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PAUL BERT

J. Colin

Translation of "Paul Bert", Science (French Edition of Scientific American), No. 12, Oct. 1978, pp 27-33.

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16. Abstract

This biographical article on Paul Bert highlights his studies on the physiology of respiration and barometric pressure and, in particular his contributions to the understanding of hypoxia, hyperoxia and anesthesia.

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PAUL BERT

J. Colin

Paul Bert was at once a political figure, researcher, and educator. He discovered the physiological effects of high and low pressures which made it possible to avoid sometimes fatal accidents resulting from an excess or lack of oxygen in the organism. /27*

If you ask a Frenchman who Paul Bert was, he will probably answer, unless he is from Auxerre or is an aeronautic physician, that he was a political figure of the Third Republic. This answer is not incorrect, but incomplete. If we open a biographical dictionary, the biography devoted to this great man will undoubtedly begin with these words: physiologist and political figure. It is true that these two activities represented the two main poles of interest of this champion of the sciences and of the Republic. But for an aeronautic physician, Paul Bert is also the father of aeronautic medicine. Indeed, the high point of his scientific career was the publication, just 100 years ago, of his now classical work entitled La pression barometrique. Recherches de physiologie experimentale [Barometric Pressure, Studies in Experimental Physiology]. It is remarkable that the peak of his scientific work came scarcely two years before he was appointed Minister of Public Instruction.

The Beginnings of Paul Bert's Career

On the face of it, Paul Bert's family environment did not seem favorable to nurturing a scientific career. Rather, it seemed to predestine him to a political career. His father, a lawyer in Auxerre, had acquired great influence there as a lawyer and then as a prefecture counselor.

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* Numbers in the margin indicate pagination in the foreign text.

He had two sons. The elder son died very young, and the parents devoted all of their attention to the younger son, Paul, born on October 19, 1833. Paul Bert began his studies at the College of Auxerre where he proved to be a brilliant student. Every year he won numerous prizes, including the mathematics prize, which he won consistently in his final years at the school. Perhaps this is why he continued his studies at the College of Sainte-Barbe to prepare for the Polytechnique. However, for reasons which escape us, in 1853 his father sent him to the Faculté de Droit (Faculty of Law]. There he obtained his liscence in 1857, after studies devoid of enthusiasm because for several years now his personal penchant was carrying him towards the natural sciences. Indeed, he had a share in the studies of a naturalist, A. Colin, creator of the Auxerre Zoological Museum and he was presenting papers to the Society of Historical and Natural Sciences of Yonne which were already receiving attention.

So it is not surprising that one day in 1857, passing in front of the Sorbonne to go to the School of Law, he went in to listen to a lecture by the physiologist Gratiolet whom one of his friends, Dr. Lemercier, had told him about. Definitely conquered by the sciences, he quit law, registered at the Faculty of Medicine and worked in Gratiolet's laboratory. A few years later, Claude Bernard, while questioning Paul Bert in the course of an examination was struck by his quick mind and took him as an assistant in his laboratory. Under his two famous teachers, Paul Bert acquired an incomparable education in plant physiology, anatomy, zoology, and animal physiology. All his life he retained a veritable cult for his teachers, showing them, in his own words, "admiration, affection, and respect alike". Throughout his career, he followed the studies connected with these diverse disciplines demonstrating his untiring curiosity. His studies on anatomy and zoology ranging from the seal to birds to the gorilla are found at the beginning of his career, however, from 1862 to 1967. The same is true for the majority of his plant physiology studies, such as the anatomy of ferns of 1859, or "systematic catalogue of wild vertebrates of Yonne, with keys of the species and diagnoses" published in 1864, and considered a model of the genre for its clarity, precision and logic of its presentation. Much later, however, he pursued some studies, such as that concerning the mechanism of the movements of sensitive plants, which kept his attention from 1866 to 1870, or that concerning the effect of different wave lengths of visible light on chlorophyll which was published in 1881. His studies on animal physiology are spread all along his scientific career and from 1864 to 1881 a large number of articles appeared on a wide variety of subjects. Among the most astonishing studies made by him, we may site those concerning the color-changing mechanisms of the chameleon, the physiology of the cuttlefish, of the lamprey, and of the amphioxus, and the respiration of young seahorses in the egg.

