Remarks

ON

"COLDS" AND THE INFLUENCE OF THE
ATMOSPHERE ON THE NASAL
MUCOUS MEMBRANE.

BY LEONARD HILL, M.B., F.R.S.,

DIRECTOR OF THE DEPARTMENT OF PHYSIOLOGY, MEDICAL
RESEARCH COMMITTEE.

EPIDEMICS of "colds" are most common when the humidity of the atmosphere is great, and the temperature variable but on the whole cool—when the weather is raw with thawing snow, or strong winds blow charged with cold rain, and the ground is wet and cold. Cold dry weather and strong drying winds do not favour these epidemics. Men living open-air lives are free from "cold" whatever exposure to extremes of weather they undergo—for example, sailors on long voyages, arctic travellers, troops at the front. The health of the navy at sea in war is better than in peace; the sailors are far less exposed to temptation to over-indulge, and to infections from the civilian population in port. Shackleton in his antarctic expedition recorded a single outbreak of "cold" after the opening of a bale of clothes packed in London. Men taken from shop or office, turned into soldiers, and put under canvas, escape the "colds" from which they suffered in civil life. When children after the holidays return to school, epidemics of "cold" usually begin to run through the community. In the holidays they may paddle all day in the sea, bare-legged, exposed to far greater cooling than at school, but they do not suffer from "colds" then. The "colds" begin when the weather confines them in shut-up and artificially warmed schoolrooms and places of assembly. The latter are the happy hunting ground of the infecting microbe, which does its work while the little innocents raise their voice in the morning hymn. A certain propinquity is required in order that the infected saliva spray sneezed, coughed, or spoken out, may be carried from a "carrier" to another victim. Out of doors folk do not crowd so closely, and the ventilation is very much greater; the saliva spray is blown away, and the infection cannot be massive, as it may be indoors or in railway carriages, where the atmosphere is comparatively still.

But this is not the whole story. Why do certain weather conditions cause epidemics to sweep through the communities of our cities? Why are those who live an outdoor life relatively immune—hardened—both to weather conditions and infection? What is the nature of the hardening process set up by exposure to weather and cold baths? In spite of the popular opinion to the contrary, it is clear that exposure, even to extremes of cold, by itself does not occasion "colds" or pneumonia. Shipwrecked folk, exposed almost to that point of chilling which stops the vital functions, do not after rescue suffer from coryza or pneumonia; neither do the troops exposed to the severest hardship in the waterlogged trenches. "Trench foot" seems to be the combined result of local chilling and waterlogging of the skin. Dry cold can be withstood very well, or prolonged exposure to salt sea water. In the case of trench foot it is the osmotic conditions of the tissues which are upset by the insoaking of rain water into the chilled skin, while the tissues are poisoned by the products of bacteria which multiply within the confinement of the boot and stocking. A local damage thus results from prolonged and extreme exposure to wet and cold. On the other hand, the troops so exposed are singularly free from pneumonia, "colds," and epidemics of the influenza type.

The domestic animals—cow, pig, horse—with a relatively scanty covering of fur, not only withstand, but thrive on, continued exposure to wintry weather in the fields, or in cold, draughty byres. Stock raisers know that artificial means of heating cannot be used with success. Fowls will not thrive in artificially heated pens. The incubator chick is not so robust as the one hatched by the hen. So is it with the child coddled in heated rooms at home and at school.

Acute rhinitis or coryza, the common cold, may be caused by bacterial infection; by dust—for example,

cycling in the dust of motor cars; by a chemical irritant—for example, sulphurous acid from furnaces; the poison gas cloud of chlorine suffocates by causing the outflow of fluid in the air passages; by the pollen of certain grasses. There is also a class of people who suffer from a nervous derangement of the nasal membrane, from vasomotor rhinitis or paroxysmal rhinorrhoea as it is called. The nasal reflexes of such people are unduly excitable—hyperaemic patches may sometimes be seen on their nasal mucous membrane. Sudden changes of atmosphere—a draught—may provoke in these an acute paroxysm. These people are pathological, hypersensitive, but it is probable that their noses have a great influence on the habits of the nation. The laity do not distinguish causes. It is manifest that some people are acutely affected by draughts, and therefore draught becomes popularly considered the chief cause of "colds." Nursery and family tradition rules habits, and tradition is usually at least half a century behind science. Science may beat against the door but tradition holds it fast.

