially necessary thing to do. Later you will have recourse to other and more complex methods. But first get the circulation of blood to the brain into the most favourable conditions, so that the heart will not have to work against gravity when propelling oxygenated blood to the head arteries. The small quantity of blood remaining in the vessels may then be still enough to support some life in the brain cells that have such instant need of oxygen. Inasmuch as the downward inclination of the head is a position indispensable for allowing the blood to irrigate the brain easily, a wounded man who has lost much blood should be laid with his head quite low, in order that the small quantity of blood remaining to him may be utilized to the utmost. That is a basic law I cannot insist upon too much.

It is perfectly well established, then, that in the case of a profuse, rapid, and overwhelming hæmorrhage, death is determined by anæmia of the encephalic region (brain and medulla oblongata); that this anæmia of the brain reacts violently on the heart and provokes heart-failure, which heart-failure, by a sort of vicious circle, very much to be dreaded, further aggravates the cerebral anæmia to such an extent that to restore the much-needed blood to the brain becomes a matter of the most pressing urgency.

Death ensues in this way when large bloodvessels like the aorta or iliac artery are severed. Death takes place then immediately, without the possibility of intervention. But in many cases—for instance, when smaller bloodvessels than the aorta and iliac artery are concerned—a less copious hæmorrhage need not be fatal. The wounded man may have lost a great deal of blood, no doubt, but he at all events breathes, is alive, and there are hopes of saving him. In such circumstances as these let us see what symptoms should be watched for.

One, of course, you know. It is the pallor of the face and tissues. Very little blood can be circulating in a quite colourless skin. But there are other symptoms to be insisted on.

The chief one is an extreme muscular weakness, an asthenia, a general debility due to anæmia of the nervous system. The nervous system giving movement and elasticity to the muscles is, in fact, exhausted. The muscles are flaccid and powerless. The wounded man who has lost much blood remains stretched on the ground without power even to raise his head, so weak is he. All movement is, I will not say painful to him, but impossible. He has scarcely the strength left to speak or look about him. His weakness is intense, universal. At the same time a veil spreads before his eyes, which is ascribable to anæmia of the retina. He can hear nothing, understand nothing. He is, as it were, in a fog. Intelligence, the first function of the brain, has vanished with the oxygen that gave life to the cerebral cells. And not only is his intellectual impotence complete, but there is partial, and in some cases complete, delirium.

At times a very grave symptom appears—grave because it accelerates organic combustion, and therefore the using up of oxygen. It is not often noticeable in men, but frequently in animals that have been subjected to copious hæmorrhage. I speak of convulsions. There have been physiologists who considered convulsions to be the sign of mortal hæmorrhage. I think this is a mistake. Cases of hæmorrhage often end fatally without convulsions supervening, convulsions being the last spasmodic throes of the nerve centres imploring a more generous allowance of blood.

Such, very briefly stated, are the symptoms of hæmorrhage in serious cases. In less serious cases another symptom is invariably present, an intense thirst. The wounded on the field of battle have always the same cry, "Water!" They are thirsty because their blood has been deprived of water, and inasmuch as the centre of thirst perception in the nerve centres is particularly sensitive to a variation in the quantity of liquid circulating in the bloodvessels, a feeling of intense thirst is the result. The organism has need of the indispensable fluid that has been lost, and a feeling of thirst is provoked by the dehydration of the nerve centres.

Several less specific symptoms follow later. Among others are the suppression of the action of the kidneys and profuse sweats. They do not concern us here. We are not going into a detailed study of hæmorrhage, and a few rudimentary remarks must content us.

We will now consider the treatment of hæmorrhage for a few minutes.

I need not go back to the simple, universal measure which is always the first thing to be done, and which consists in laying the wounded man with his head low. Nor will I enlarge on the operations devised to attack the hæmorrhage at its root. Clever surgeons will do that for you far better than I can. It is indispensably necessary to bandage a bleeding wound, to stop the flow of blood, either by compressing the bloodvessel or by tying the arteries, in the wound or at a distance from it. The resources of surgery at your disposal are varied and numerous. I need not detail them.

When a wounded man has lost a large quantity of blood, there are three ways in which surgery interposes to remedy the effects of the hæmorrhage. They are—injections of serum, inhalations of oxygen, and transfusion of blood.

Injections of artificial serum into the veins are often efficacious, and, what is more, absolutely inoffensive. They are chiefly resorted to in the most urgent and desperate cases, when the strength of the organism is insufficient to allow of the water drunk and absorbed into the stomach to penetrate the circulation and replace the quantity of liquid lost by hæmorrhage. The surgeon must act quickly, for the wounded man is at the point of death.

Artificial serum is water distilled and sterilized in which are dissolved 7 grammes (108 grains troy) of sodium chloride to the litre ($\frac{8}{9}$ imperial quart). The ratio is taken at 7 grammes per thousand, because that is the exact proportion of sodium chloride in the blood, and is the ratio required to maintain the vitality of the corpuscles, or, as it is called, their state of *tonicity*. Should the proportion of sodium chloride be smaller, the hæmoglobin will desert the red corpuscles and diffuse itself in the plasma. On the other hand, should it be larger, the corpuscles will shrink, lose bulk, and be deprived of a portion of their water. The liquid must be therefore neither *hypertonic* nor *hypotonic*, but, as the physiologists say, *isotonic*, meaning of the same tonicity as the blood, because it contains the same proportion of sodium chloride as the blood.

After severe hæmorrhage the danger symptoms proclaiming death to be imminent, and requiring instant attention, are: disturbed breathing, a respiration which becomes deep, stertorous, and uneven, and more especially a serious weakening of the pulse; when this is irregular and hardly perceptible, it heralds impending syncope. Then do not hesitate a moment. An injection of artificial serum is needed at once. It is not yet fully understood why an artificial serum should possess the property of restoring vigour to the functions of the heart and nervous system, as it evidently cannot give back any oxygen to the blood. It returns water and sodium chloride, which, from the point of view of oxidation, is wholly insufficient. We are led to the conclusion that this water and sodium chloride act, not on the oxygenation, but on the blood-pressure in the arteries.

The liquid circulating in the arteries is, as a matter of fact, subjected to a pressure called "arterial pressure." If an artery is put into connection with a manometer, anyone can satisfy himself that under normal conditions the blood's pressure is equal to a column of mercury 16 centimetres (6·4 inches) in height. Now, after every severe hæmorrhage, owing to the loss of so much liquid, the pressure of the blood falls very low. An injection of serum into the blood-vessels raises it again, and this is enough to make the interchange of the gases an easier matter and to provoke organic combustion, a certain level of arterial pressure being indispensable to the oxygenation of the cells. We are therefore able to come to the rescue of the organism by means of an injection of artificial serum, or water containing sodium chloride, thus, so to speak, mechanically increasing the pressure of the blood in the arteries.

Then a most remarkable phenomenon takes place before our eyes. There is complete resurrection. The heart, which had been beating hesitatingly, weakly, with a pulse so syncopic and intermittent as to make one expect it to stop at any moment, suddenly regains strength under the influence of the injection. The pulse reasserts itself. The breathing, which had been stertorous, uneven, interrupted, becomes normal, and all the vital functions resume their usual course.

If, therefore, as may often be the case, a transfusion of blood is impossible, there must be no hesitation about making an injection of serum, though if, for some reason or other, this latter operation is likewise impracticable, then resort must be had to inhalations of oxygen, which are capable, though not to the extent that might have been expected, of augmenting the quantity of oxygen contained in the blood.

When we find ourselves in the presence of an individual suffering from violent hæmorrhage, and on the point of death through anæmic heart-failure, injections of artificial serum and inhalations of oxygen are our means of coming to his assistance.

But another very effective means exists by which, in desperate cases, a considerable number of wounded men have been saved from death. It is the transfusion of blood.

