TABLE 3.

MEDICAL EXAMINATION OF SCHOOL CHILDREN AT SEA BREEZE—SUM-
MERS 1905 AND 1906.
Girls 5 to 15.

Age.	Height.			Chest circumference.			Weight.		
	No. ex.	Aver.	Stand. ¹	No. ex.	Aver.	Stand. ¹	No. ex.	Aver.	Stand. ²
5	81	42.1	41.4	97	20.7	21.	58	37.3	37.
6	130	43.4	43.6	147	21.3	22.8	98	37.8	38.8
7	124	44.3	45.9	141	21.7	23.5	97	43.24	42.4
8	147	47.1	48.	162	21.24	23.8	121	45.5	46.8
9	133	47.9	49.6	152	22.83	24.5	119	51.2	51.9
10	146	50.1	51.8	159	23.5	24.7	123	57.11	55.12
11	123	53.08	53.8	131	24.4	25.8	91	62.3	61.4
12	130	55.3	57.1	142	25.24	26.8	99	70.5	68.8
13	72	57.1	58.7	83	26.2	28.	57	75.9	78.9
14	45	57.4	60.3	49	27.5	29.2	33	86.7	89.5
15	13	60.4	61.4	15	26.9	30.3	10	88.8	97.9

TABLE 4.
Boys 5 to 11.

Age.	Height.			Chest circumference.			Weight.		
	No. ex.	Aver.	Stand. ¹	No. ex.	Aver.	Stand. ¹	No. ex.	Aver.	Stand. ²
5	74	41.2	41.7	89	20.9	21.4	81	35.4	38.6
6	119	41.3	44.1	137	36.1	23.2	137	40.5	40.6
7	157	43.2	46.2	171	21.9	23.7	161	39.4	44.3
8	135	46.5	48.2	144	23.2	24.4	140	45.5	49.1
9	123	49.7	50.1	138	20.8	25.1	134	53.6	53.14
10	96	51.2	52.2	107	24.34	25.8	109	57.7	57.
11	101	52.9	54.	115	25.05	26.4	110	63.05	63.1

2. The seriousness of a large number of these defects become manifest so soon as the child enters on school life.

3. If these defects be not removed, the child becomes and continues dull, lethargic, lazy, stupid and backward and at times recalcitrant, obstinate, unmanageable and immoral.

4. In many instances where these last conditions have existed and have been alleviated, the child soon begins to assume a more normal aspect of physical and mental well being.

5. Some more active means are necessary to put the burden of responsibility on the parents and to instruct them in the necessity of attending to the health of their child, no matter how apparently trivial the ailment or defects may be.

AEROPATHY OR COMPRESSED AIR ILLNESS AMONG TUNNEL WORKERS.*

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Exposure of the human subject to an environment of greatly altered barometric pressure so disturbs the organism which has always been adjusted to the normal atmospheric pressure of fifteen pounds to the square inch that there frequently arises a train of symptoms at once most interesting and most varied.

No one term has ever been adopted for this curious affection; therefore *aëro*pathy suggests itself as simpler and more comprehensive than the older and more re-

stricted terms, "caisson disease," "diver's palsy," "bends," "compressed air illness" and "balloon sickness," for even this last-named disease is similar in its manifestations and probably identical in its etiology with that of compressed air illness.

The vast engineering feats of the past half century in which compressed air has been used to permit men to work under water for mining, for laying foundations of bridges, buildings, jetties, etc., and in submarine tunneling, have in effect created this disease, which has been aptly spoken of as "the disease of modern civilization" and "the nineteenth century disease."

From earliest times the human intellect has aspired to master the watery element. Indeed tradition has it that over 2,200 years ago Aristotle conceived the idea of the diving helmet and that the contemporary ruler, Alexander the Great, descended to the bottom of the sea in a diving bell. However this may be, the first authentic accounts date from 1525 A. D., when Sturmius or, according to other writers, Taisnier, invented the primitive diving-bell in which the only ventilation was afforded by the breaking of bottles of air carried in by the workers.

In 1605, a diving bell was used to raise parts of the sunken Spanish Armada.

The caisson in a practical form was designed in 1839 by Trieger, a French engineer, who employed it with success in coal-mining operations beneath the River Loire, and his observation of the occurrence of pains in the arms and legs of the workers constitutes the earliest mention of this new disease.

During the past sixty years, numerous contributions have been made to the literature of *aëro*pathy, in French by Pol and Watelle, Paul Bert,¹ Raneaux and others, in English by Snell,² Hill and Macleod,³ Hill and Greenwood,⁴ Oliver⁵ and others, in German by von Schrötter, Heller and Mager,⁶ and by our Americans, A. H. Smith,⁷ Jeminet and others.