It is generally believed that more nasal catarrhs are contracted through cold feet than in any other way, and yet soldiers whose feet are chilled to the local death of tissues do not have "colds" in the head therefrom. Under what conditions does chilling of the feet inflict punishment on the nasal membrane? and how is it influenced by conditions of humidity and draught? These are questions which are well worthy of inquiry, but little attention do they seem to have received so far.

F. F. Muecke and the writer¹ drew attention nearly three years ago to the appearance of the nasal mucous membrane when the subject is exposed first to outdoor conditions, and secondly to those conditions of heating and ventilation which are not uncommon in rooms. Out of doors the wind moves at a much greater velocity at head than at foot level, owing to friction of the moving air against the ground; the ground, too, is warmed by the sun. As a rule, then, excepting such unpleasant conditions as pertain to thawing snow, the head is cooled at a greater rate than the feet. Cool breezes blowing round the head, the radiant heat of the sun, and a warm ground to stand on, are the ideal outdoor conditions. The healthy mucous membrane of the nose, examined by aid of a speculum, under these conditions appears pale and taut. If touched with a probe it does not pit, and there is no thick secretion upon it. Indoors, in those conditions which are unfortunately only too common, when the feet are chilled by draught blowing over a cold floor, and the head is immersed in warm stagnant air, the nasal membrane appears swollen, congested, and covered with thick secretion. A probe pushed into the swollen membrane forms a pit, showing how boggy it is, and the airway is so diminished that a person with a spur of bone or any kind of obstruction cannot breathe through the affected nostril. Warming the feet at a fire at once relieves the congestion and does away with the obstruction, so that the airway again becomes free. It is this congestion and swelling of the nasal membrane, and no doubt also of that of the air sinuses opening into the nose, which largely causes the feelings of stuffiness in the head and headache felt in crowded, overheated places of assembly. This headache is generally, but erroneously, attributed to the absorption of chemical poisons supposed to be present in the stuffy air.

In the chamber of the House of Commons the ventilating current is driven up through the floor in such a way as to cool the members' feet, while their heads are exposed to more stagnant air. Cold feet and stuffy heads result—just the wrong conditions for legislators. The thermometer, it is true, shows a uniform temperature of 63° F.; but the katathermometer,² an instrument invented by the writer for measuring rate of cooling at body temperature, shows that the members' feet are cooled at a rate which is 50 per cent. or more greater than the cooling of their heads. The writer has his left nostril obstructed by a deflected septum. Sitting on a bench in the House of Commons he found his left nostril became completely obstructed in the course of a very few minutes. During the inquiry of the Ventilation Committee of the House of Commons he was allowed to make experimental alterations in the system of the ventilation in one part of the chamber; closing up the floor inlets there, he introduced air at the Gallery level. Under these conditions his feet were warm, his head agreeably cooled by a slight and grateful movement of the air, and his nasal airway unobstructed. Changing to and fro, from the part ventilated on the old system to that

ventilated by the new, his left nasal airway each time became obstructed by the old, opened by the new.

An easy and striking way of demonstrating the change in the nose is to install in a small shut-up room a gas fire fitted with no flue, so that all the heated air escapes into the room and rises into the upper part. Then with the aid of mirror and speculum examine the noses of, say, half a dozen subjects who first have been in the open air, secondly have been for some minutes in the room. A properly flued gas fire, which warms the floor and feet by radiant energy, will of course put the nose again into good condition. Toasting the feet at such a fire immediately relieves the nasal congestion and opens the airway.

Cold feet *per se* do not have this effect on the nose. The writer has observed in himself, when walking in melting snow or cycling in a cold wind along snow-covered roads, that his feet may be most uncomfortably cold, but his left nasal airway is wide open. His head, under these outdoor conditions, blown upon by the cold wind, has been as cold as his feet. It is the indoor conditions of cold draughty floor and warm stagnant air round the head which produce the congestion, swelling, etc., of the nose. These are conditions entirely opposed to the natural conditions out of doors.

A leg put into warm water responds by local vaso-dilatation; a leg put into cold water becomes pale with constriction and may even shiver, while the rest of the body is warm and keeps quiet. Out of doors the cold air is inhaled, and the naked face more than any part feels the cooling effect of the wind. The nose then is made taut—constricted—even though the feet be cold. Indoors, when the feet on a draughty cold floor are chilled and constricted, and the head is in a bath of warm stagnant air, the nose becomes congested, both by the local effect of the warm air and also by the blood, which is determined to all dilated parts from the cold-constricted feet. Warming the feet, therefore, at once lessens the congestion of the nose and opens the airway.