The history of the transfusion of blood is a singular one. You may have read how during the seventeenth century transfusion of blood was believed to be efficacious for the cure of people suffering from delirious frenzy. By injecting into their veins the blood of a gentle, inoffensive animal like a sheep, it was hoped to instil into them the animal's gentleness along with it. The illusion was a strange one. Far from curing these sick people of their frenzies, death often followed as the result of the operation; so much so that the Government was compelled to prohibit transfusion of blood by special edict. The dangerous practice had become too fashionable.

Since then the system has been again adopted in exceptional cases, and some excellent results have been recorded.

Remember this, however: No large quantity of the blood of any animal can be infused into a man's body with impunity. That the farther removed an animal is from the human species, the more the transfusion is likely to be hurtful. That the blood of reptiles and fishes is extremely toxic; the blood of birds fairly so; and that, lastly, the only blood wholly inoffensive to man is that of man himself. In order, therefore, to transfuse enough blood to make the operation effective, recourse should be had to human blood.

At the same time, the blood of animals is really noxious only when transfused with all its components, corpuscles and plasma. The blood of a horse in its entirety is toxic. But a serum made from it is relatively innocent. Fifty cubic centimetres ($3\frac{1}{8}$ cubic inches) of serum may be quite easily injected, whereas the transfusion of an equal quantity of blood in its natural state would be a really dangerous proceeding, owing to the corpuscles and the divers ferments they contain.

If, therefore, hæmorrhage is imperilling the life of a wounded man, there ought to be no hesitation as to the use of human blood for transfusion purposes. I need not tell you there will always be devoted people ready to sacrifice themselves for the wounded. I should be calumniating you were I to suggest that any one among you would hesitate to give the 200 to 300 grammes (7 to 11 ounces avdp.) of blood needed to save a dying man's life.

Practised in proper conditions, transfusion works veritable miracles. The life of the anæmic patient, which was fast ebbing away, takes a new turn. The heart all at once beats with renewed vigour. Breathing that was laboured, interrupted, and painful, becomes normal. There is a reawakening of the intelligence. In a word, there is *resurrection*. Nothing describes so well the change wrought by transfusion of blood in a person exhausted by violent hæmorrhage.

What is it, however, that we are to transfuse? Is it to be blood with its corpuscles or without them? Blood before coagulation or after it has coagulated?

If we beat up blood smartly with a glass rod, the fibrin agglomerates round the rod. The rest is whole blood less its fibrin. It is red because it retains its corpuscles, and it cannot coagulate because it has lost its fibrin.

Is it simply the serum of human blood that is to be injected, or a blood containing only serum and corpuscles, or the integrally complete blood with its fibrin? Surgical opinion is divided on the point. It may be preferable, perhaps, to pass the blood of the transfusor directly into the organism of the transfusee by bringing the artery of the transfusor and the vein of the transfusee together. But the operation requires considerable skill.

V

FEVER

My purpose to-day is to give you a few elementary conceptions of fever from the point of view of the physiologist, not of the physician. Indeed, it is well that a physiologist should have his say on the subject, exclusively medical though, at first sight, it may seem; for nobody can understand the laws of pathology without some knowledge at least of the laws of physiology.

I will not go into details of the nature, causes, and symptoms of the different fevers. It would involve a synopsis of medicine. Besides, I do not propose to deal with *fevers*, but with *fever*, which is something rather different. Fever, without any qualifications, can be studied by itself, and its phenomena, known in medical parlance as "febrile," may be examined. They are very much the same in all fevers.

I propose giving you an account of these febrile phenomena: first of the symptoms of fever, then, of its usual causes, and lastly, very cursorily, of its treatment. But do not imagine for a moment that I am going to discuss this fever or that fever, scarlet fever, typhoid fever, or tuberculous fever. Nothing of the kind. All we shall do is to consider the functional complications common to all these illnesses, which are known as fever.

To explain the precise nature of fever appears simple enough, but, as usual, when going to the root of things, difficulties crop up at every step. Nothing really is less easy to define than fever. Nevertheless, we will do our best to arrive at a definition. It may be an illusion on my part, but I doubt your finding the very simple things I propose explaining to you to-day in the regular textbooks.

Fever has three radical symptoms: (1) A state of general discomfort, of uneasiness, of suffering, which constitutes the feverish condition; (2) an acceleration of the pulse; (3) a rise in the temperature. Occasionally, in any one patient, one or other of these symptoms of general uneasiness, quickening of the pulse, and high temperature may be absent, or only slightly developed. But, generally speaking, all three are present, and when coexisting (in varying intensity) are the characteristics of fever.

Fever has undoubtedly other symptoms. I will touch briefly upon the many effects of a febrile condition later. But first of all I would call your attention to the three fundamental symptoms.

1. Discomfort and Delirium.—Feverishness—a discomfort you have all felt more or less, for it is impossible you should not have had fever—is due to change or disturbance in the nervous system. On this head I may tell you at once, definitely, so that this simple generality will serve you as a clue through the complications of fever, that fever is a *poisoning*. Feverishness appears when poison or poisons have entered into the blood.

The nervous system, being the most fragile piece of machinery in the organism, is the first to be harmed by poison. Thus febrile poison is the poison of the nervous system; and we arrive ultimately at a very simple conception of fever: *fever is a poisoning of the nervous system.* Its consequences must now be quite clear to you.

The immediate effect of the poisoning of the nervous system is a vague feeling of discomfort, of confusion in the ideas, a want of power to fix the attention, and to work. The mind functions abnormally. According to an ancient and popular expression, it is in a feverish state. Speech becomes jerky, agitated, strident. There is no positive delirium, but slight mental confusion. The patient feels out of sorts, has pains in the limbs, and violent headache.

The sensation of well-being which characterizes the normal state (the euphoria of the ancient authors) gives way to one of discomfort and suffering. I need not describe it further, because to some extent you must all have experienced it.

When the fever is more intense—that is to say, when the poisoning is more serious—the mental change manifests itself in incessant restlessness and delirium, which in extreme cases may take the form of paroxysmal mania. There are many varieties of this psychic trouble. They vary according to the individual, and according to the fever. In some children, for instance, a slight attack of fever caused by a harmless sore throat will bring on delirium.

Delirium is, generally speaking, a grave symptom in fever, because it shows that the malady has seriously affected the organism. Hippocrates noticed that delirium was a bad symptom in fevers, especially in pneumonia, while all medical men agree that delirium indicates severe shock to the nervous system. If at the very beginning of infectious fever there is delirium, without any great rise in the temperature, one must reserve prognosis, because this early delirium means that some grave injury has been done to the nervous system.

2. Acceleration of the Pulse.—The acceleration of the pulse has been recognized throughout the ages as a symptom of fever. The frequency of the pulse—that is to say, the frequency of the heart-beats—may vary 100 per cent. You know that a man's pulse ought in ordinary health to beat about 70 times in the minute. When there is fever it nearly always beats more rapidly, the frequency indicating fairly well the intensity of the fever. The pulse may reach from 100 to 120 a minute in cases of slight fever, and in cases of serious fever, especially in children, to 140, 160, and even 180 pulsations. The pulse is then so rapid that it can scarcely be counted.

To this enormous acceleration of the pulse is superadded (again especially in the case of children) a quickening of the breathing, which rises from 20 to 30, and sometimes to 50 or 60 respirations in the minute. The rapidity of the breathing is an invaluable indication in the diagnosis and prognosis of disease. Whenever doctors wish to ascertain the nature of a fever, they note, not the temperature only, but also the pulse and breathing.

All these phenomena—namely, a rise in the temperature, quickening of the pulse, and exaggeration of the breathing—are simultaneous, parallel, and interdependent, springing all three from the same radical and essential cause, the poisoning of the nervous system.

You have to remember that the nervous system regulates the frequency of the heart's beating in accordance with laws too complex for me to attempt to give them here in detail. I will summarize them roughly by saying that it is the mission of some nerves to retard or stop the heart's action, and of others to accelerate it. So that the acceleration of the heart's action in fever is probably due to disturbance in cardiac innervation.

We may take it that in normal conditions the pneumogastric nerves restrain the heart's movement, and that these nerves, the duties of which are to retard and inhibit, draw their activity from the central nervous system. It follows that if the central nervous system is weak or exhausted, out of order, and unable any longer to bring its usual energy to bear on checking the heart's action, the heart will beat faster, owing to the disturbance or the paralysis of the retarding machinery.