The extensive use of compressed air in recent engineering enterprises has made the occurrence of *aëro*pathy much more common, to-wit: in the building of the new Firth of Forth Bridge in Scotland, the Brooklyn bridge, the great bridge at St. Louis and the Blackwall tunnel under the Thames in London, which till twelve years ago was the greatest undertaking of this kind.

To-day, in New York, the construction of numerous great river tunnels and of foundations for tall buildings and bridges, engages the labor of many more men in compressed air than at any previous period, and cases of illness, distributed, as they are, throughout the city, are daily being brought to the attention of greater numbers of practitioners of medicine.

The subject matter of this paper, apart from the historical and certain theoretical considerations, is founded on my experience of more than a year on the medical staff at the East River tunnels from Thirty-fourth street, New York, to Long Island City.

For the use of the Pennsylvania, New York & Long

1. La Pression Barométrique, Paris, 1878.

2. The Blackwall Tunnel from a Medical Point of View, Hospital, London, 1897, xxii.

3. Caisson Disease and Diver's Palsy, Journal of Hygiene, 1903, iii, 401-445.

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5. Dangerous Trades, G. P. Dutton, 1902; A Lecture on Caisson Disease, Lancet, 1899, vol. 1; Caisson Disease (translation), Annals d'Hygiene Publique, 1906, 4 s., v, 385-410.

6. Heller, Mager and von Schrötter: Luftdruckerkrankungen (2 vols.), Vienna, 1900.

7. A. H. Smith: Physiologic, Pathologic and Therapeutic Effects of Compressed Air, New York, 1894.

1. Bowditch's standard. Standards reduced to net weight according to scheme suggested by Holt (Dis. of Children, edition 1897, p. 19).

2. Porter's standard.

* This paper was read before the Quiz Medical Society of New York City, May 11, 1907.

Island Railroad, the firm of contractors, S. Pearson & Son, Inc., is constructing four great tunnels under the East River, one beside the other, at a depth of from 80 to 90 feet below high-water level. Each tube is of a diameter of 23 feet, with its roof more than 20 feet beneath the river bottom.

According to the physical laws governing submarine work, approximately one pound of compressed air is required for every two feet in depth of water; and, as the river bottom consists, in large part, of soft silt or muck, nearly as fluid as water, and subject to the same hydrostatic laws, it follows that most of the tunnel construction must be carried on under an air pressure of $+ 30$ to $+ 37\frac{1}{2}$ pounds or $+ 2$ to $+ 2\frac{1}{2}$ atmospheres.

The starting point for the tunnels is some 200 feet inshore from the river, where great shafts were sunk by means of caissons filled with compressed air, and at the necessary depth of over 80 feet the horizontal tubes were started toward the opposite shore. Before advancing many feet, a heavy bulkhead, 12 feet thick, was built entirely to block the mouth of the tube. This bulkhead is pierced by three horizontal cylinders, called "locks," each being about 7 feet in diameter and 20 feet long, and fitted at both ends with steel doors opening inward toward the tunnel ahead. Two of the cylinders, on a lower level, are for supply cars and muck cars, the one above is for men.

On completion of the bulkhead, compressed air was no longer necessary in the shafts, which were uncovered and fitted with elevators to the surface, and now the compressed air, supplied by the seven great compressing engines, is conducted directly into the tunnels forward of the bulkhead.

A visitor to the tunnels to-day descends the open shaft in an elevator, or cage, and at the bottom is confronted by the great cylinder, 23 feet in diameter, made up of rings of heavily-flanged iron plates, bolted securely together. The bulkhead with the locks, in the near foreground, obstructs a view of the tunnel "heading" where the boring is proceeding.

A shift of men has just left the tunnel and the visitor finds the upper lock "out," i. e., only the door at the farther end is closed. He enters the lock, which resembles a great horizontal boiler, and close behind is the steel door, with its thick facing of rubber, called the "gasket." A valve is opened, and the compressed air from the tunnel ahead enters the compartment with a great rushing noise. Immediately the door behind is sealed so tightly that no human force could stir it. By the electric light in the lock, the visitor can watch the pressure gauge and thermometer, both of which begin to rise.