The ideal method of warming and ventilating rooms would give us abundant radiant heat, a warm floor, and agreeable movement of cool air. Such conditions are found in one-storied foundries where the roof openings are designed of ample size. The health of men engaged in foundries is very good. The Roman hypocaust gave a warm floor, and with unglazed openings must have secured warm feet and cool heads.

Open fires, and properly flued modern gas fires, give us radiant heat, and a warm floor within the range of this heat. We can toast the feet at these, and much of the hot air goes up the chimney. The so-called radiators, gas or steam, and artificial lights, together with the heat and moisture from the bodies of people, make warm and humid the upper strata of rooms, and afford the conditions bad for the nose.

Suppose the nasal membrane has become swollen, congested, and covered with thick secretion in these bad conditions, and the subjects go outside again into the cold air; then the membrane at once becomes pale, owing to vaso-constriction, but for some little time it remains swollen and boggy, pitting on the touch of the probe. I believe that these conditions of the nasal membrane have a great deal to do with the "catching of colds." In crowded rooms infection takes place from mucous spray, sneezed, coughed, or spluttered out in speaking. The inhaled bacteria will be caught by the swollen mucous membrane covered with thick secretion. In cold outside air not only is the membrane kept taut, but the flow of blood through it is rapid, for the inhaled air has to be warmed up and moisture rapidly evaporated from the membrane so as to saturate this air at body temperature. Thus more lymph comes out into the membrane from the blood vessels, and this contains the immunizing substances. The offensive bacteria are washed away or destroyed and thus kept out. On the other hand, in the condition where the membrane is covered with thick secretion, congested and boggy, there is a medium more suitable for the bacteria to settle and grow on, for it is boggy and stagnant, not flooded with fresh lymph, particularly when vaso-constriction takes place on passing from an over-hot, moist atmosphere into the wintry outside air.

The washing away of bacteria by the outflow of secretion must be one of the most important methods of defence. In the alimentary canal poisonous concentrations of substances—for example, sugar—are diluted and kept away from the living membrane by the secretion of

mucus. In the respiratory tract fluid is poured out to dilute and wash away a chemical irritant such as chlorine. Now the rate of evaporation from the nasal membrane must be of first importance in promoting the outflow of lymph through it, and the factors which determine this are worth considering.

At 30° F. air saturated with water vapour holds 1.9 grains per cubic foot. At body temperature the saturated air holds no less than 19 grains. Exhaled air is warmed up to, and saturated at, body temperature, and a cubic foot of air is breathed by a resting man in about four minutes. Thus the nasal membrane, if it saturate air inhaled at 30° F., will evaporate $19 - 1.9 = 17.1$ grains of water (about 1 c.cm.) every four minutes. If the man is taking exercise the nose will evaporate this amount every minute, or even every half-minute, owing to the increased respiration. This means that two or three ounces may be evaporated from the nasal membrane in the course of an hour's exercise on a wintry day.

The argument so far has taken it for granted that the nose does it all—it may not; when exercise is taken other parts of the airway may share in the evaporation and beneficent outpouring of lymph.

Now let us turn to the atmosphere in spinning mills or weaving sheds saturated, say, at 75° F. Such air holds 9.4 grains per cubic foot, and to saturate it the nose will only evaporate 9.6 grains a minute—a little more than half the above amount of water. I will set out the figures for the whole range of temperatures from 30° to 90° F.

TABLE I.—Amount of Water in Air Saturated at Various Temperatures.

Air saturated at 30° F. holds 1.9 gr. per cub. ft.			
"	"	40° F.	" 2.8 "
"	"	50° F.	" 4.1 "
"	"	60° F.	" 5.7 "
"	"	70° F.	" 8.0 "
"	"	80° F.	" 10.9 "
"	"	90° F.	" 14.8 "
Air saturated at body temperature holds 19.0 gr. per cub. ft.			

It is of course the rapid increase in the containing power of the air, as the temperature rises, which enables us to keep our bodies cool, by sweating, in saturated atmospheres when the temperature is even 80° to 90° F. There is a big difference between 10.9 at 80° and 19 at body temperature, and on this the tolerance of humid tropical conditions depends.