We, therefore, come to the conclusion that the accelerated beating of the heart in fevers is due to the exhaustion of the restraining apparatus of the heart. But it is always possible that cardiac acceleration in fever is due as much to activity in the accelerating nerves as to exhaustion of the moderating nerves. Physiologists are not at one in the matter.

3. Thermic Elevation.—I shall go more deeply and more insistently into the third essential phenomenon of fever, the rise in the temperature.

Is it not singular that we should have had to wait so long for the use of the clinical thermometer, and for a more exact means of ascertaining a rise in the temperature* of an invalid than by the mere contact of his

* I am anxious to raise my voice energetically against a vicious mode of expression many people use. When referring to a person with fever, they say *he has a temperature*. Now, whether we are ill or not, we all have a temperature. Without falling to absolute zero or -273° C., it is impossible we should not have a temperature. When speaking of a patient, never say *he has a temperature*. We all have a temperature,

skin? Yet the present practice is comparatively novel. A French physiologist and his partner, a French physician (the physician was Andral, and the physiologist Gavarret), were the first, in 1838, to take the temperature in illness. They saw that in the case of a patient suffering from intermittent fever the temperature rose parallel with the fever.

It is indispensably necessary to know something of the laws governing normal temperature before judging of its pathological condition. For without knowing something of physiology, nothing can be known of pathology. I am in the habit of telling my pupils when they do not show enough zeal in their physiological studies that the best way of becoming learned in morbid phenomena is first to understand normal phenomena. What, I ask you, would be thought of a watchmaker who said: "I know nothing about how a watch works when it is going properly, but I know how to repair one that has gone wrong"? Obviously you would have only a very moderate confidence in that watchmaker, because to be able to repair a piece of mechanism that is out of order, he evidently ought to know first how it works when perfect.

Man is a warm-blooded animal, or perhaps it would be more correct to say an animal whose temperature is constant. He resembles a well-regulated stove, which, as you know, remains always at the same temperature, whether the surrounding air is hot or cold. The contents of bottles put in that stove never vary the

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only some of us have normal and others pathologic temperatures. If you like, you can say a patient has hyperthermia, or a high temperature; but never say *he has a temperature,* lest people hearing you should think you uneducated both from the point of view of medicine and literature.

tenth of a degree, whether in winter or summer, by day or night. In like manner, our temperature is constant. In spite of the most violent physical exercise, in spite of Arctic cold or African heat, despite a very hot bath or a very cold bath, our temperature is always what our controlling nervous system gives us.

This temperature, however, varies. Between morning and night, and night and morning, it passes through a regular series of rhythmic phases, which can be shown on a diagram by a demi-schematic curve. Say our temperature at midnight is 36·2° C. Well, it falls to 36° C. at from 3 to 4 a.m., where for a time it remains stationary. Towards 7 a.m. it rises gradually till 3 o'clock in the afternoon, when it registers 37·5° C., then gradually falls again, returning to 36·2° C. towards midnight.*

Our normal temperature follows, therefore, a daily curve, and varies 1½° C. (2·7° F.) in the twenty-four hours. This fact has been proved in an impeccable manner by, among others, a Danish physiologist, who took as many as 13,000 temperatures of healthy persons, and followed this normal physiological change in its every detail. Thus towards 3 o'clock in the morning our temperature is 1½° C. lower than at 3 o'clock in the afternoon.

Why should there be this variation in temperature controlling the production and loss of our calories, if not because we have a directing nerve system? The nervous system regulates our temperature in two ways, and we may compare it to a merchant who orders his affairs both according to his receipts and to his expenses. On the one hand we produce a greater or less quantity of calories (variation in receipts), and on the other give

* To get Fahrenheit, multiply Centigrade by $\frac{9}{5}$ and add 32.

out heat in greater or less intensity (variation in expenses); and it is by establishing an exact balance between our budget of receipts and our budget of expenses that we are able to keep our temperature at an even level.

The capillaries of the skin, for instance, so shrink in cold weather that the blood is no longer able to reach the surface of the skin, and there is consequently less radiation of heat on the periphery.

On the other hand, in hot weather blood flows freely to the surface of the skin, and there is a more rapid cooling in the mass of blood distributed to the cutaneous envelope. Radiation through the skin (variable according to the temperature of the air) permits of our maintaining our thermic equilibrium in spite of enormous changes in the external temperature.

Yet another regulative process lies in the *perspiration* of the skin. The skin's glands secrete a greater or less quantity of moisture according to the temperature, and the function of the perspiration is to produce cold as the moisture evaporates. A porous earthen jar allowing water to sweat through to the surface outside, remains (owing to evaporation) at a lower thermic level than the surrounding air. Again, a person entering a dry stove (*e.g.*, the hot room of a Turkish bath) does not die of heat, because the abundant perspiration exuding from the pores of his skin produces enough cold to maintain the temperature of his organs unchanged.

To understand how heat-production varies, it is enough to remember that in the first place we have glands which, when excited by the nervous system, display increased chemical and therefore thermic activity. And in the next place, and above all, we have our muscles. It is muscular contraction that mainly warms the body, and so much so is this the case that but for the cooling apparatus provided by perspiration through the skin for correcting an extreme radiation of heat arising from muscular action, any physical exertion, in the least violent, would lead to a very considerable rise in the temperature.

By muscular exertion, combustion is made three or four times more intense than it is in a state of rest. The amount of oxygen consumed and carbonic acid given off increases correspondingly with the chemical activity, and so also in consequence does the production of calories.

During fever everything goes on as it would in the normal organism. There is still thermic regulation. Only the regulating stove, the nervous system, the apparatus for controlling heat, is out of order, deranged, tampered with, just as a stove would be if anyone altered its heat level. Normally we have an apparatus regulating our temperature at 37° C. In fevers the poisoning of the nervous system alters the adjustment to 39° C. A fever patient's temperature will change during the twenty-four hours exactly as does that of a healthy person. In the morning it is 37·5° C., and in the afternoon 39° C. So we find in sick people the same hour by hour variation of temperature that we have noticed in the case of the healthy, and we may conclude that the apparatus governing heat has not been destroyed. Nor can we say (as do some physiologists) that it has been paralyzed. Not at all! The heat-adjusting apparatus continues to control the temperature. Instead of regulating it at 37° C., it regulates it at 39° C. That is all! But it is enough to demonstrate the poisoning of the central nervous system.

In this way it may be seen that the heat-adjusting apparatus maintaining equilibrium between receipts and expenses subsists in the fever-stricken no less than in the healthy; but it functions at a different level.

I cannot go into the history of fever-theories, though I must mention two which appear to me singularly mistaken. None the less they are still occasionally upheld.

Traube declared fever to be due to the imprisonment of produced heat. Now, this is manifestly absurd, since it is a matter of common observation that the skin of a patient with strong fever is always excessively hot. If you go close to him, you notice that he warms the air about him, and to do this he must be radiating more heat than usual. If his heat were imprisoned, his skin would be cold, and all the heat produced by organic combustion would be locked up in his viscera. But this is evidently not the case, because his skin is burning hot, and therefore radiating at high pressure, and losing a large amount of heat.

Fever has also been attributed to intensive calorie-production. But the theory fails altogether to explain the high temperature. The harvester working under a noonday sun, the man running and taking violent exercise, produce five or six times more calories than a person at rest; yet their temperatures remain normal. Of course, there is usually a surplus production of calories in every fever, about 25 per cent. more than in the normal state. But this excess of combustion would have no effect on the temperature if the regulating nervous system were not out of order. In fact, the normal individual retains his usual temperature even when producing 500 per cent. more calories than usual, as he does in the case of violent muscular exertion.

Hence we arrive at this simple conception of fever:

Fever is an assemblage of symptoms due to the poisoning of the nervous system, and especially of that part of it regulating heat. It is a disturbance, not in the production, but in the control of heat.