The so-called physiologic effects of compression may be described at this point:

(1) In the first place, there will very probably be a feeling of nervousness if one is unaccustomed to the roar and the queer sensations. (2) Next a sensation of pressure from without on the ear-drums, soon becoming a positive discomfort, or even exquisitely painful, unless one equalizes the pressure on the ear-drum, which may be done by swallowing or performing the valsalva, which opens the Eustachian tubes. At this point, a man with impervious Eustachian tubes, from a coryza, or catarrh, may have to desist from entering the tunnel; he is "blocked" and returns to the physician's office, where a Politzer bag at once gives him relief. In my experience, several cases of rupture of the membrana tympani have occurred, when a man through ignorance or foolish

determination has continued to raise the pressure when he was blocked. (3) The temperature in the locks may rise to 95° or even 100° F during compression, and one breaks out into a profuse sweat. (4) Above 15 pounds the tip of the tongue and the lips feel slightly numb, much as if covered with oil or vaselin, and it becomes difficult or impossible to whistle or to whisper. (5) One becomes conscious of a slight resistance to expiration, and a very few forced expirations make one giddy. (6) The voice loses its timbre and individuality and acquires a high-pitched nasal quality. (7) A lighted candle burns with a smoky flame and can scarcely be blown out, as it tends to relight itself in the more abundant oxygen. (8) I have demonstrated that the boiling point of water at $+ 15$ pounds is 248° F., and at $+ 30$ pounds my feeble alcohol lamp could not produce boiling, although the thermometer registered 268° F.; hence this would be an admirable place for surgical sterilization even in an open boiler.

At $+ 32$ pounds, the roar of entering air fades away and the pumping of the huge compressors in the powerhouse, way above, can be heard distinctly. The pressure in the lock is now equal to that in the tunnel, and there is no difficulty in pushing open the further door and entering the tunnel ahead, where the air is damp, but cooler, i. e., from 65° to 80° F.; humidity, 90 per cent.

Were it permissible in a paper of this sort, nothing could be more interesting than a description of the work at the "heading" and of the wonderful steel shield advanced by hydraulic jacks, as ring after ring is built in place behind it, but I must proceed with the mention of further so-called physiologic effects, which, however, I feel are open to question, if they be not absolutely erroneous. (1) Pallor of the skin, described by A. H. Smith,⁷ has been entirely discredited by von Schrötter's observations of the skin, mucous membranes, vocal cords and ear-drums. I have repeatedly failed to notice any blanching during compression, and attribute the observation either to pure theorizing or to a nervous pallor, which I have occasionally noticed among frightened visitors. It is true that after some days or weeks of tunnel work the men become pale, but who would not if kept entirely away from the sun and in an atmosphere nearly saturated with humidity, like a Turkish bath? (2) The pulse does not disappear, nor is there any demonstrable alteration in its volume, as claimed by Smith, but disproved by the pulse tracings of von Schrötter. By several competent observers the pulse rate is said to be slowed after a transient increase; von Schrötter claiming a loss of 14 beats per minute. My own series of fifteen cases demonstrates no appreciable change, either on first entering the air or after remaining several hours, for the figures show only an average slowing of one-half beat a minute. (3) That the veins are compressed or emptied (Smith) is not substantiated by other observers, and repeating the experiments of von Schrötter⁶ and Hill and Macleod³ I have watched the circulation in the web of a frog's foot under the microscope while the pressure was being raised to $+ 30$ pounds, also during decompression, and certainly there was no perceptible change in size of the small vessels nor in the rate of flow; nor is any change in a man's radial pulse noticeable by palpation. (4) The effect of pressure on the arterial tension has been variously described; Oliver,⁵ of England, claims that the pressure is heightened; others say that it is lowered. My own series of sixteen cases, observed by means of the Janeway modification of the Riva Rocci sphygmomanometer,

shows an average lowering of only 2.5 mm., which is practically negligible; certainly there is no increase. (5) The respiration, claimed by Oliver and Smith to be quickened, according to von Schrötter is probably not altered in rate, or, if anything, slowed by one or two per minute; nor is the vital capacity changed (von Schrötter⁶), although Smith claims that the chest expansion is diminished. Personally I experience a tendency toward slight inspiratory effort. (6) Jemmett, of St. Louis, claims to have demonstrated increase in urinary secretion in two cases, but I can not learn of any such change according to the experience of many old air-workers. (7) Smith believed that the tunnel air, saturated with moisture, prevented sweating; but Hill and Macleod³ show that, so long as the body temperature is higher than that of the tunnel, evaporation will continue, and it is certainly my experience that the men do sweat on exertion in the tunnels. Did the temperature in the tunnel rise above 85° to 90° F. evaporation would be lessened and there would be some danger of heat exhaustion, of which there were several cases last summer. (8) Several writers state that the hollow viscera are compressed and that the men must habitually tighten their belts on entering the tunnel. I have failed to elicit this statement from any old workers questioned, and a series of waist measurements taken by me showed absolutely no change in girth, or in one case a slight increase, probably due to intestinal fermentation. (9) Hissing of the urine, or passing of gas per urethram, on leaving the tunnel, has never been heard of in my cases, although I have catheterized several patients suffering with the "bends" and have questioned many old workers.