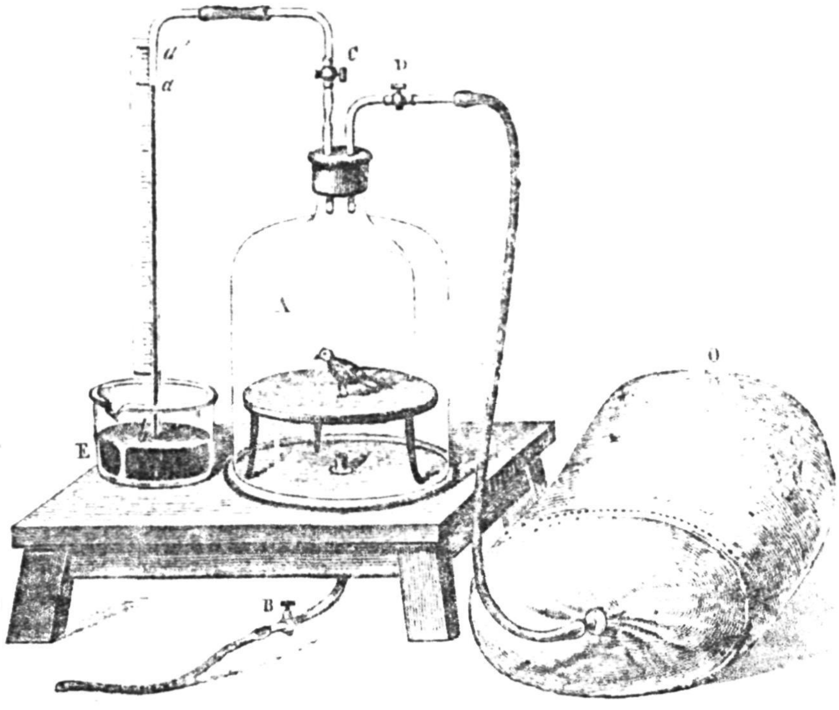
Among his first experimental physiology studies, particular mention should be made of the study of animal grafts. Bert made this the subject of his doctoral thesis in medicine, which he presented in 1863, then of his doctoral thesis in natural sciences, which he defended brilliantly before the Faculty of Sciences of Paris in 1866. In 1865, the same work won for him the prize in experimental physiology and the title of laureate of the Academy of Sciences. At this time, grafts were rarely practiced. Only a few skin autograft techniques were known which had been discovered in the Indies. Bert had the distinction of demonstrating the possibility of performing transplants from one animal to another. This remarkable research, which alas was to receive practical applications a few years later during the War of 1870, had, along with certain lectures, (such as that on the physiology of the nervous system at the Sorbonne in 1866) attracted the attention of the greatest scientists of the time. This is why, in 1867, he obtained the chair of zoology at the Faculty of Sciences in Bordeaux. He was then, at age 34, the youngest Faculty professor in France. He was only to spend

a brief time in this town. In late 1967, he was in fact re- /28
called to [line missing in photocopy] Flourens to his course of the Museum of Natural History, then to replace Claude Bernard at the Faculty of Sciences who had just succeeded Magendie to the chair of medicine at the Collège de France.

1. Paul Bert (1833-1886). This photograph was taken around 1880. Besides his talents as a physiologist and his taste for politics, Paul Bert tried to give a more elementary and practical character to the teaching of physics, chemistry, and physiology.

Physiology of Respiration

When he was substituting for Flourens, in the chair of comparative physiology at the Museum, Bert chose as the subject of his course "the comparative physiology of respiration". His concern for scientific accuracy led him to repeat all the experiments done in front of him and to verify the explanatory hypotheses proposed. What's more, this experimental work allowed him to ob-



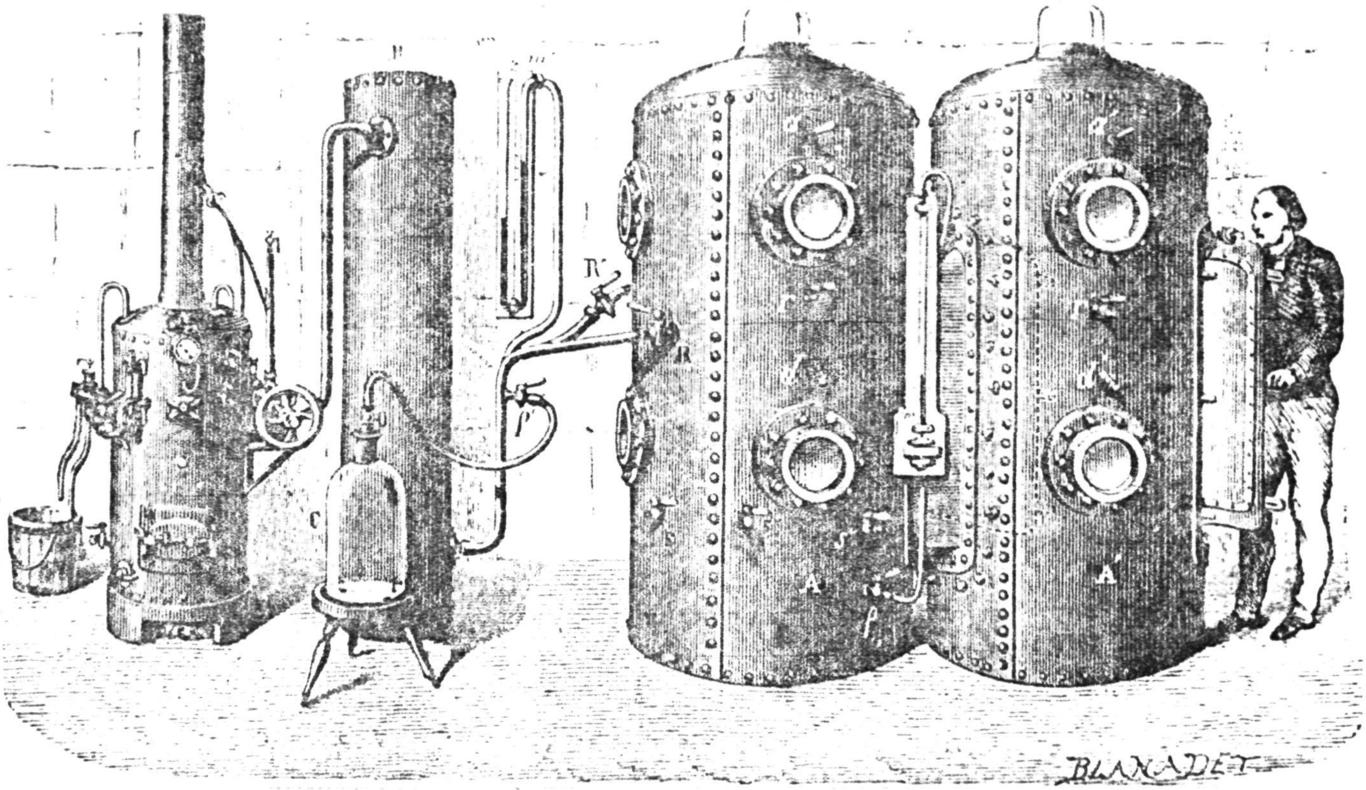
2. It was possible to observe the effect of a decrease in pressure by means of the apparatus shown in this drawing. A partial vacuum is made in the bell jar by a vacuum pump (not shown) connected to stopcock B and the pressure in the jar is measure by the height of the mercury in the glass rod on the left. Oxygen is contained in the reservoir sack on the right. Birds showed the same symptoms as man when pressure was decreased: nausea, vomiting, increased pulse, psychic and motor disorders, etc, and finally asphyxia. The animal showed better resistance when, at the same pressure, the oxygen partial pressure was increased, "the soon dangerous drops in pressure gradually became harmless because a concentration of oxygen in the air had been sufficiently increased".