Under ordinary indoor conditions, with a temperature of about 60° dry and 55° wet bulb, there will be about 4 grains of water vapour in each cubic foot of air; at 30° F. there is 1.9 grains. We see, then, that the difference between the evaporation from the nose on passing from wintry air to the indoor conditions is about 12 per cent.—17 grains per minute in the one case, 15 in the other. In the spinning mill at 75° F. (saturated) the evaporation is about 42 per cent. less than out of doors on the wintry day.

The demands made on the circulatory and evaporative mechanisms of the nose are, then, great on changing suddenly from this warm atmosphere to the cold outdoor conditions. A much greater supply of blood is required to keep the nose warm, and a greater passage of lymph to keep up the evaporation in the cold outdoor air. No wonder sudden changes of conditions from over-hot, humid rooms to raw, wintry weather strain the vaso-motor and secretory mechanisms and help to cause "colds." No wonder, when "colds" are upon us, that it is advisable to keep to one uniform temperature and stay indoors—as we cannot very well stay out. These sudden changes are quite unnatural to the wild animal, but the dog shares them with civilized man. The dog, however, is another story—he is not, as a rule, crowded with his fellows indoors; he hardens himself by wearing no clothes, is less infected and more immune, like the man whose work is in the open air. Our feeling of comfort depends very closely on the effect of atmospheric conditions on our skin and nose. It is probable that we are sensitive to any change in the rate of evaporation from the nasal membrane. Humid air must check evaporation until the nasal membrane has warmed up the air and so made it capable of holding more moisture. This is particularly so in the case of mist or fog; the cold particles of water must first be evaporated before any evaporation from the membrane can take place. The cold particles also chill the nerve endings in the cold spots of the skin, while the moisture

adsorbed by the clothes lessens their heat-retaining properties. Hence our discomfort and the chilly effect of a fog. Relatively dry air, on the other hand, does not check evaporation or cool the nerve endings in the same uncomfortable way.

Miserable raw wet weather, wind-driven rain or sleet, impels us indoors, and makes us shut up windows and crowd in heated rooms. Exposure to infection is thus made greater while the inability to take open-air exercise in such weather may diminish the vigour of health, which depends so intimately on the rate of metabolism and the influence of exercise on the digestive organs. There is evidence that the prevalence of cases of cerebro-spinal fever is associated with cold, wet weather and the crowding of soldiers in the humid, confined atmosphere of huts and billets.³ Under canvas the ventilation is far freer, and the atmospheric conditions favour evaporation from the nasal membrane and prevent its congestion. In stove-heated huts crowded with men, with damp clothes steaming, the temperature and humidity rise to heights which are quite impossible under canvas.

The effect of the cool outdoor air in promoting the flow of blood through the nasal membrane is no less noteworthy than that of evaporation. A greater blood flow is not only required to maintain the evaporation, but to keep the membrane at body temperature.

The specific heat of dry air at constant pressure, and 20° C. is 0.24—that is to say, 1 gram of air takes 0.24 small calorie to warm it up 1° C.; 1 gram of air has a volume of 778 c.cm. measured at normal pressure and temperature. To warm to body temperature each litre of air breathed, then, approximately 0.3 small calorie is required, that is for each degree centigrade through which it is warmed.

If the atmosphere is at freezing point, 11 small calories will be required for each litre breathed—say 77 small calories a minute for the resting man. At 65° F. this amount will become 38; at 75° F. only 26. At ordinary room temperature, then, only half the heat will be required to warm the air breathed as at freezing temperature.

Taking exercise out of doors on a cold winter day and breathing 40 litres per minute, a man may lose 4 to 5 large calories of heat per minute in warming the air he breathes, against 0.38 sitting in a room at 65° F. We see, then, how much more blood is required to keep the nose warm in the outdoor conditions.

Herein lies one explanation of the benefit of open-air exercise, sleeping in the open air, etc. The greater circulation in, and evaporation from, the nasal membrane we have carried out some observations on the temperature of the nose and the fluid secreted by it, first indoors and then outdoors exposed to cold winds.

To test the views put forward above as to the circulation in, and evaporation from, the nasal membrane we have carried out some observations on the temperature of the nose and the fluid secreted by it, first indoors and then outdoors exposed to cold winds.

If the temperature within the nose is maintained almost at body temperature not only indoors but when the face is blown upon and cooled by strong wintry winds and cold air is breathed, it is clear that much more blood must then flow through the nasal membrane per minute. Now this is what is found to be the case in observations carried out on different days and on four subjects. The temperature was recorded by inserting a delicate flat-bulbed thermometer far up, so that the bulb lay below the inferior turbinate.