Other Effects.—(1) Certainly there is a slight sense of exhilaration to one in the tunnel, and heavy, leather-shod rubber boots seem lighter as one climbs ladders and walks about. (2) Wounds bleed just as freely and heal just as quickly as in the open air. (3) The body temperature may be slightly raised (99.6° F.). (4) Many men say that the appetite is increased.

PATHOLOGIC EFFECTS.

Proceeding now to the pathologic effects of compressed air, one is first impressed with the fact that there are never any such manifestations while a man is entering or abiding under pressure, and that the disease is, in reality, one resulting from decompression. Although theoretically it is possible to occur in the locks during decompression, in our series of 1,419 cases we have encountered no such instance. The onset of symptoms is usually some minutes after arriving at normal atmospheric pressure. We found that over 43 per cent. of the cases began within less than one-half hour; 32 per cent. between 30 and 60 minutes, making 75 per cent. of all cases during the first hour. A few rare instances of delayed onset up to ten or twelve hours have come to our notice.

Incidence.—Our 1,419 cases occurred among 3,500 different individuals starting work at our tunnels, where the pressure has averaged over + 30 pounds or + 2 atmospheres, giving an incidence of 40 per cent. illness among all workers, which figure would possibly be doubled if every case of minor, transient pains and itch were recorded. This 40 per cent. represents cases severe enough to come under treatment at the medical office. The majority of cases occur among new men or among old workers who have been away for a period, showing that one may become, to a certain extent, habituated.

Causative Factors.—Undoubtedly the three factors of chiefest importance in the production of this disease, as

set forth by Paul Bert¹ in 1878, are: (1) Amount of pressure; (2) duration of exposure to pressure, and (3) shortness of the period of decompression. Other factors are the age and physical condition of the worker, general hygiene and ventilation.

Barometric and telluric conditions have been assumed by some men to be of moment, but charts kept by us for a period of months, setting forth the daily temperature, humidity, barometric readings, condition of the weather, and direction of the wind, have failed to show any constant influence on the incidence of cases of illness.

Young men from 20 to 35 years of age are preferred, and no one with any gross organic lesion should attempt the work. The Anglo-Saxon and the negro stand the work the best, while Poles, Slavs and Turks rarely do well; but this difference seems to me largely due to the generally flabby, underfed condition of the latter class, who seem lacking in resistance. Fat men do not endure so well as the slender, a possible reason lying in the fact, recently demonstrated by Professor Haldane, of England, that animal fat absorbs much more gas, under pressure, than the other body tissues. Arteriosclerosis is a serious defect. Constipation and working on an empty stomach certainly predispose to attacks of illness.

The length of the shifts, *ceteris paribus*, directly influences the number of cases of illness and should be regulated as follows: For pressures below + 30 to + 32 pounds, two shifts of four hours for each man; for pressures + 32 to + 38 pounds, two shifts of three hours, with an interval of three hours; for pressures above + 38 pounds, two shifts of two hours, with an interval of four hours. For very high pressures the shift must be correspondingly shortened.

The time occupied in decompression, i. e., coming out, is a most important factor, and for safety should not occupy less than eight minutes per atmosphere. Exercise of the arms and legs during decompression aids the circulation in eliminating the air and practically we find that there has been much less illness among the men from the time that a second bulkhead with locks was built 500 feet from the first one, and thus necessitating a break in the decompression and compulsory exercise in walking the distance between locks at half pressure. Severe exertion after coming out is said to cause "bends;" on the other hand, old workers often walk off an attack of "bends."

Symptoms.—The protean manifestations of compressed-air illness will appear in the following analysis of our 1,419 cases, which shows that in at least a third of the cases a combination of two or more of the symptoms was present. In locality, pains in the lower extremity, chiefly in the legs and about the knees, occur with greatest frequency, being present in 74 per cent. of the cases; next, the upper extremity, 38 per cent., chiefly about the elbow. In the extremities the right and left sides seem to suffer alike. Vertigo occurred in 7 per cent. of the cases; abdominal pains, in 5 per cent.; nausea, 2 per cent.; vomiting, 2 per cent.; numbness, 2 per cent.; general prostration, 2 per cent.; pains in chest, 2 per cent.; pains in head, 1 per cent.; pains in back, 1 per cent.; extreme weakness, or partial paralysis of an extremity, 2 per cent.; true motor and sensory paralysis, 1 per cent. (paraplegia); a peculiar blotchy, bluish mottling of the body, 1 per cent.