The height of the temperature in fever contributes very precious information. In bad fevers, infectious from the start and overwhelmingly violent, like some cases of meningitis and scarlet fever, the temperature leaps at once to a very high level, 41° C., 42° C., and even 43° C. Yet, notwithstanding their gravity, these high infectious fevers are perhaps less alarming than the fevers which, instead of exciting, depress the nervous system at the outset, and are accompanied by hypothermia, a temperature less than the normal, and a condition indicating deep, and perhaps irremediable, injury to the central nervous system.

But sometimes the very rise in temperature is a dangerous thing. The rise is not a symptom merely, but owing to its extreme intensity amounts to a complication—that is to say, a phenomenon capable of bringing about accidents due to hyperthermia alone. An exaggerated heat of the tissues is in itself a peril. Should the temperature of the body rise, owing to any cause whatsoever, 3° C. or 4° C. ($5\frac{2}{5}$° F. or $7\frac{1}{5}$° F.) above the normal, grave disorders will occur, due solely to this high temperature. The patient may escape if the temperature of 42° C. or 42·5° C. is not prolonged. Many such instances have been observed in science. The temperature in a few exceptional cases has gone up to 43° C. and 44° C. (111° F.) without death ensuing, but such instances are isolated and exceedingly rare. As a general rule, when a fever reaches 42° C. and 42·5° C.

(108·5° F.), you may assume that the illness is extremely serious.

In every eventuality the thermic curve of a disorder shows its progress with almost faultless precision. Medical men quite rightly attach the utmost importance to a heat diagram, inasmuch as it admits of their following at a glance the course of a febrile complaint.

Every malady has, as it were, its own heat curve. I could give you endless proofs on this head, but I could not go into the details of them, as it would entail a long chapter in pathology. I have explained what you are to understand by the words "thermic elevation." They mean *disturbance in thermic control due to the poisoning of the nervous system.*

Such are the three essential symptoms of fever. There are others, accessory to it, but which are also very important. They are loss of appetite, stiffness of the muscles, emaciation, rigor, and perspiration.

Loss of appetite, called by the medical profession *anorexia*, is a thing you certainly have all observed for yourselves. Appetite completely fails whenever there is fever. And why? Probably because of an arrest in the secretion of the gastric juices. Conclusive experiments have been made on animals, as well as on men, in a feverish condition, and show that the gastric juices dry up at such times. The stomach is therefore unable to digest, as it no longer secretes an effective assimilant. Thanks to the constant relation existing between the needs and functions of the organism, loss of appetite follows, because, the digestion having failed, food cannot be assimilated—indeed, would do more harm than good.

Stiffness of the muscles is another symptom common to all fevers, and accompanies the general discomfort. Its origin is rather obscure; but we can ascribe it to the poison pervading the entire organism. We are not nourished during fever because we can neither eat nor digest. Yet the body requires nourishment, and can get it only at the expense of its own substance, and particularly of its own muscles. We therefore consume our own muscles in fever, which, with the consumption of our own fat, explains not only muscular stiffness, but emaciation also. The patient is emaciated to begin with through not being hungry and not eating, and then through a consumption of tissue, which is accelerated by his high temperature, the tissues burning more rapidly as the temperature heightens.

Accordingly, we consume more and eat little, or not at all. You can understand how natural it is that the weight of the body should decrease following on the excessive consumption.

Rigor in fevers is very easily explained by the fact that the feverish organism has to be provided with a higher temperature than the normal. A fever patient feels cold if his temperature falls below 39° C., just as a healthy person feels cold if his temperature falls below 37° C. To obtain a temperature of 39° C., the former must increase organic combustion, and this he can best do by muscular contractions. Both healthy and fevered persons shiver to warm themselves. The rigor of fever has, then, the same origin as the shiver of health—that is to say, a general contraction of the muscles, which contraction increases the combustion, and consequently the missing calories.

It is not an uncommon thing, particularly in malarial fevers, to see the ague shivering fit coinciding with a relatively high temperature. It is quite natural that a fever patient should feel cold at 39° C., because by the very fact of his being feverish he ought to be at 40° C., and he will feel cold till he is at 40° C.

Profuse perspiration is another of the phenomena of fever. Perspiration, or evaporation of water, is the only means Nature can employ for cooling the heated body, so it is usually a good sign. It shows that the patient is about to cool down, just as shivering showed him to be about to grow warm. When a fever abates, a profuse sweat pearls the skin of the invalid, and the temperature falls.

In an attack of intermittent fever, often taken as the type of the fever process, one notices a first period of rigor (convulsive), and lastly a period of profuse perspiration (final abatement).

I will now go on to study the causes of fever.

I will set aside the very rare and exceptional cases when a shock to the nervous system brings on feverish symptoms, occasioning what may be called nervous fever. The phenomenon is very rare. Very few cases exist, and they interest the physiologist rather than the physician. All that need be remembered about them is that a lesion of the nerves may produce fever symptoms, equally with a poisoning of the nervous system.

Bacteria, vegetable parasites swarming in the blood, where they reproduce myriads of successive generations, are usually, if not always, the purveyors of fever. The mechanism by which they produce it has been discovered for us through the experiments of a number of physiologists, and especially through those of Yersin and Roux. These scientists have proved that microbes secrete substances which produce the same symptoms as do the microbes themselves. Fever can be set up with certainty in an animal by injecting a microbe into that animal. Precisely the same symptoms are obtained by injecting the soluble substances that the microbe secretes in its culture-broth. It excretes toxins, soluble matter—nitrogenous, noxious, complex, multiform — which possess the unfortunate property of developing toxic action in the cells of the organism. One can follow almost the same series of symptoms whether the poison injected is the microbe itself or the toxic substances secreted by it in its culture-broth. From which we may infer that when morbid microbes provoke such or such symptoms in the human organism, it is because they secrete such or such poisons. Given a microbe, you will have the secretion of poison. Given this poison, and you will have morbid symptoms identical with such as the microbe would have let loose if it had been present in the organism itself. To put it once more in a different way: whether microbes develop in the body and produce poisons there, or whether they develop outside it and produce poisons in their culture-liquid, the poisons will be the same in both cases, and the general results alike. Only there will be this essential difference: The toxic consequences of an injection of bacterial poison are much attenuated and even disappear after an hour or so, half a day at most; whereas if the parasites themselves are allowed to vegetate in the blood, they will reproduce after their kind, and go on shedding poison. So after an injection of the soluble matter the ill effects soon go off, but after an injection of the bacteria themselves the parasites continue their ravages with daily secretions of fresh toxins. As fast as the poison is got rid of, it is reproduced, and there can be no end to the malady save with the ejection of the microbe.

It is not the microbe that kills, but the substance it excretes.

These toxins have the remarkable property of acting powerfully on that portion of the nervous system which is the centre of heat control, and from this fact they derive their power of producing fever. It is a very singular circumstance, and one greatly to be insisted on, that mineral poisons rarely cause fever. Broadly speaking, only bacterial poisons produce fever. Physiologists have repeatedly searched in the vast arsenal of chemistry and therapeutics for an experimental means of producing fever and hyperthermia in animals. They have never succeeded in creating feverish conditions except when they used substances secreted by bacteria.

Strychnine will induce convulsions; morphia, sleep; atropine dilates the iris; carbon monoxide poisons the hæmoglobin. These are admitted facts. But not in the whole of mineral chemistry, or even among known organic substances, can a drug be found that will infallibly cause fever. To produce this recourse must be had to bacterial poisons—that is to say, to poisons secreted by microbes during their culture.

To prove the close relations between bacteria and fever I could not find a better example, at once instructive and popular, than the whitlow, a small fester caused by a foreign body in the finger. The foreign body has introduced a microbe, and set up slight suppuration. Now, this minute microbial vegetation produces toxic substances, infects the blood, poisons the nervous system, and brings on fever. That the fever is due to toxic substances deposited by the parasites vegetating in the diseased finger is proved by the fact that it stops immediately when the finger is lanced, and the microbes it contained are expelled, together with their poisons.

