CHAPTER XXIV

THE AIR AND VENTILATION

376. Composition of air. — Every 100 parts of air are composed of about 20 parts of oxygen and 80 parts of nitrogen: $\frac{4}{100}$ per cent of the air is carbonic acid gas. Air contains water in varying amount. Some dust particles are always floating about, and also a few living germs of plants like those producing mold and yeast. These substances are found in all air, and none are harmful.

377. Ozone in the air. — There is a form of oxygen called *ozone* which is much more active than common oxygen. It can be made by passing a strong current of electricity through a tube of oxygen. During thunderstorms some is formed, which imparts a peculiar odor and exhilarating property to the air. Some is formed in pine forests, and to it the beneficial effects of the forests upon consumptives may be due. It is never found in any great amount in the air.

378. Argon. — It was discovered in 1894 that the part of the air supposed to be pure nitrogen contains a gas hitherto unknown, to which the name *argon* has been given. One per cent of the air is argon. Like nitrogen, it cannot be made to unite with any substance directly from the air, and so both act simply to dilute the oxygen. But, unlike nitrogen, it does not form a chemical combination with anything at all, but is always found simply mixed with the

air, or with a few other substances. Its discovery has not modified our ideas of the physiological effects of the air.

379. Dust in the lungs. — If the dust in the air is small in amount, it adheres to the moist surface of the nose and pharynx, and does not enter the trachea. If some enters the trachea, it becomes entangled in the cilia of the epithelial cells and is forced back towards the mouth and then coughed out. If the air is very dusty, some dust will enter the air sacs. Instead of letting it remain to fill up the lungs, nature has given the lymphatics the power to take the dust particles and to carry them to the nearest lymph nodes, where they are deposited and remain harmless.

380. Occupation diseases. — Even though the lymph nodes take care of inhaled dust, after a while the continuous irritation of the hard particles injures the delicate lining of the bronchi and air sacs, and causes bronchitis or asthma or pneumonia. Tool grinders are especially liable to the trouble, for the fine particles of stone and steel which fly off in their work and are inhaled, cannot be taken up by the lymphatics. Potters, miners, flax workers, and pearl button makers are all subject to lung troubles to a greater degree than workers in a dustless atmosphere. Those who work with quicksilver or phosphorus are liable to inhale the fumes and be severely poisoned.

381. Amount of oxygen needed to support life. — When inspired air contains less than 20 per cent of oxygen, a shortness of breath comes on, which is in proportion to the lack of oxygen. A candle will not burn in air containing less than 17 per cent of oxygen, while air containing only 15 per cent of oxygen will support life, but there will be great shortness of breath. In old wells and cellars oxygen is often replaced by carbonic acid gas, and men have been suffocated in them. A simple test of the safety of entering them is to lower a lighted candle into the suspected place. If it burns, there is surely enough oxygen to support respiration. When the amount of oxygen is diminished to ten per cent, animals die in a few moments with all the symptoms of suffocation.

382. Rarefied air. — Every square inch of surface, including that of the body, sustains a weight of fifteen pounds of air, but it is balanced by an equal pressure of air inside the body, in the lungs and stomach and other cavities, and so it is not felt. At high elevations there is less atmosphere pressing from above, and so the air expands and becomes lighter. Then a lung full of air will contain less oxygen. At a height of three and a half miles the air is only one half as dense as at the surface of the earth, and at the height of five miles it is almost impossible to breathe enough oxygen to sustain life. The lessened pressure upon the body disturbs the flow of blood, especially in the brain, and produces dizziness and fainting.

In mountainous regions the air is lighter and holds less moisture than in lower regions. It is also purer, for it is removed from the contamination of cities which crowd the lower waterways. So those regions are favorable for those suffering with lung diseases such as consumption. Probably a still greater benefit is derived from the respiratory exercises and the full expansion of the lungs which are necessary in order to obtain sufficient oxygen.

383. Effect of increased pressure of air. — In working under water in laying deep foundations for buildings, a large box called a *caisson* is sunk to the bottom, and into it air is forced so as to keep out the water. Men work within the caisson subjected to double or triple the natural pressure of air. Although more air is inspired with each breath, the blood does not seem to take up more oxygen than usual; but the increased pressure of air upon the arteries and veins produces great disturbances of the circulation. It is impossible to remain in the caisson longer than an hour or two at a time. In leaving the caisson, the air pressure must be diminished as slowly as on entering, so as to permit

the liberated gases to expand slowly. The ear drums could be easily ruptured by a quick change in pressure. Sometimes the pressure causes a severe injury of the spinal cord.

384. Effects of carbonic acid gas. — Carbonic acid gas itself has very little harmful effect upon the body. When air containing one fourth its bulk of carbonic acid gas is inhaled, the air sacs soon contain more of the gas than is found in the blood. Then carbonic acid gas is no longer given off, but remains in the blood and air sacs, and prevents the entrance of oxygen. Shortness of breath, unconsciousness, and death soon occur, caused mainly by the displacement of the oxygen. Carbonic acid has been used to produce insensibility during surgical operations but its effects cannot be controlled, and its use is unsafe.