Other symptoms more rare are: dyspnea, or "chokes"; anesthesia; anesthesia dolorosa; retention of urine; exaggerated, diminished or absent knee-jerks; ankle clonus; spasticity; convulsions; unconsciousness; nystag-

mus; blindness; diplopia; deafness; ataxia; tongue deviations; localized edema, or emphysema; râles in the lungs; bloody vomitus; temperature elevation; pain in testicles and kidney region; fluid in the knee (probably not due to air); a hemorrhagic skin lesion, resembling erythema circinata, or iris, is occasionally to be seen and may appear after several days; toothache in carious or poorly-filled teeth; perforated eardrums; sinusitis, frontal, maxillary, or ethmoidal. Epistaxis is rare and easily accounted for by the existence of a coryza and the rough handling of the nose in performing valsalva. Also, there should be mentioned a very common pruritus corporis, or "itch," immediately on coming from pressure, especially if a man does not sweat freely; it is usually relieved by a hot bath.

Some of the more common groups of symptoms may be: (1) Pains in one arm and one leg, with or without numbness; (2) vertigo, or "staggers," with nausea, vomiting and frequently epigastric pain; (3) weakness and numbness of both legs, with or without retention of urine; (4) true motor and sensory paraplegia; (5) extreme prostration or collapse, with vomiting, rapid, weak pulse, mottling of the body, coma and death.

Fatality.—At the St. Louis Bridge work, Jeminet reports fourteen deaths in 119 cases, nearly 12 per cent. A. H. Smith,⁸ in 110 cases at Brooklyn Bridge, reports 3 deaths, or nearly 3 per cent.

At the first Hudson tunnel, among from 45 to 50 workers, 12 deaths occurred in a year, or 25 per cent. of all the men who worked, but this figure drops to less than 1 per cent. after the introduction of the medical air-lock by Mr. Moir.

Snell² reports 200 cases, with no deaths, at Blackwall tunnel. In our series of 1,419 cases, there was less than 1 per cent. mortality.

FATAL CASES.

Two patients with myelitis and paraplegia lived for several months, finally succumbing to septic complications. One patient seemed to improve for three days, then suddenly developed paraplegia, subcutaneous hemorrhages, went into collapse and died. The remainder all died within twenty-four hours from the onset, and with only two exceptions were unconscious from the start, or rapidly became so, presenting the symptoms of general collapse and heart failure, with vomiting and mottling of the skin. Hence, pain is not often complained of in the most serious cases.

Autopsies.—I have notes on 7 autopsies, of which I personally witnessed 4.

Free bubbles, or collections of gas, were found in the blood in all 5 of the cases in which autopsy was performed within eighteen hours after death. The 2 delayed autopsies showed no free bubbles.

Summary.—To group the gross pathologic findings, there were: Air collections, distending the right heart; air in the vena cava, in the mesenteric, meningeal and coronary vessels and generally distributed in the veins; bubbles in the cerebrospinal fluid; one case of edema of the brain; congestion of the liver and kidneys; interstitial emphysema of the lungs; minute hemorrhages in the cord, with myelitis; raised patches of gas beneath the mucous membranes of stomach and intestines; myocardial degeneration and a softening of the voluntary muscles; intense mottling of the skin.

Other lesions mentioned in literature include congestion of the cord and brain, actual splits or clefts between

the nerve cells, due to bubbles; thrombosis of the pulmonary artery; thrombosis of medullary artery of the femur, with resulting necrosis of the bone.

TREATMENT.

Prophylaxis.—This embraces the selection of men who are physically fit; proper regulation of the length of the shifts and the period of decompression, *v. s.*: Proper attention to the general hygiene of the body functions; not entering the tunnel with an empty stomach, and on coming out the use of hot coffee and a warm bath and warm clothing, and the avoidance of cold drinks.

Active Treatment.—The only active treatment of compressed-air illness which is at once the rational treatment, and by all odds the most efficient, consists in recompression in a specially constructed lock, called "the medical air-lock." We have two such locks adjacent to the physician's office in Thirty-fourth street. Each is similar to the tunnel lock in shape, but is divided into two compartments, the inner one corresponding to the tunnel, the outer corresponding to the entering lock. By this arrangement the physician or attendant can go in and out to the patient without disturbing the pressure in his chamber. The inner chamber is fitted with two wire couches, a telephone, electric lights, clock, pressure gauge and glass porthole, through which the patient may be watched. It is heated by electricity to avoid danger of a steam leak.