These poisons have now been studied. If the pus containing them is subjected to the action of heat, they are not destroyed—at least, not altogether. They remain dangerous. Culture-broths and their microbes which have been heated—that is to say, liquids in which all living bacteria have disappeared—are still capable of giving fever, so no doubt remains that fever is caused by the poisonous substances the microbes secrete.

I have mentioned whitlow, but I might just as well have included all wounds. Whenever a wound festers, that is whenever microbes have got into it, there will be fever, for fever is the faithful companion of suppuration. But in normal conditions wounds ought not to fester. Cicatrization and the repair of skin and tissue would proceed without fever but for the presence of parasites and microbial germs. Fever begins only when microbes intervene, and are able by poisoning the blood to injure the nervous system, throw thermic control out of gear, and bring about febrile complications.

A surgical operation should not cause fever. Childbirth should not cause fever. People believed at one time in milk fever. It was a gross error. Childbirth is a physiological phenomenon not febrile in itself. There can be no fever without infection, an invasion of the nerves by bacterial poisons.

This will convince you of the value of asepsis and antisepsis in averting fever from the wounded. No wounded man would ever have fever if disinfection were perfect. Unhappily, in the case of our terrible war wounds it cannot be faultless. But at all events fever should not supervene in the case of an operation performed on healthy tissues. In such circumstances it should be unknown.

To sum up: There is no fever without bacterial infection. Whether it be a question of scarlet fever, diphtheria, or tuberculosis, if there is fever it is because there is infection, and the infection is due not so much to the microbes themselves as to the poisons they secrete.

This being clearly understood, we shall now be able, with a certain degree of assurance, to inquire into the therapeutical means that should be taken to combat fever. Ought we to act directly on the microbes or on the bacterial poisons, or, again (a therapeutic measure not to be despised), on the organism itself, by providing it with the additional strength required to resist bacterial invasion?

But first I will ask one question which may appear singular: Should fever be treated at all? In other words, is this hyperthermia I spoke of just now harmful or beneficial?

Take, for instance, a patient with pneumonia or tonsillitis. We can, if required, stop his fever and reduce his temperature. But is it the best thing to do? Are we not likely to interrupt the normal course of the malady (which we should remember nearly always tends towards recovery) by preventing the patient from having a high temperature? Many inquiries have been made on the subject, and there are many affirmative answers, though as yet no reliable conclusion can be deduced from them. On the one hand there is no harm in subjecting bacteria to a high temperature, which perhaps hinders their development. Pasteur proved that the anthrax bacillus is harmless to birds at a temperature of 42° C., but that at a temperature lowered artificially to 38° C.

a hen becomes liable to anthrax infection. Again, animals slightly chilled and exposed to infection have been observed to die more quickly than others in which feverish hyperthermia was allowed to take its natural course. On the other hand, there is a good deal of argument to the contrary, and experimental physiology is unable so far to pronounce an opinion. The onus of deciding must be left to clinical medicine.

Here the conclusion seems to have been come to that in some cases of illness it is a good thing to lower the temperature, but that in others it is useless, and may be prejudicial. In all cases a very high degree of hyperthermia should be combated as being a symptom liable in itself to become a danger. For example, in the treatment of typhoid fever a very favourite method, and one that has given excellent results, is the system of cold baths. This may be because they stimulate reaction on the part of the organism, though it also may be because they carry away a great number of calories, and so for a time lower the temperature of the body. In any case the classic method of affusion with cold water has achieved very remarkable cures, especially in particularly grave cases with hyperthermia.

Hyperthermia is so bound up with fever that together they create a dangerously vicious circle. Fever raises the temperature, which in its turn augments organic combustion, and this also raises the temperature, a chain of cause and effect which must be broken up by reducing the fever artificially.

We possess febrifuges for lowering the temperature, which are termed "antithermic." They modify thermic action, and so act on the nerve centres. Salicylic acid, aspirin, and several derivatives of carbolic acid, are of this nature. But there is one that is very powerful and entirely admirable, namely, quinine. Quinine lowers the temperature rapidly, and so relieves the feverish symptoms, especially in the case of malaria. But in what manner? It is presumably by acting on the parasitic element—that is to say, on the hæmatozoa of malaria. For quinine possesses the marvellous property of killing these hæmatozoa, or at least of reducing them to impotence by obstructing their reproduction. The fact that the temperature of a healthy person is not lowered by quinine tends to prove that its efficacy is due to antibacterial action. It is hypothermic only in the case of invalids suffering from hyperthermia. Other people, all other people, who have neither hyperthermia, fever, nor microbes, can take quinine with perfect impunity. Their normal temperature will in no way be affected by it.

So we may infer that in all probability quinine acts on the bacteria, and not on the thermic nerve centres.

At any rate, there is abundant evidence that the best way to combat fever is not to employ medical means against the symptoms, not to attack hyperthermia, which is only a manifestation, but to go straight to the source of the disorder.

1 did not mention whitlow to you just now without good reason. Here is a person with a festering sore and strong fever. The best way to reduce his fever is not to give him antithermic remedies or cold baths. It is to open the whitlow, wash and cleanse the wound, and stop the bacterial suppuration that is the cause of the fever. *A fever is cured by attacking the cause and not the symptoms.*

In the case of whitlow treatment is easy. In that of infectious fevers it is infinitely more complicated. But this does not impair the value of the precept.

You must forgive a very rudimentary and miserably incomplete sketch. My purpose has been to give you only very general laws, and to let you see by means of a striking instance the important part played by physiology in medical problems. Not that I mean to put physiology in sacrilegious opposition to medicine! I have said times without number that those who would oppose medical practice to experiment understand nothing of either. And this is self-evident.

But at all events, keep fast hold of this, a fundamental principle which will indicate the essential nature of fever with absolute precision: *Fever is a bacterial poisoning of the nervous system, and especially of that part of it which regulates heat.*

VI

ASPHYXIA

As commonly used, the word asphyxiation implies the suppression of respiratory action. So that to understand the phenomenon of asphyxia thoroughly, it is necessary to know in what respiration consists.

I think I have told you that it was Lavoisier who first described the essential character of the breathing. Atmospheric air is a gaseous compound of oxygen and nitrogen. One hundred litres (22 gallons) of air contain 21 litres (4½ gallons) of oxygen and 79 litres (17½ gallons) of nitrogen, though nitrogen seems to play no part in respiration beyond that of diluting the oxygen. The oxygen is the sole useful ingredient, the " breath of life " that supports existence. An animal put in an atmosphere lacking oxygen dies asphyxiated. Fish breathe oxygen dissolved in water. If placed in boiled water—that is, water deprived of its oxygen by ebullition—they suffocate, just as birds and mammals do in a gaseous medium destitute of oxygen. Plants, too, require oxygen to live. It is oxygen alone that keeps all things alive on the earth's surface.

Life is unharmed by a proportion of oxygen higher than 21 per cent. Indeed, animals have been able to live a long while in pure oxygen. But the opposite is not true. When the quantity of oxygen in the air is diminished, death ensues with a rapidity that depends on the rarefaction of the vivifying gas.

An animal is asphyxiated if shut in a confined atmosphere, one not renewable by access to the external air. Directly the proportion of oxygen falls below 18 per cent., difficulty of breathing is observable, with unrest and signs of anguish and suffocation; while in an atmosphere containing less than 12 per cent. of oxygen, asphyxia supervenes, at first slowly, but more rapidly so soon as the proportion of oxygen falls below 8 per cent.

In a confined place like an hermetically closed room, where people and animals are breathing, there is not only a diminution of the oxygen, but also an increase in the quantity of carbonic acid gas exhaled by the lungs in the course of respiration. Suffocation is often believed to be owing to an excess of carbonic acid, but this is a gross error. Though carbonic acid is useless to the respiration, it is not poisonous. Life is possible in a gaseous medium containing 15 per cent. of carbonic acid and even more. It is the deficiency of oxygen that causes death in a confined atmosphere.