serve a number of new facts. All of these studies were published in 1870 in a work dedicated to Claude Bernard and entitled Leçons sur la physiologie de la respiration [Lectures on the physiology of respiration]. In particular, he was interested in tissue respiration, the transport of oxygen by the blood, and exchanges in the lungs (for example, he used an original method to measure the composition of the alveolar air). Moreover, following these papers, it became classic to describe the entire respiratory function by breaking it down into these three levels. He was also interested in mechanisms of asphyxia in different types of animals. In this connection, having found that in natural death the blood is deprived of oxygen, he stated something that appeared paradoxical to the physiologists of the time, i.e. that death is always caused by asphyxia. Intrigued by the resistance of certain animals to asphyxia by immersion, he looked for the reason behind this. Thus, he showed that if a duck can be kept up to six minuntes under water before dying, while the chicken can last only three or four minutes, it is because a duck has one and a half times as much blood as a chicken of equal weight and an equal volume of duck's blood fixes more oxygen. He made many more observations concerning, on the one hand, the mechanics of pulmonary ventilation, such as the movements of the ribs and of the diaphram, the mechanism of expiration, of screaming and singing and, on the other hand, on the frequency of respiration and its modifications, on lung capacity, etc.

The interest which Bert was going to bring to bear later on on the effect of barometric pressure on living creatures was already attested to by the existence of a lecture devoted to this subject in 1868 in his teaching on the comparative physiology of respiration. There he especially expressed his enthusiasm for the ideas of Jourdanet concerning the mechanisms of altitude thickness and he emphasized the interest which would lead him to an experimental study. But to carry it out, he would need, he 729
said, a cumbersome and expensive apparatus which one could not dream for a moment was possible of obtaining with the modest resources available to French laboratories. However, he reported several experiments done on animals breathing mixtures of gases low in oxygen and he put forth the hypothesis which suggested to him the results obtained: the respiration of air low in oxygen made the same symptoms appear at ground level which were caused

by breathing air at high altitudes or where the barometric pressure is lower. This finding evidently suggested that it is the drop in the partial pressure of oxygen which is responsible for the observed disorders.

Appointed full professor at the Faculty of Sciences, Place Claude Bernard, on January 18, 1869, Bert gave his inaugural lecture on "general physiology and the vital principle". It was this year that Jourdanet, realizing the dream Bert had judged impossible a short time before, furnished him with the necessary funds to construct a pressure chamber. The chamber was ready for use in 1870 and, in March of this same year, Bert published the first result obtained by him on cats and guinea pigs. Four months later, the war broke out against Prussia. After the abdication of Napoleon III in September, a provisional government was formed and Gambetta became Minister of the Interior. Paul Bert was named Secretary General of the Prefecture of Yonne. In December, at Bordeaux, he met Gambetta who had escaped from Parix by balloon in October. The two men made a large impression on one another, and, on January 15, 1871, Gambetta named Bert Prefect of the North. A little later, in disagreement with the government concerning the armistice with Prussia, Gambetta resigned and Bert returned to Auxerre. At the end of the war he returned to Paris to resume his teaching and research. Gambetta, however, had inspired him with such enthusiasm for the Republic that Bert was no longer to abandon political life. He was elected Counselor General of his canton in 1871, then, in June 1874, Deputy of Yonne. At the National Assembly he sat on the extreme left. From that time onward, fortunately endowed with a robust constitution and exceptional working powers, he divided his existence between Bourbon Palace and his laboratory keeping abreast of his research, his teaching, his scientific articles, and his political work, but he focused on teaching. He even became Minister of Public Education in 1881 in Gambetta's cabinet and he had most of the bills proposed by Jules Ferry on primary and secondary teaching adopted. It is remarkable that this period of intense political activity also coincides with the peak of his scientific work, La pression barometrique [Barometric Pressure].