It is, indeed, gratifying and little short of miraculous to see a man completely paralyzed from his waist down or bent double with excruciating pains in his abdomen or legs placed in this lock, the pressure turned on, and long before the tunnel pressure is reached the paralytic is walking about, and the sufferer is smiling.

In treating the patients, the pressure is rapidly raised to tunnel pressure, and at once very slow decompression is instituted at the rate of two minutes to one pound. Frequently after this treatment the pains return and recompression once, twice or more times is advisable. For persistent pains, defying recompression, counter-irritation, heat locally applied, massage, hot baths or exercise, often accomplished the desired result; also the Faradic current is frequently of benefit. Very rarely anodynes are necessary; in these cases the pains may continue for two or three days and then finally wear off. The use of ergot, as advocated by A. H. Smith, I have never seen do the slightest good, and, inasmuch as, in most of his cases, he combined it with plenty of opium, and the men recovered in from one to three days, I believe he merely deadened the pain and allowed Nature to effect the cure. His theoretical indication for the use of ergot I believe is fallacious.

Of our cases, 1,343 of the 1,419 patients were treated by recompression, complete relief being afforded 869, or 64 per cent.; 50 per cent. were completely relieved by one recompression; 28 per cent. were so much relieved as to be able to go home and carry out therapeutical measures, and only 8 per cent. failed to get relief at all.

But note that only in 2 cases of the 1,343 did the men not experience entire relief while under recompression, although the pains returned in some cases.

The cases of collapse and cardiac weakness naturally received appropriate stimulation. Retention of urine demands the catheter, and mild abdominal pains may sometimes be relieved by the administration of aromatic ammonia, ginger, peppermint, etc.

In our 21 cases of true paralysis, paraplegia or monoplegia, 13 patients were relieved entirely by one recom-

⁸ Cases of Caisson Disease. Med. and Surg. Reports, Presbyterian Hospital, New York, 1896.

pression; 4 cases cleared up in from 1 to 10 days, 2 persisted for from 2 to 6 months; 2 resulted fatally after several months from complications.

THEORIES REGARDING ETIOLOGY.

We are firm believers in the gas emboli theory, which is the one more commonly accepted to-day. First suggested in 1857 by Hoppe-Seyler, it remained for Paul Bert,¹ 1872-78, to prove this by animal experimentation, later elaborated by von Schrötter,² Hill and Macleod,³ and others.

The theory rests on Dalton's law that: "The weight of a gas dissolved by a liquid is directly proportionate to the pressure," which law applies with only minor modifications.

When a man enters the air lock, his blood gradually becomes saturated, so to speak, with the larger amounts of nitrogen, oxygen and carbon dioxide, which are under tension in the air he takes into his lungs, and this absorption by the blood continues until the gaseous tension in the alveolar air and the blood is equal. As Langlois⁴ points out, 64 per cent. of the body tissue is water, and may be similarly saturated; but the more remote tissue fluids require a longer period for saturation than does the circulating blood. Hence, the time element of exposure to pressure enters into consideration.

Hill and Macleod,³ by analysis of the gases from the blood of animals, exposed to $6\frac{1}{2}$ atmospheres for varying lengths of time, show that after 30 minutes the nitrogen equals 8.41 per cent.; after $2\frac{3}{4}$ hours the nitrogen equals 11.61 per cent.

As nitrogen is the predominant element in the air, being nearly 80 per cent., we readily see that we have chiefly to do with nitrogen absorption.

"The amount of N. in solution in the body at normal pressure is 675 c.c., but at + 22 pounds it is double this, or 1,350 c.c.

"The O. is practically negligible; at most at 22 pounds there would only be 50 c.c. to get rid of.

"The CO₂ tension in the atmosphere is so feeble and it enters into compounds in the blood so readily that at 22 pounds the amount free is almost none" (Langlois⁴).

Now, so long as a man continues under pressure, his body fluids may contain great quantities of air in solution, without giving him any symptoms, and this is proved by the fact that "bends" never develop in the air.

What, then, happens on decompression? If the circulation is good and plenty of time is taken in decompression (variously quoted at from 3 to 20 minutes per atmosphere), the blood gradually gives up the extra amount of gas to the rarefying alveolar air, and similarly the tissue fluids yield their gas to the blood, whose gaseous tension is constantly falling.

On reaching normal atmospheric pressure, or rather a short time thereafter, the man should be entirely rid of the abnormal amount of gas. (It has been suggested that oxygen inhalation at the end of decompression would hasten the elimination of nitrogen.)