Oxygen wields this great, this invaluable power because, when taken into the lungs through the breathing, it penetrates to the blood. The red corpuscles contain a substance called "hæmoglobin," which has the property of fixing atmospheric oxygen, and of forming with it in the blood a chemical combination known as "oxyhæmoglobin." Thanks to the hæmoglobin of the corpuscles, a litre of blood will absorb about a quarter of a litre of oxygen.

Oxyhæmoglobin possesses a very curious faculty. Having drawn the oxygen out of the lungs, it can pass it on quite easily to the living cells. All the cells of the organism, whether in the brain, muscles, or glands, receive an abundant flow of arterial blood, and appropriate the oxygen it contains to the purposes of their own existence. This being a form of combustion, if combustion is not brought about, they die. For one reason or another, should the blood not be able to take up oxygen and carry the vital gas to the cells, the cells must die, and die asphyxiated.

Thus the blood may be looked upon as a vehicle for carrying oxygen. The circulation is the current of arterial blood (charged, you understand, with oxygen) which visits all the cells and brings them the oxygen they stand in need of. Then, becoming venous, it leaves the cells to return to the heart and lungs, where it again takes up oxygen.

As Lavoisier so beautifully expressed it, "life is a flame." A candle burns because the carbon and hydrogen it contains combine with the oxygen of the air to give off carbonic acid and water, with light and heat. The cells burn their carbon and hydrogen to give off carbonic acid and water, with the disengagement of heat. Should no oxygen remain in the atmosphere where the candle is burning, its flame goes out. If our cells are deprived of oxygen from the blood, the flame of life goes out.

The first question that has to be answered is, How long does it take to die of asphyxia?

But put in that way the problem has no solution, inasmuch as the duration of asphyxia varies enormously according to the species of the animals experimented upon.

You are doubtless aware that the so-called cold-blooded animals have a temperature equal to that of their environment: one, that is, with a few rare exceptions, far lower than that of warm-blooded animals (mammals and birds). The temperature of the latter is constant whatever the external atmospheric changes may be. Cold-blooded and warm-blooded animals alike require oxygen. But in the cold-blooded the need is less urgent. With them, the flame of life burns but feebly. It is a pale, flickering light. Whereas combustion in the case of birds and mammals is intense. Warm-blooded animals asphyxiate very quickly. Cold-blooded animals resist longer.

If we put a pigeon and a frog in a vacuum under glass, the pigeon will die in a minute, while the frog remains to all appearances unconcerned.

Even after a couple of hours it shows hardly any signs of asphyxia.

Some animals asphyxiate, therefore, very quickly, and others very slowly.

Moreover, cold delays combustion in cold-blooded animals, and they take a very long time to asphyxiate when the temperature is low. A frog kept in iced water and deprived of air is not asphyxiated in twenty-four hours. But interesting as these studies in comparative physiology are, I propose here to examine asphyxia from the point of view of medicine—that is to say, asphyxia in the case of human beings.

We are able to judge of the time a man can remain without breathing by suspending our own respiration. The anguish becomes unbearable after about a minute and a half, and we are forced to take a long, deep breath. Even if before making this little experiment we take several long breaths, and fill our blood with all the oxygen that it will hold, we shall still find ourselves unable to hold our breath for more than two minutes. The most experienced diver cannot stay longer than three minutes under water unless artificially supplied with air.

Asphyxia takes place even more rapidly in the case of a man who is unable to swim, and who falls into the water and sinks. He is dead in about a minute and a half. He has expelled all the air that was in his lungs in involuntary irresistible expirations, and has replaced it with water, which is unbreathable.

I have been at some pains to ascertain the time required for asphyxiating various animals by drowning. Small birds die in thirty-five seconds, hens and pigeons in forty-five seconds, dogs in one minute fifteen seconds, though between one minute fifteen seconds and one minute forty-five seconds we cannot be certain that death is inevitable. By the use of various devices dogs that have remained under water less than one minute forty-five seconds have sometimes been saved, but not always. After submersion for that time they can never be brought to life again. So in the case of dogs, and we may take it that the same holds good in the case of man, survival is certain after only one minute fifteen seconds, but after one minute forty-five seconds it is impossible.

You must not put any faith, therefore, in the tales you hear of wrecked men surviving immersions of five, ten, and twenty minutes. When immersion is total, when the unfortunate people do not come to the surface again for a few breaths of air, two minutes will decide their fate. It is the people who look on at the wreck who make these singular mistakes in judging time. Two minutes appear, no doubt, at such a moment extraordinarily long, and they declare in all innocence that the submersion was impossibly protracted.

Death from hanging and strangulation is due to other causes than asphyxia properly so called. The rope in all probability breaks the spinal cord and lacerates the medulla, which is the fundamental organ of life.

Again, the effects of toxic gases must not be confused with asphyxia. One commonly hears in these days of *asphyxiating gases* given off by the enemy shells. But that is poisoning, not asphyxia. One-thousandth part of chlorine or of carbon monoxide, or a five-thousandth part of carbon oxychloride will make air unbreathable. There need be no lack of oxygen in such circumstances. A modification by a thousandth part in the proportion of oxygen would mean no appreciable change at all, provided the gas that replaced it was harmless, like nitrogen or hydrogen. But it is a totally different matter when the gas introduced is of the toxic and irritant nature of chlorine, which destroys the epithelium or lining of the lungs, or carbon monoxide, which combines with the hæmoglobin of the red corpuscles to render them inert and incapable of performing their duty of taking oxygen to the cells. The *waves* of chlorine and bromine sent over by the Germans do not kill by suffocation, but by poison. However, the common term, though misleading, has been adopted, and the whole world speaks incorrectly of "asphyxiating gases."

The capacity of resisting asphyxiation is much stronger in the newly born than in the adult. Buffon, the great naturalist, noticed the curious fact that new-born kittens were not asphyxiated by drowning under five or ten minutes. The newly born still enjoys the all but anaerobic existence of the fœtus, able to satisfy itself with the very feeble quantities of oxygen taken by diffusion from the mother's arteries, in proportions altogether insufficient for an adult.

Hibernating animals (marmots, hedgehogs, bats), possessing an extraordinary faculty of prolonging existence at very low temperatures, are also capable of resisting asphyxia during lengthy periods. The comparison with a flame will again recur to you. When the flame is weak and combustion feeble, it takes a long time to consume the reserve of oxygen in the blood.

Another singular instance I must mention is that of the diving animals that, by means of various mechanisms which it would take me too long to explain here, have the faculty of remaining a long time under water. I often show my class a highly instructive experiment. I put a duck and a pigeon together into a tub of water. At the end of forty-five seconds the pigeon is taken out dead. I put in another, which after another forty-five seconds is also taken out dead. I seem to have forgotten the duck. I show my pupils that the pigeons really are dead, and put in a third, leaving it a minute, when it, too, is taken out dead. Then only do I think of the duck, which is still alive and well, and comes out apparently none the worse for its experience. As a matter of fact, ducks can stay five, six, or seven minutes under water without risk of asphyxia.

One of the earliest external symptoms of asphyxia is the change in the colour of the blood. Hæmoglobin in combination with oxygen is of a clear, bright, sparkling red. It is the colour of arterial blood, which, coming from the lungs, returns into the left side of the heart, and thence is sent out to the tissues. When deprived of oxygen, hæmoglobin turns to a deep, dark, purplish red, almost black, the colour of the venous blood which returns to the right side of the heart, to be sent thence to the lungs, where it takes up oxygen again.

Blood that can no longer be oxygenated (arterialized, as it is often called) remains of a deep black colour. An animal with no more oxygen in its lungs has this black blood in its arteries even. Bichat has shown this in a very fine experiment. Before his time asphyxia was believed to be owing to the stoppage of the blood's circulation in the lungs, the lungs of asphyxiated animals being always highly congested. But Bichat proved that the blood still circulates during asphyxia, for an open artery continues to give (just as before asphyxia) an alternating, rhythmic jet of blood answering to the systolic or contracting movements of the heart. Only, instead of the bright, sparkling vermilion colour it shows normally the blood is deep black. The arterial blood has become similar to venous blood, and indistinguishable from it.