TABLE II.—Temperature of Inside of Nose under Various Conditions.

Subject.	Temperature within Nose.		Temp. on Roof.	Temp. Indoors.
	On Roof.	Indoors.		
L. H. ...	37° C.	35.5°-36° C.	10.4° C.*	15.9° C.
F. ...	34.5°	35°	"	"
W. ...	34.5°-35°	35°	10.1°	16.9°
B. M. ...	36°	35.5°-36°	2.2†	16.3°
F. ...	37°	36°	"	"
L. H. ...	36°	36°-36.5°	"	"
B. M. ...	36°	35.5°-36°	"	"
L. H. ...	35°	35°	;	16.2°
B. M. ...	35.5°	35.25°	;	"

* Strong cool wind. † Cold wind. ‡ Snowstorm, cold wind.

We conclude, then, that when out of doors a man has much more arterial blood flow through his nasal membrane per diem than when indoors in heated atmospheres.

It is a common observation that exposure to cold wind makes the eyes water and the nose run—signs of that flood of fluid which is poured out to keep exposed surfaces wet and warm.

The secretion from the nose was measured in a way which gives a rough but none the less trustworthy indication. We passed a weighed probe covered with absorbent cotton-wool up the nose, left it there for three minutes, and then weighed again. A number of such weighed probes were first made ready; then a probe was passed up the nose to mop up whatever secretion might be there; after this we waited three minutes and then the observation went forward, first for three minutes indoors, and then for three minutes outdoors on a roof exposed to the wind. The results obtained were as follows:

TABLE III.—Amount of Nasal Secretion under Various Conditions.

Subject.	Secretion taken up by Probe in Three Minutes.		Temperature Indoors.	Temperature Outdoors on Roof.
	Indoors.	Outdoors on Roof.		
F. ...	0.119 grm.	0.269 grm.	16.2°	2.2°; snow, cold wind.
W. ...	0.065 ..	0.186 ..	"	" "
L. H. ...	0.173 ..	0.253 ..	15.9°	10.1°; cold wind.
B. M. ...	0.063 ..	0.208 ..	"	" "
B. M. ...	0.10 ..	0.352 ..	16.3°	Snowstorm, cold wind.
L. H. ...	0.067 ..	0.123 ..	"	" "
B. M. right nostril	0.135 ..	0.173 ..	16.2°	Snow'g, cold wind.
B. M. left nostril	0.029 ..	0.286 ..	"	" "

The last pair of observations on B. M. are of interest because the right tear duct was blocked and the right side of the nose "stuffed up" as the after-result of a "cold." We only put stress on the general sense of the figures, not on the actual amounts given as representing the secretion caught by the probe. We believe the increase out of doors was generally under-valued; in the case of W., for example, when exposed to cold wind, the secretion ran down the probe and dropped off its end—the wool had become too wet to absorb it. The internal structure of the nose is so arranged that the secretion mostly runs backwards into the pharynx when the head is held in the normal position, and it is only the anterior part which furnishes the secretion which runs to the tip of the nose and enforces the use of the handkerchief.

The above figures, then, confirm the theoretical views which have been set forward, and before laying down the pen we would point out that the conditions which we have discussed in regard to the nose no less pertain to wounds; the flow of lymph through, and evaporation from, the wound counteracts infection and hastens healing. A suitable dressing and ventilation are required to ensure the adequacy of lymph flow. The dressing must prevent premature closing of the wound by a scab. Sir Almroth Wright's salt treatment by osmotic force pulls out lymph with its immunizing properties, and the outflow washes away infecting bacteria. Now that the open-air treatment of wounds is extolled, the surgeon's attention may perhaps be directed to the problems of evaporation from, temperature of, and blood flow through wounds, in so far as these may be influenced, not only by dressing, but by the relative dryness, temperature, and movement of the atmosphere.

The writer is indebted to Dr. Benjamin Moore, F.R.S., for help in carrying out the measurements.

REFERENCES.

- ¹ *Lancet*, May 10th, 1913. ² *Trans. Roy. Soc.*, B, 207, 1916, p. 183. ³ Arthur Compton, *Journal of the R.A.M.C.*, November, 1915.

UNDER the will of the late Mr. Lewis R. Ross, the University of Rochester, New York, has received a bequest of £140,000, to be used for the establishment of a department of dietetics in which research work on foods will be carried out.