3. The beginnings of aeronautic medicine. Bert's pressure chamber constructed in 1869, consists of two chambers connected by an air tight door. On the left is a vacuum pump (operated by steam) and a manometer. With the aid of this pressure chamber, Bert was able to study the effects of oxygen defficiency on man.

Barometric Pressure

Altitude sickness had been known about for a long time. The first accurate description of it was given by the Spanish Jesuit Priest Jose De Acosta in 1590. Having had the occasion to cross the Andes, he has the distinction of attributing the cause of this sickness, called "sorroche" by the South American Indians, to rarifaction of the air. It was only much later, in

1835, that a physician by the name of Junod constructed the first low-pressure chamber. With it, he made clinical observations on the disorders caused by high altitude, without finding out the physiological mechanisms. At this time, altitude or mountain sickness was also associated with "balloon sickness" described by the first aeronauts to go to high altitudes, such as Robertson in 1800, Gay-Lussac and Biot in 1804. Glaisher, head meterologist of Greenwich Observatory, in his book entitled Travels in the Air published in 1871, gave a striking description of the various disorders which preceeded his loss of consciousness during his ascent in 1862 which carried him to a height of 8,833 meters. After a series of high mountain expeditions, /30
Jourdanet concluded at this time that the disorders caused by high altitude were due to the drop in the pressure of oxygen in the blood, and he introduced the term "anoxemia" to designate this drop in pressure. It is known how much this hypothesis impressed Bert. For his part, Jourdanet was counting on Bert to clarify experimentally the physiopathology of anoxemia.

Thanks to the funds made available by Jourdanet, Bert had installed in his laboratory at the Sorbonne two cylinders of bolted steel plate in which a vacuum pump created a vacuum or compressed air. Thanks to this apparatus, he was able to complete the experiments which he had already done on birds or small mammals placed under the bell jar of a vacuum pump. The work that he accomplished this way in a few years is fairly amazing, since he describes no less than 678 experiments in his book, La Pression Barométrique, published by Masson in 1878. This masterful work of 1,178 pages presents his studies (which won for their author the biennial prize of the Institute in 1875) as well as a very complete historical review of the scientific studies which had preceeded his own in this area. This book also won for its author the title of perpetual president of the Society of Biology, upon the death of Claude Bernard, and in 1881 opened to him the doors of the Academy of Sciences. Among the conclusions drawn by Bert from his studies, we can note the following points which are still valuable in aeronautic and diving medicine.

"The decrease in barometric pressure acts on living creatures only by decreasing the pressure of oxygen in the air which they breathe and in the blood which keeps their tissues alive (Jourdanet's anoxemia).

"An increase in barometric pressure acts only by increasing the pressure of oxygen in the air and in the blood...; above five atmospheres, oxidation reactions decrease, probably changing such that when the pressure increases sufficiently, they stop completely."

"The untoward effects of a decrease in pressure may be effectively combated by breathing air sufficiently rich in oxygen to keep the pressure of this gas at the normal value. The effects of an increase in pressure are combatted by using air rather poor in oxygen to achieve these same results."

"Generally speaking, beneficial or harmful gases (oxygen, carbonic acid, etc.) act on living creatures only according to the pressure which they have in the ambient atmosphere..."