The blood of asphyxiated people is black throughout. The veins swell. The mucous membrane becomes blue. In cases of asthma, when the patient is almost suffocating for want of breath, the lips turn a purplish colour. The progress of asphyxia in a dog can be followed by watching the state of the circulation in the tongue. So long as the tongue remains pink, no asphyxia threatens; but once it starts getting blue or black, asphyxia is imminent. In this connection you should watch the colour of the tongue carefully in the case of a patient under chloroform. You will get from it the best possible indication of the condition of the breathing.

I will give you another experiment you can try on yourselves. Put your hand before a strong light in a dark room and try to hide the whole light of the lamp. You will see the light through your palm in a very clear reddish-pink glow. This is given by the colour of the blood. Then make a tight knot round your wrist so as to stop circulation in your hand. The pink colour will gradually disappear, and be replaced by one growing gradually darker, owing to local asphyxia in the hand. The tissues are consuming the oxygen the blood had brought them, and as there can be no further supply owing to the ligature round the wrist, the blood is being deprived of oxygen and is growing blacker and blacker in consequence.

Let us now follow minute by minute, almost second by second, the progress of asphyxia in a dog or rabbit, brought about experimentally by means of a pipe with tap affixed introduced into the open trachea. The breathing of the animal is conditioned by the opening and closing of the tap.*

Perhaps you may remember what I told you in the case of chloroform: that chloroform begins by poisoning the nervous system, and does so in a particular order of precedence, first poisoning the very sensitive cells, then the sensitive, and lastly the less sensitive.

Among the nerve cells, the most fragile are those of ideation, intelligence, and memory. They are the first to be paralyzed. After a few seconds of mortal anguish, the mental faculties lose their power and the sufferer becomes unconscious. A vertigo passes before his eyes, and all trace of mental action is extinguished. Nevertheless, he tosses about, struggles, and makes efforts to move, though of what happens he will remember

* Death in this case comes much more slowly than in that of asphyxia by drowning, inasmuch as the animal is able to avail himself of all the air in his lungs; while in the case of drowning the air in the lungs has been expired and replaced by water. No reserve of oxygen remains. A dog whose trachea is tied, dies only after five or six minutes in water.

nothing. This is the first stage of asphyxia, and is precisely analogous to that of chloroform. Consciousness is lost in about a minute.

In the second period reflex action is still present, though it gradually grows weaker. The breathing, which had begun by being troubled, deep, painful, and stertorous, slackens and disappears. The second stage comes to an end in about another minute with the suspension of respiration.

The third stage lasts about half a minute, when reflex action ceases. Then everything has disappeared. The nervous system has no power except for the innervation of the heart. We observe neither consciousness, respiration, or reflex action. The pupils are widely dilated. The colour of the mucous membrane is of a blackish purple. The intestines are congested, and there is some evacuation of urine and fæcal matter.

The heart still beats, and even very powerfully, but its pulsations are very slow.

We must take a moment to consider this slowing down of the heart, because it is one of the most interesting phases of asphyxia.

The pneumogastric nerve, or nerve of the tenth pair, connects the medulla oblongata with the heart (or, more correctly, with the nerve ganglia of the heart). If excited by electricity, the nerve does not stimulate the heart's action, but quiets and even stops it. It is therefore a moderating nerve, a nerve of inhibition.

If the two pneumogastric nerves are severed, the action of the heart will be accelerated, whereas if, on the contrary, they are excited, the heart beats more and more slowly, and eventually suspends all movement.

When during the fourth stage of asphyxia, therefore, the heart, which at first beat very fast, now beats very slowly, it is because it has been affected by the pneumogastric nerves, and it has been affected by the pneumogastric nerves because the medulla oblongata, whence these nerves start, has been affected by the want of oxygen, a deficiency that acts in the same way as a poison.

Physiologists have proved this to be the fact by a few highly illuminating experiments. They have severed the pneumogastric nerves of an asphyxiated dog, the heart of which was beating quite slowly, and the heart has immediately regained its quick rate of pulsation, as under normal conditions. If instead of cutting the nerves an injection is made of atropine sulphate, a poison with the attribute of suppressing all physiological connection between the cardiac ganglia and the pneumogastric nerves, the heart does not slow down. The slackening of the heart in asphyxia is never seen in animals poisoned by atropine; because the pneumogastric nerves then no longer exercise their moderating influence.

The ultimate object of their deterrent action is not difficult to understand. The faster the heart beats, the greater is the consumption of oxygen. And to spare the precious element there must be economy of combustion. All the more so that the contractions of the heart, when the myocardium is anaerobic (living without oxygen), produce deleterious poisons. An asphyxiated animal dies more rapidly when the heart does not slacken speed. A dog whose pneumogastric nerves have been severed, or which has been subjected to an injection of atropine, dies in three minutes, whereas a dog whose heart can slacken normally will not die for five or six minutes.

At the end of five or six minutes the heart, which has been beating very slowly, all at once begins to pulsate with extreme frequency. And if at this moment air is not restored to the lungs, and artificial respiration resorted to, death is certain. So long as the heart beats slowly nothing is to be feared; but when, after a period of slackening down, the heart accelerates, oxygen must be given quickly to prevent its death.

Nothing is so wonderful as the return to life following the giving back of the vital gas. It is a sight I always watch with admiration. In a very few seconds the heart recovers its normal state. The mucous membrane, which had been purple, grows pink. The deep, natural breathing returns. Reflex action begins again. Consciousness is restored. The resurrection is almost miraculous. It is as though a corpse had revived. A flame that had been all but extinct burns brightly, just as a candle in a close atmosphere regains light and heat when air is introduced into the bellglass, where its flame has been wavering and flickering.

If, however, artificial respiration is not resorted to, the heart will beat more and more feebly and will stop, and this time stop once for all. Nothing on earth can restore its contractility. And then a phenomenon supervenes which from time immemorial has impressed the imagination of man. This is what is termed the last sigh. For some time there has been no effort to breathe, and now, just as the heart has definitely stopped, there comes a long, deep inspiration, a *last breath*, as though the organism were making a desperate effort to introduce a few atoms of vital air into the lungs.

The attempt is generally unavailing. Nearly always, at the time when the "last breath" occurs, there is no chance of life returning, even through artificial respiration.

The "last breath" is not always solitary, but is followed by two, three, or even four dying inspirations, each weaker than the foregoing, and that is the end.

At autopsies of asphyxiated animals the viscera are found gorged with blood that is entirely black. The heart is at its maximum dilatation, and the blood in the left side is as black as that in the right.

I may say here, in passing, that it was this fact which led Claude Bernard to distinguish between asphyxia from lack of oxygen, and death from carbon monoxide. Before his time it had been believed that suffocation by charcoal fumes (CO, carbon monoxide) was merely asphyxia. Claude Bernard declared this to be impossible, because in animals killed by carbon monoxide the blood is everywhere of a bright, clear, sparkling red—in the veins as well as in the arteries. So it is not asphyxia. It was his noticing this that led him to make one of his most wonderful discoveries—viz., the combination of carbon monoxide with the hæmoglobin of the red corpuscles.

Death through diminution of barometric pressure is closely akin to death by asphyxia.

You are aware that the higher one rises into the air, although the proportions of oxygen and nitrogen remain the same, the pressure of the atmosphere diminishes, and diminishes pretty rapidly.

As a help to memory I will give you a technical example of this weakening of pressure. On Mont Blanc, the highest mountain in Europe, with an altitude of 4,800 metres (16,000 feet), the barometric pressure is about half that at sea-level. Hæmoglobin does not combine with the air's oxygen unless the barometric pressure is over 100 millimetres (4 inches). As the pressure of the oxygen diminishes, a certain loss of the gas held in solution by the blood occurs, and it follows that as the atmospheric pressure becomes weaker and weaker, the blood contains less and less oxygen. There is still oxygen, but in decreasing quantities, and the organism suffers in consequence.