When many persons are confined in a small room, the oxygen is speedily used up, and carbonic acid gas takes its place. When the amount of oxygen is diminished to ten per cent, death will occur, caused rather by the lack of oxygen than by the presence of the carbonic acid gas or other substances in the expired air. But discomfort will be felt long before the oxygen is diminished to an appreciable degree.

385. Foul air. — Besides the carbonic acid gas, the expired air contains a greater or less quantity of water and of foul-smelling vapors. Odors are constantly given off also by the skin of the most cleanly persons. In the air of a closed room in which several people have been for some time, there is a characteristic odor which belongs to man, just as certain odors are peculiar to different lower animals. These odors are very oppressive. They cause sickness in sensitive persons mainly because of their unpleasantness. This effect passes off when pure air is breathed. The heat of a closed room greatly intensifies the effect of the foul air.

386. Cause of bad effects of foul air. — No one thing can be found in stuffy air to account for all the bad feelings which it produces. The diminution of oxygen is too slight to produce noticeable effects, but the combination of heat and foul odors is very oppressive to persons not accustomed to them, while the carbonic acid gas tends to cause drowsiness and dullness of mind. Those who live in a foul atmosphere continually are usually too poor to buy nourishing food, and too busy to take exercise in the open air, and, moreover, are greatly overworked. These causes produce even more ill health than the foul air.

387. Bad odors. — Decaying matter gives off bad odors. Many animals and vegetables have an offensive smell, and in many manufactures foul odors are continually poured into the air. These odors in the air are seldom harmful, yet the source of the odors is usually dangerous to health, and the odors are given off as a warning. It is nearly always true, that harmful things have an offensive smell and taste. So a bad odor reveals a decaying body which might poison a well, or a disease which might be communicated to others.

Since odors are only signs, the danger is not past if only the odor is destroyed. Ammonia, carbolic acid, or perfumery may mask the odor, but they only obscure the source of danger.

388. Sewer gas. — Sewer gas is exceptionally offensive and penetrating. The odor is not especially harmful, but disease germs which are emptied into the sewer from sick rooms are easily carried with the gas. Usually the strong odor betrays the leak in the pipes before the germs have gained an entrance.

389. Cellar air. — Cellars are apt to be closed, so that little fresh air and light can enter. Decaying vegetables and other substances may accumulate in the corners. This makes a breeding place for disease germs, which may be carried up through the floors into living rooms above. A cellar should be kept dry, clean, and well aired.

390. Malaria. — Malaria, chills and fever, fever and ague, or intermittent fever, as the disease is variously called, is caused by germs which come from stagnant water or wet earth. The air in low localities within a few rods of a marsh may be full of the germs, while a hill in its midst may be free.

Drainage of infected ponds, or sleeping in the upper stories of houses, or removing to a hill overlooking the marsh, will probably overcome the infection. Newly turned earth or damp cellars may also be breeding places for the disease.

391. Night air. — There is a popular belief that during the night the air contains some harmful substance which disappears during the day. But the air of the early evening, which is supposed to be the worst air of the day, has been purified by hours of sunshine, while the air of early morning, which is supposed to be the best of the day, has been exposed to hours of the noxious influences of darkness. So the belief is a contradiction in itself.

392. Contamination of air by fire and light. — In addition to the impurities produced by breathing, the air of inhabited rooms is further rendered impure by fires and lamps. A tallow candle will consume half as much oxygen in a given time as a man. A lamp burning a pint of oil in an evening uses as much oxygen, and gives off as much carbonic acid, as a man gives off during a whole day. A stove uses an immense amount of oxygen, but the gases pass up the chimney. Candles and lamps often pour bad-smelling gases into the air.

393. Coal gas. — When coal is heated, it gives off a gas called *carbonic oxide*. Carbonic oxide is the main part of illuminating gas, and in a stove, burns with a blue flame. It is extremely poisonous when breathed. It unites with the hemoglobin of the red blood cells and destroys their power of carrying oxygen. Gas from a smoking coal stove or a leaking gas pipe may smother a whole family while they are asleep.

In treating a case of poisoning by gas, an abundance of fresh air should be admitted, and artificial respiration should be performed.

394. Germs of disease in foul air. — Disease germs may be breathed into the air. If the air of a room smells stuffy, it is a hint that the germs as well as the stuffy odors may be accumulating. Lung diseases are especially frequent among those who work in close rooms. The germs of measles, scarlet fever, and all other "catching" diseases, are also likely to accumulate in a close room. Sick persons often breathe out the germs of disease, which may reënter the body and continue the disease. Moreover, every discomfort retards recovery, so in sick rooms and hospitals a continuous supply of fresh air is especially necessary, while in every room the air should be changed often enough to prevent the stuffy odor from developing.

395. Consumption. — Tuberculosis of the lungs, or consumption, is an infectious disease, caused by the growth of living germs within the lungs. A person suffering with consumption is continually giving off the germs in the secretions from his air passages. His handkerchief contains millions of them. While moist they remain on the handkerchief or clothes, but when dry they may float through the air, and when inhaled may produce the disease. A consumptive is always a menace to other occupants of a room, especially if he does not exercise great care with the secretions from his nose and mouth.