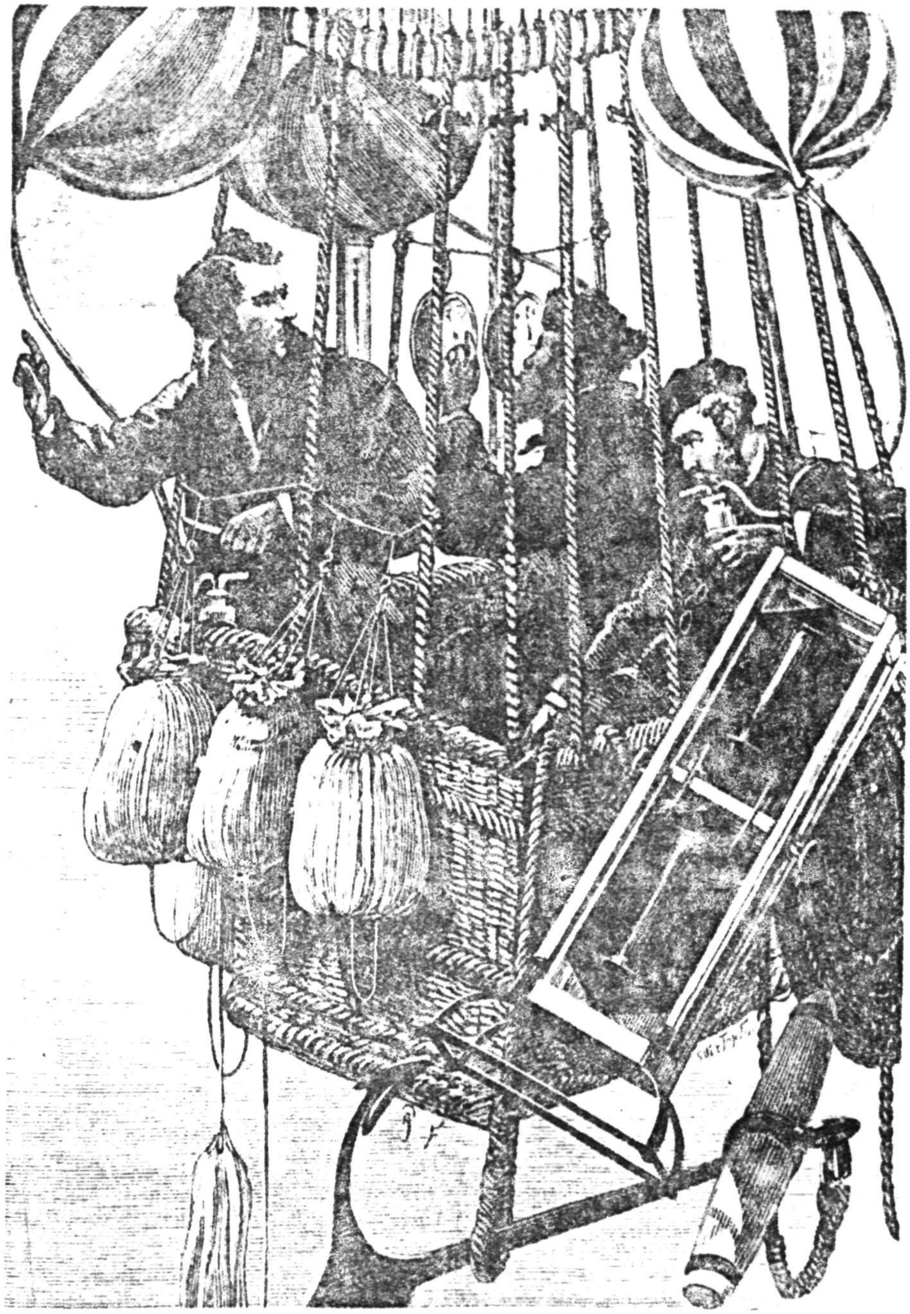
"When animals possess reservoirs either completely closed off... or in communication with the air... by means of openings which are too narrow, a decrease or increase in pressure can have physicomechanical effects."

"Sudden decompression...has no effect (apart from the one mentioned above)... but that of allowing nitrogen, which was dissolved in the blood and tissues as a result of the pressure, to return to the free state."

Thus, as early as 1878, the mechanisms were clearly stated for the syndrome such as hypoxia, barotraumatisms, aeroembolism, hyperoxia, and hypercapnia, which are so important for aeronautic medicine and diving medicine. It is interesting to take a closer look at three of these points.

Hypoxia

The term hypoxia designates a decrease in the amount of oxygen contained in the blood. From his first conclusion, Bert had logically deduced the third, namely that breathing oxygen-rich air so as to keep its partial pressure constant made it /31 possible to avoid hypoxic disorders. He demonstrated this on himself. He closed himself into one of the cylinders of his pressure chamber and gradully decreased the barometric pressure inside. As the simulated high-altitude conditions thus created were increased, he was able to analyze on himself all of the symptoms described earlier by aeronauts and mountain people: increased pulse rate, increased pulmonary ventilation, vision disorders, discomfort, psychic and motor disorders, etc. When he felt he was about to faint, he inhaled oxygen contained in a bag, and all of the symptoms disappeared. One day he was thus able to reach an altitude of 9000 meters, an altitude greater than that reached by Glaisher and the English dentist Coxwell during their famous ascent. It will be remembered that these two balloonists lost consciousness and owe the fact that they were saved only to the rapid descent of their balloon. On the day that Bert attained the 9000-meter altitude, he was accompanied by a bird which fell lifeless at his feet. Before returning to normal pressure, he reanimated the bird. He relates this experience with good humor: "...Before descending, I put the tube of oxygen for a moment under the beak of my bird who regained consciousness immediately, and we both got ourselves out of this situation very well, which was only painful for him."



4. The catastrophic ascent of Tissandier, Sivel, and Croce-Spinelli on board the balloon Le Zénith in 1875. Sivel is about to release the ballast, Tissandier is looking at the barometer, and Croce-Spinelli is holding his oxygen inhaler furnished with a wash bottle to rid the oxygen of its organic impurities. The oxygen reserves (in the three small balloons) proved to be insufficient and only Gaston Tissandier survived this ascent. A letter from Paul Bert warning them of the danger of not carrying an adequate supply of oxygen arrived too late for the balloonists to take this into account.