The suffering caused by the rarefaction of the air is known to all aeronauts and mountain climbers as mountain sickness. Paul Bert conclusively proved mountain sickness to be due to paucity of oxygen. Atmospheric pressure being decreased, the blood is unable to obtain the quantity of oxygen sufficient for its needs. The trouble, as you will easily understand, is owing to disturbance in the nervous system, always in that respect the most accessible part of the body. Headaches, vomiting, or at least a sick feeling, total loss of appetite, sleeplessness at night and nightmare, invincible drowsiness by day, total absence of moral energy, extreme lassitude that almost amounts to complete physical impotence, palpitations of the heart, painful difficulty of breathing and dyspnœa—disturbance, in short, of all the organic functions controlled and regulated by the nervous system.

These accidents due to rarefaction of the air are not quite comparable with asphyxia. But to discuss this important matter would take us too far out of our way. I must be satisfied with mentioning a notable discovery first made by Viault, Professor of Physiology at Bordeaux. It will prove to you better than any theory the wonderful adaptation of our humours and tissues to the varying conditions of existence.

As barometric pressure diminishes, the number of red corpuscles augments. The blood succeeds in overcoming the deficiency of oxygen by this very singular and still obscure process, the increase of the red corpuscles.

The increase is rapid. In the space of three or four hours, some say even faster, the number of corpuscles rises in a proportion of from 5 to 7·5. Oxygen being deficient, Nature remedies the loss by increasing the quantity of those elements which take up oxygen in the blood.

The treatment of asphyxia must now be briefly noticed.

And naturally (though it seems an obvious thing to say) the first thing to be done is to get rid of the cause. If there are any foreign bodies in the air passages, remove them. Have recourse to tracheotomy should the larynx be narrowed or blocked. Administer oxygen if there is a deficiency of it in the surrounding air, etc.

In principle the treatment of asphyxia is rudimentary in its extreme simplicity. It is to furnish the lungs with air.

Cases of asphyxia fall into two categories. Either the patient still makes efforts to get breath, or he does not.

If he retains the power to breathe, the nervous system is not as yet profoundly affected, and it usually means that an obstacle is preventing air from reaching the lungs, or that there is no air.

In the case of submersion, the drowning man who has just been taken out of the water, and who can still breathe, has his lungs full of water, and the first thing to do is to free the lungs of the liquid they contain. To do this the drowned man should be laid with his head as low as possible.

But always provided that there is no mechanical obstruction to the passage of air in the air channels, the cases of asphyxia where the power to breathe is still present are not the most dangerous.

An asphyxiated person rarely runs much risk if still able to breathe by spontaneous effort, and if the trachea and bronchial tubes remain unobstructed.

An important and fertile source of asphyxia should not be overlooked, especially at the present moment, when war projectiles may perforate the thorax.

If the thorax is pierced, air enters the pleura and respiration becomes impossible. The impulse to breathe continues in anxious, desperate efforts, but it is ineffectual for sending air to the lungs.

Air enters the lungs because the thorax in dilating carries with it the pulmonary parenchyma adhering to it; for when completely closed there is no air in the pleura. If an external wound of any kind punctures and opens the pleura, air can enter, because the lung, an elastic mechanism, will exert its elasticity to the utmost and shrink back, adhere to the spinal cord, and collapse. No respiratory effort on the part of the muscles of the thorax can after that have any effect on its expansion.

The lung accordingly remains motionless, its normal mobility being entirely owing to its adherence to the thorax, and to its following the thorax in its alternate movements of dilatation and contraction. The penetration of air into the pleura is called *pneumothorax*, and when penetration is caused by a wound in the chest it is called *traumatic pneumothorax*.

For various reasons pneumothorax is not always fatal in itself. But it is a fruitful source of asphyxia. In such cases the asphyxia resulting must be striven against by aid of that heroic and almost sole remedy, at once simple and effective, artificial respiration.

Artificial respiration is the rhythmic introduction of air into the lungs by any practicable means. From a physiological point of view, artificial breathing sustains life quite as well as natural and normal breathing. Dogs and rabbits unable, for one reason or another, to breathe spontaneously, can be kept alive for hours by introducing air into their lungs by means of a pair of bellows that work regularly and rhythmically.

That you should know how to practise artificial respiration is of the first importance. I say again, it is the sole, quite the sole, means of bringing the asphyxiated back to life.

If, as usually happens, you have no apparatus at your disposal, you must rhythmically compress the thorax, and this you can do by bearing heavily and always rhythmically on the chest. After being compressed the thorax returns to its primitive position, and the manœuvre must be repeated until natural breathing is restored.

One of the advantages of the method is that compressing the thorax not only assists the respiration, but also in some measure helps the heart, which at a time of profound asphyxia is dilated and gorged with black blood. The compression tends to empty the right ventricle of poisoned blood.

While compressing the thorax, it is as well to draw the tongue forward also, so as to keep the glottis open. Laborde advocated a rhythmic traction of the tongue, and obtained remarkable results with it in numerous cases of asphyxia. The rhythmic traction of the tongue determines useful movements of the lungs, as one can judge for oneself when noting on the dead body the results of tongue traction in the expansion of the lungs.

In order to introduce air into the lungs by a more energetic method than pulmonary compression, you may use insufflation from mouth to mouth. There is seldom time for tracheotomy, and a pair of bellows is not always handy. By pressing the mouth close to that of an asphyxiated or drowned person and blowing hard, we can force air from our own lungs into his.

In short, in default of a full equipment, there are only three means of applying artificial respiration. Neither hinders the other, and each should be employed in turn, and *without respite.* They are the compression of the chest, rhythmic traction of the tongue, and mouth to mouth insufflation.

Please understand that there are other auxiliary means that are of use, and that may, indeed, be very necessary. The patient should be placed with his head low to prevent brain anæmia. He must be kept warm by means of hot clothes, and have skin and thorax stimulated by a modified form of flagellation, and by powerful electric irritants.

In the case of newly born babies, the first breath is not always drawn immediately after birth. The medulla oblongata, which is the seat of respiration, may be slow to react. The infant, as they say, is in a state of apparent death. Reflex excitement of the skin most effectively stimulates the medulla in starting breathing.

I venture to conclude with a formal reminder of very great importance.

So long as the heart beats, be it ever so feebly, one may hope to save an asphyxiated person by means of artificial respiration. No effort must, therefore, be suspended until it is certain, absolutely certain, that the heart has ceased to beat. Once the heart has stopped for half a minute or a minute, it will not return to life; whereas the nerve centres controlling the respiration may be inert for several hours and yet awaken and recover their activity.

Therefore, while the heart beats, persevere with artificial breathing vigorously and without respite.

Go further still. Even after the heart has stopped, persist in artificial respiration. You can never be sure that a few feeble and all but imperceptible contractions of the heart may not remain undetected. To have continued a fruitless artificial respiration too long is better than to neglect the chance of saving the asphyxiated.

TABLES OF QUANTITIES

TABLE I.

Carbohydrates contained in Food (Sugar or Starch) in 100 Grammes (3½ ounces).

Sugar	100	Potatoes	17
Rice	83	Raisins	14
Flour	68	Almonds	9
Lentils	56	Apples	8
Peas	52	Milk	4
Haricot beans	50	Eggs	0·8
Bread	47		

TABLE II.

Nitrogenous Matter contained in Foods (in 100 Grammes).

Cheese	33	Rice	5
Lentils	26	Milk	4
Peas	22	Cabbage	2
Haricot beans	22	Potatoes	1·3
Meat	21	Raisins	0·7
Wheat flour	13	Apples	0·4
Bread	7		

TABLE III.

Titles of various Antiseptic Solutions (in Grammes to the Litre (17 Grains to the Quart).

Salts of mercury or silver	0·05	Permanganate of potash	3·50
Oxygenated water	0·05	Alum	4·50
Iodine	0·25	Tanin	5
Salts of copper	0·50	Boracic acid	7.50
Salicylic acid	1	Chloral	9
Picric acid	1·50	Sulphate of iron	10
Mineral acids	2·50	Alcohol	95
Phenol (carbolic acid)	3	Sodium chloride	165
		Glycerine	225

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