On the other hand, if the decompression period be too short, or if the cardiovascular system be inefficient, the gas can not be eliminated fast enough at the lungs, and is given off in the form of tiny free bubbles in the blood or body tissues, which process has been likened to the opening of a soda water bottle with effervescence of gas bubbles.

These small bubbles may, and often undoubtedly do, circulate without difficulty, and gradually are given off

by the lungs; but if they run together and form larger bubbles they interfere with the circulation as emboli, or by pressure in a nerve sheath, spinal cord or periosteum, cause paralysis or pains. The hasty ebullition of bubbles may rupture the delicate capillary wall and cause the tiny hemorrhages in the spinal cord, or vital centers found at autopsy; or may cause myelitis.

That this is not pure theory has been beautifully demonstrated by Hill and Macleod,³ who placed the web of a frog's foot against the window of their pressure cylinder in such a way as to be able to watch the capillaries through a microscope. Pressure was raised to 200 pounds, followed by rapid decompression, when they beheld tiny bubbles hurry by, soon collecting to form obstructing emboli; but immediately recompression was instituted the bubbles became smaller and were absorbed and the circulation continued normally.

I have attempted experimentally to produce air emboli in three guinea-pigs and three frogs, which were placed in the tunnel at 33 pounds' pressure and kept there for from 6 to 72 hours, then decompressed as rapidly as possible (1 min.), but no symptoms of "bends" were evident in any case, nor did the web of the frog's foot show any circulatory change. Two of the guinea-pigs appeared normal. The third guinea-pig, at an early (15-minute) dissection, showed some almost microscopic bubbles in the blood of the vena cava inferior. All the experimenters on gas formation in animals have used pressures of from + 5 to + 10 atmospheres, which it was not possible for me to secure.

As to the clinical evidence of free gas bubbles: In several cases in literature, observers have felt sure that they could detect an emphysematous crackle in the vicinity of a painful joint. Again, we have had a number of interesting cases of trauma with laceration and a subsequent extensive surrounding emphysema, subcutaneous or intracellular; but the query here is: Did the air enter through the wound or was it given off from the extravasated and stagnant blood? Possibly both, although I must acknowledge that I have never detected emphysema in the cases of hematoma without laceration.

The presence of free gas bubbles at our autopsies, and in animals experimented on, seem indisputable facts; but if evidence be required in the living subject I have been fortunate enough to obtain some. Recently two very similar cases of persistent pain in the leg came under my observation. In each case, by very careful palpation, over a slightly raised, non-inflammatory swelling, above the ankle, over the inner surface of the tibia, I detected a soft billowy fluctuation, with the faintest indication of crepitation. In neither case had there been any trauma and the skin was intact. In each case the leg was submerged in water.

An aspirating needle was partially filled with alcohol and all the air forced out, and with the entire aspirator and operator's hand also submerged the swelling was punctured and the plunger drawn, and not a drop of blood came in either case, but a succession of bubbles of clear gas streamed up through the alcohol.

In one case, on moving the needle about, there was the gritting sensation of bare bone in all directions, and the collection of air was manifestly beneath the periosteum.

OTHER THEORIES.

The carbon dioxide theory, held by Snell and some others, regards the increased amount of carbon dioxide as responsible for the symptoms, by poisoning and by interfering with tissue metabolism. A chart kept by Dr. McWhorter at the East River tunnels for months,

9. Hygiene Generale et Applique, Paris, 1906, I.

with daily carbon dioxid analysis from the tunnel air, showed variations of from .04 per cent. to .10 per cent., averaging .07 per cent.; but no relationship could be noted with the incidence of illness in these tunnels. Hall and Greenwood⁴ have themselves been in air of .62 per cent. carbon dioxid without ill effects.

Oxygen Poisoning Theory.—This theory is based on the experiments with animals subject to high pressures of pure oxygen, i. e., from + 5 to + 10 atmospheres, which usually kills them, and some of the symptoms faintly resemble rare cases of "bends." One observer claims that the carbon dioxid tends to inflame the lungs and cause pneumonia and may be responsible for other symptoms.

I believe that the one fact, that compressed-air illness never develops while a man is under pressure, is sufficient to entirely discount any theory of poisoning either by carbon dioxid or oxygen. Also 99 out of 100 cases of illness bear not the remotest resemblance to the toxic effects of either carbon dioxid or oxygen.

Cold.—Trieger's theory of loss of body heat on decompression with a consequent "catching cold" is insufficient, although it may be an element in disturbing circulation and so predispose to "bends."