It did not take long to apply oxygen inhalation as protection against high-altitude hypoxia in actual conditions. First of all, Bert had two aeronauts, Croce-Spinelli and Sivel, make two simulated chamber ascents and they established the efficacy of the process. Then, on March 22, 1874, these two aeronauts carried with them small balloons filled with oxygen in their balloon christined the Etiole Polaire [Polar Star]. They were thus able to stay for two hours at an altitude of 7,300 meters. Reinforced with this success, they wanted to repeat their exploit in 1875, on board the Zénith taking Gaston Tissandier with them. Informed by word from Croce-Spinelli, Bert wrote to his friends to warn them because their oxygen supplies were very insufficient. "...In the high regions where this form of artificial respiration will be indispensible to you, you should count on a consumption of at least twenty liters per minute for three men: your supply will quickly be exhausted". Bert's letter arrived too late. The day for the ascent was already set and the balloonists, in order to save oxygen, decided only to use it in case of extreme necessity. The fatal consequences of this unwise decision are well known. Paralyzed by hypoxia, the balloonists were unable to grab the oxygen tubes and lost consciousness. The balloon stayed for two hours at 8600 meters, and only Tissandier regained consciousness when it descended. His two companions were dead. Tissandier gave a famous account of this catastrophe, describing in detail and dramatic tones the various hypoxic disorders which preceeded their loss of consciousness.

Subsequently, the use of oxygen as a means of protection against hypoxia was universally adopted. Thus, Berson, a German, was able to reach an altitude of 9100 meters in a balloon in 1894, then 10,500 meters in 1901 without suffering any attacks of hypoxia.

5. An excess of oxygen under high pressure (in this case four atmospheres) causes death. This dog, with tetanus and bulging eyes is having convulsions caused by oxygen poisoning: "he knashes and grits his teeth until they appear to break and death may occur after one or two crisis."

Aeroembolism

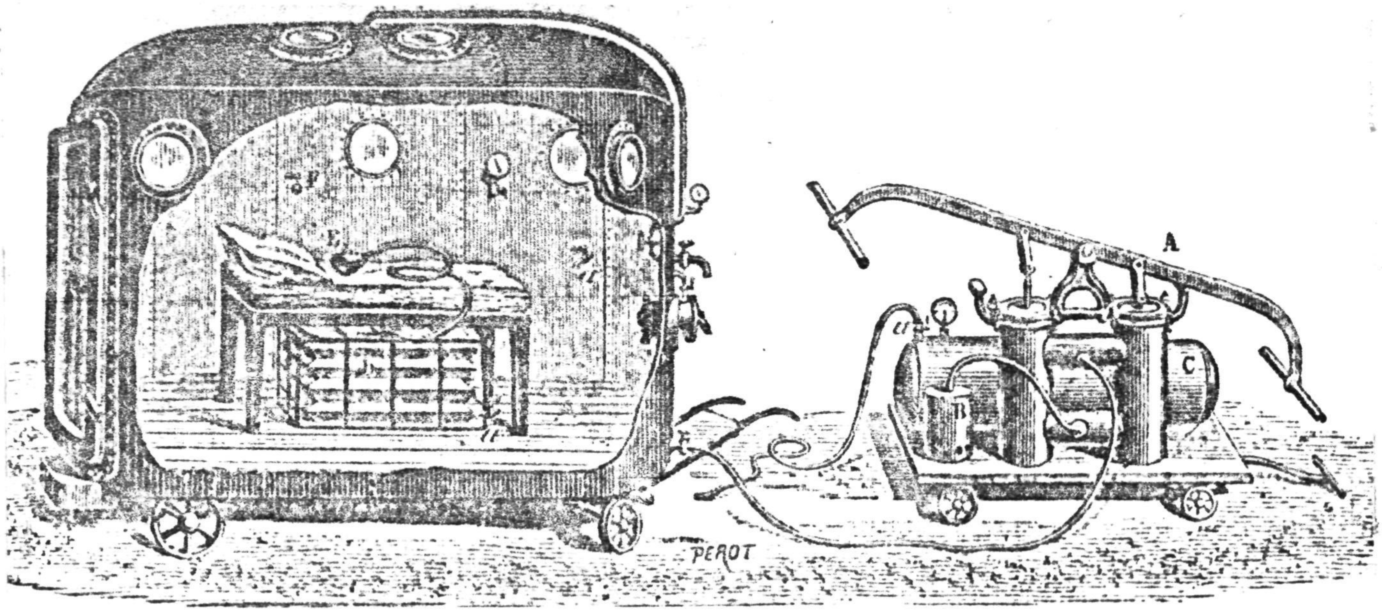
Bert's contribution to the conquest of the air was thus outstanding and his contribution to high-altitude physiology won for him the deserved title of the "father of aeronautic medicine" which is not contested by any doctor of aeronautic medicine in the world. But Bert would certainly equally deserve the title of "father of diving medicine" for his research on the effect of /31 an increase of barometric pressure on living organisms, which would now be called the physiology of high-pressure environments. It was known for a long time about the problems, sometimes very serious, which struck workers working in an atmosphere of compressed air when they returned to normal pressure. Death was not rare, and in Bert's time, dramatic examples of these kinds of accidents were numerous. In 1869, during the construction of a bridge over the Mississippi at St. Louis, the workers had to work in water under a pressure of 4 3/4 atmospheres. When leaving the caissons in which they were working, the majority of the workers showed symptoms of aeroembolism and twelve of them died. In 1867, out of 24 divers engaged in fishing for sponges at a depth of 54 meters, 10 had died. As we have seen, Bert showed that the dangerous effects of decompression were due to nitrogen passing into the gaseous state which had been dissolved in the organism as a result of the high pressures to which it was subjected. It was in fact the physician Bucquoy, whom Bert sites in his book, who was the first to put forth this hypothesis in 1862. But it was Bert who proved it and, by logical deductions drawn from his experiments, proposed prophylactic and therapeutic measures. He thus proposed the following:

-- To slow down the speed of decompression to allow the excretion of gaseous nitrogen through the lungs, observing a decompression time of 10 minutes per atmosphere;

-- To have the subject breathe pure oxygen if minor symptoms appear;

-- To recompress immediately then slowly decompress in case of paralysis.

Thanks to this advice, many accidents could be avoided and Bert was often consulted by construction companies. Thus, the company Fives-Lille, which was building a bridge in Aalborg, Denmark, wrote to him: "We have sent to our yard in Aalborg the information that you so willingly gave us on the precautions to be taken for work by man at high pressures. We have gone past the depth of 32 meters below the surface of the water and the accidents have disappeared as a result of increasing the length of time the exit is kept locked."



6. Mobile chamber for anesthesia by administering nitrous oxide under pressure. "The fact that the nitrous oxide must be administered in a pure state indicates that the pressure of this gas, in order for it to penetrate in sufficient quantity into the organism, must be equal to one atmosphere. Under normal pressure, to obtain this the gas must be in a proportion of 100%. But if we assume that the subject is placed in an apparatus where the pressure is increased to two atmospheres, the subject can be subjected to the desired pressure by having him breathe a mixture of 50% nitrous oxide and 50% air. A sort of anesthesia will thus be obtained, while maintaining the normal amount of oxygen in the blood and, as a result, maintaining the normal conditions of respiration."

Hyperoxia

Besides studying the effect of going from a compressed atmosphere to a normal atmosphere, Bert also studied the effect of stable, high barometric pressure. In this way he discovered that oxygen was toxic when breathed under high pressure.

To be sure, by postmortem examination of rats and guinea pigs subjected to the inhalation of pure oxygen, Lavoisier, in 1885, had found hemorrhagic effusions of blood in the organs, but the observations made by Bert were completely new for the scientists of the time. The symptoms caused by oxygen seemed peculiar. For example, when he placed an animal in a vessel filled with oxygen under several atmospheres of pressure, after a certain amount of time he found violent and generalized convulsions recalling the clinical picture of strychnine poisoning. It is for this reason that doctors often use the expression "Paul Bert effect" to describe an attack of the central nervous system which dominates the picture of hyperoxia, when pure oxygen is inhaled at a pressure greater than two atmospheres. This is in contrast to the "Lorrain Smith effect" which describe a predominant pulmonary attack when pure oxygen is inhaled under a pressure less than two atmospheres. We have seen that Bert had the great merit of attributing the toxicity of oxygen to an effect on cellular metabolism. Even today, little is known about this effect on the enzymatic mechanisms of cellular metabolism, but Bert guessed its existence. In the same way that he conceived of protection against hypoxia by breathing oxygen or oxygen-enriched air so as to reestablish the normal partial pressure of this gas, he proposed the breathing of air poor in oxygen to prevent hyperoxia. Nowadays, this principle is applied in the use of gas mixtures for deep dives.

In studying the effect of barometric pressure on man and animals, Bert thus gleaned a considerable scientific harvest. But he spread his domain even more. For example, he became interested in the effect this parameter on plants. At that time it was thought that if vegetation became sick and then disappeared on high mountains, cold was the determining cause. Bert found experimentally that low pressure, like barometric overpressure, slowed down the growth of plants or the germination of seeds and killed them when a certain pressure level was reached. He made the same findings on tissues, isolated cells and microorganisms. In particular, he noted that oxygen under pressure stops the development of the microorganisms responsible for various fermentations, while diastases or poisons were resistant to its effect. He used this method to find out whether or not oxidation or fermentation were due to the intervention of a living microorganism.

Paul Bert and Anesthesia

Besides his research on barometric pressure, and in spite of the preoccupations of his mandate of Yonne, Bert was also interested in anesthesia. Once again, his research on this subject contain original and interesting findings. Among the anesthetics, he was particularly attracted to nitrous oxide and Chloroform. His idea (in part false) of the effects of nitrous oxide led him to recommend its use under pressure. To this end, he had a pressure chamber constructed from which he derived a mobile model. This mobile operating room experienced widespread fame in a large part of the civilized world between 1879 and 1883. It was used by the great surgeons of the period. After studying nitrous oxide, Bert got interested in chloroform, the anesthetic properties of which had been discovered by Flourens, and with which Simpson had experimented on humans in Edimbourg. After experimenting on animals, he developed a breathing mixture. The mixture technique had the great advantage of permitting an exact dosage, while with the "compress" method it was not possible to know the amount of anesthetic absorbed by the patient. This mixture, which immediately enjoyed widespread use in France and abroad, no longer presented the drawbacks and dangers inherent in the saturated compress method of anesthesia used up to that time.

Bert was not only a great researcher, he was also an eminent teacher. In fact, he loved to talk, and his talents as a speaker were perhaps not far removed from his taste for politics. In any event, his interest in pedigogy led him to take a deep interest in teaching, and this was well before he was named Minister of Public Education. For example, he argued in favor of the education of women, was interested in religious, moral, and civic education at the school level, and organized primary teaching. He was particularly devoted to introducing the teaching of natural sciences in the primary schools. For this teaching, he edited manuals which enjoyed great success and were translated into many languages. He proved to be an excellent popularizer in this area, with the ability to speak to children on their level. Besides this speciality which was his preferred domain, he also edited manuals for moral and civic education, and even a geometry book.

The Later Years

On January 28, 1886, Paul Bert was named Resident General of Tonkin. He left for this country, inspired by the highest ideas about the duties and responsibilities of France with respect to the populations of the overseas territories. Moreover, a short time before, he had expressed his liberal ideas on the policy to be followed in the colonies in his Lettres de Kabylie [Letters from Kabyle] published in 1885. He reached Hanoi, where the Resident General was located with his entire family, (he was accompanied by his wife, his three daughters, and his son-in-law), firmly decided to devote himself to the population which he was going to administer. He organized scientific and teaching establishments and, not forgetting his scientific vocation, planned to carry out a study on the flora and fauna of Indochina. Unfortunately, he contracted dysentary and his physical condition deteriorated rapidly. However, although undermined by the illness, he continued up to the end to be concerned about those under his administration. The following letter, written a short time before his death, is moving proof of his devotion. In it he asks one of the members of the Academy of Sciences, Marcel Deprez, who is the first to think of using rivers to produce electricity, if this process could be used in Hanoi.

Office of the Resident General
Hanoi, October 18, 1886

My Dear Colleague,

You know how happy I am to greet you thus and to have voted for you well before the vote which paid you justice. I come to ask you for payment in the service of the state.

Our town of Hanoi is watered by a mighty river, 800 meters wide with deep (5-10 meters depending on the time of year) fast-flowing water. It also runs through dark planes, its 30 hectares of surface (maximum distance of the river: one kilometer) being impassable at night. I have it illuminated by burning oil, but this is a crude method, the gas is too expensive and moreover it makes a deathly smell.

I come to ask your advice.

Can the river be used to produce the light? Would the expenses be enormous?

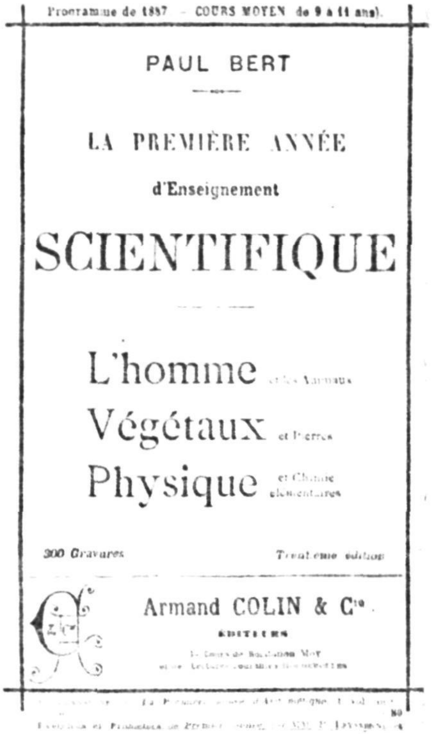
Imagine, if we succeed, we would be ahead of England and even Japan!

Reply quickly, my days are numbered, and thank you.

Yours,

Paul Bert

Consumed by the dysentary, Paul Bert died in Hanoi on November 11, 1886. Thus disappeared from his post, mourned by all Frenchmen, this great physiologist and devoted citizen of the Republic who, thanks to his rare intellect and exceptional capacity for work, had accomplished equally rich and very full political and scientific careers.



Programme de 1887 — COURS MOYEN (de 9 à 11 ans).

PAUL BERT

LA PREMIÈRE ANNÉE

d'Enseignement

SCIENTIFIQUE

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ÉDITEURS

7. "The first year of scientific instruction" is a book designed for children between the ages of 9 and 11 years. This book by Paul Bert was published in 1882 when he was Minister of Public Education. In his preface, Bert congratulated himself on the conformity of his book with the programs edited by the superior council of Public Education, which is not totally surprising since he had been seated on the council for a long time before becoming Minister.