Pressure.—The mechanical pressure theory is the greatest opponent of the gas emboli theory, and has for its advocates Pol, Watelle, A. H. Smith and others, the idea being that the pressure on the surface vessels drives the blood into the skull and spinal canal, causing congestion or even hemorrhages in the central nervous system. According to Corning, of the Hudson tunnel, on decompression this congestion is changed into an anemia by the rush of blood to the peripheral vessels.

What I have already stated about the peripheral circulation and blood pressure, during compression, demolishes many of the premises of this theory. Also, why do not the symptoms of nervous congestion manifest themselves in the air? von Schrötter killed and dissected animals in the compressed air and saw no evidence of any such congestion.

And, lastly, this theory, as also the others just mentioned, fails utterly to account for the liberation of a single bubble of air; on which point our observations and the autopsy findings seem absolutely conclusive.

If we hypothecate the emboli theory, the rationale of the recompression treatment is at once apparent, for by recompression we immediately give to the blood and body fluids their increased ability to take into solution the obstructing or offending bubbles, and by slow decompression the gas is gradually eliminated at the lungs.

CONCLUSION.

Several points suggest themselves as demanding further inquiry and explanation. Why can a man, working with impunity for months, one day develop "bends," under precisely the same general conditions? Why is a new man more susceptible than those who are accustomed to the work? Is there a condition of the blood which retards the elimination of the gas? Why are symptoms sometimes delayed so long as from six to twelve hours?

These and many other problems in the study of aëropathy will doubtless soon be solved in these days of extensive compressed-air operations, furnishing, as they must, ever greater opportunities for clinical and laboratory observations.¹⁰

10. Other articles which may be consulted are those by Hermann, *Über Caisson Krankheit*, Samml. klin. vorträge, 1902; C. J. Aldrich, *Medical News*, November, 1904; Henry Brooks, *Caisson Disease*, Long Island Med. Jour., April, 1907.

Clinical Notes

DERMATITIS EXFOLIATIVA NEONATORUM.*

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That this is a rare condition may be inferred from the little that is known of it and its cause. In reporting a case before the Rochester Academy of Medicine in 1904 I stated then that it was the only one I had ever seen. Dr. Rotch, in his book, says: "I have myself seen but one case in which it seemed to me that this diagnosis of dermatitis exfoliativa neonatorum could reasonably be made."

Since making that report several other cases have come under my observation attended by such dramatic conditions as to bring the subject more vividly to the minds of those interested than any words of a reader could, and as the number of those who had the opportunity to observe them was limited, I am constrained to make this additional report at this time.

Exfoliating dermatitis in the new born is a definite affection which was first described by von Rittershain in 1878, and stated by him to be a septic process, self-limited, and accompanied by definite characteristics. It occurs in children from one week to one month old, generally during the second week, and is known by the common name of Ritter's disease. von Rittershain says that it begins in the face generally about the mouth as a diffuse erythema, and spreads more or less rapidly over the entire body. The epidermis separates with slight or no serous exudate underneath and leaves a deep beefy red shining surface which dries in a short time with the formation of thin dry crusts or scales. There is apparently very intense irritation attendant on the course of the disease and more or less fever. There is generally some gastrointestinal disturbance. The upper layer of skin separates very easily, often coming off in large sheets, especially where subject to any friction. When it has passed to the drying stage and the crusts are removed, there follows a furuncular eruption of greater or less severity, which may sometimes become phlegmonous.

The duration of the acute trouble is about ten days, after which time the surface is covered with a fine papular eruption which has a tendency to become eczematous. The question of prime importance in this discussion is, not so much the character of the disease, as a consideration of its cause and its bearing on the relation of one patient to another, and it is that phase of the question that I shall emphasize.

CASE 1.—Infant, D., female, born July 25, 1904, after a very rapid but otherwise normal labor. The mother had an uncomplicated puerperium. The baby was breast fed and the establishment of functional routine was normal. The last regular visit of the physician was August 4, when the child was ten days old. On August 6, when the child was twelve days old, he was called because of a purulent discharge from the umbilicus, together with swelling and intense redness which radiated for some distance over the abdomen. The abdominal wall was very tense and the child was crying constantly. This condition had been observed the day before. A rigorous disinfection was performed and a compress wet with mercury bichlorid 1 to 1,000 was applied. In the afternoon of August 7 an intense redness was noted about the mouth, extending to the cheeks, with some spots of erosion and a few very small blisters. The child was very restless, crying all of the time, and the hands had to be restrained. At this time a diagnosis of eczema was made and Lassar's paste was applied to the

* Read before the Monroe County Medical Society, May 21, 1907.