396. Ventilation. — Continually replacing the impure air of a room with fresh air is *ventilation.* Nowadays, with air-tight rooms and closed stoves, openings need to be provided for the exchange of air. When, by breathing, the quantity of carbonic acid gas in the air is increased by one half its natural amount, other substances have also entered the air, so that it begins to be stuffy. When the

quantity of carbonic acid gas is doubled, the air is markedly oppressive. If the carbonic acid gas is increased to three times its natural amount, the air is too oppressive for comfort, and may contain enough germs of disease to be dangerous to health.

397. Computation of amount of fresh air. — About $\frac{4}{100}$ per cent of fresh air is carbonic acid gas. When $\frac{2}{100}$ per cent more of carbonic acid gas has been added to the air, the air begins to be stuffy and unfit for use. Suppose there is an air-tight room twenty feet square, and ten feet in height, and in it one man is living; the room will contain 4000 cubic feet. $\frac{2}{100}$ per cent of 4000 cubic feet is $\frac{8}{10}$ of a cubic foot, which is nearly the average amount of carbonic acid gas breathed out by the man each hour. Thus in an hour a man renders 4000 cubic feet of fresh air stuffy. In reckoning the amount of fresh air to be admitted to rooms, 4000 cubic feet per hour is the smallest amount which can be safely allowed. Therefore, if only one person breathes the air of a room twenty feet square, and ten feet high, the air needs to be wholly renewed each hour, and yet it contains enough oxygen to last a week. Fresh air is needed when the air of a room smells stuffy to a person coming from pure air.

398. Natural ventilation. — When air is heated it expands so as to fill more space. While a cubic foot of air at a temperature of 32° F. weighs about 1.2 ounces, at 80° F. it weighs about 1.1 ounces. So heated air, being lighter, tends to rise. The air is slightly warmed in breathing, and so tends to rise to the ceiling, while the cool air which enters the room remains near the floor. So the floor is usually cooler than the ceiling. If an opening is made near the ceiling, and another near the floor, the warm air of the breath will naturally pass out at the upper opening, and the cool fresh air will enter the lower opening. If only a few persons are in a room, the openings about windows and doors may be sufficient without special ventilation. If many persons are together in a room, the natural cracks and openings are not sufficient, but other openings must be made.

399. Methods of ventilation. — In ventilation a perceptible current of air must be avoided, for many people easily take cold when a single part of the body is cooled

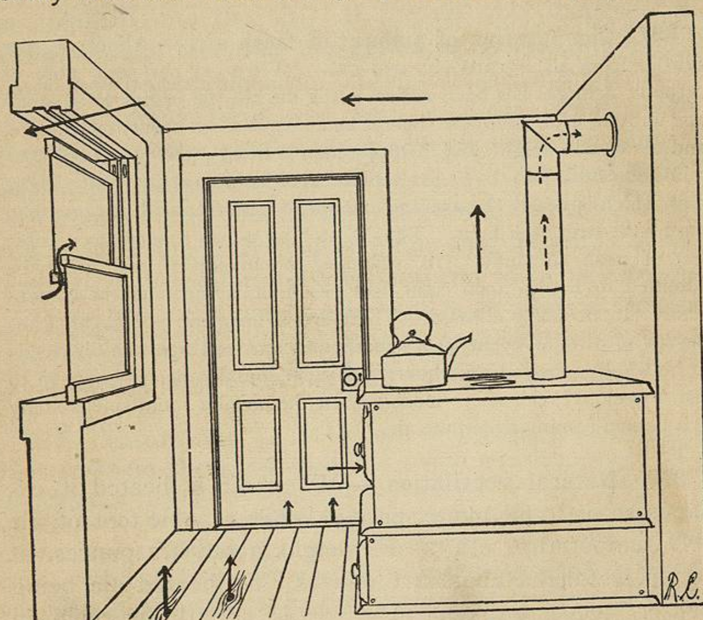

Diagram of the natural ventilation of a room.
The arrows indicate the direction of the air currents.

as by a draft. The air of a room can be changed only three times an hour without producing noticeable drafts throughout the room.

Many devices have been used to secure an even distribution of the incoming fresh air. The simplest is to lower the upper window sash. Warm air will pass out above the upper sash, while the cooler fresh air will enter between the two sashes, and will be given an upward direction toward the warmer air of the ceiling. There it will become warm, and finally will spread through the room like a gentle shower, instead of in a rushing stream.

A modification of the same idea is to raise the lower sash a few inches and insert a narrow board in the lower opening, so that a space is left between the sashes for the entrance of fresh air. The opening for fresh air may be through the floor under the stove, and thus the air will be heated as it enters the room. An open fireplace produces an upward current of air. An opening into the chimney flue near the ceiling will carry off much of the foul air.

In many churches a small part of the window is hinged so that its top can incline inward. If the window is placed about two thirds of the way between the floor and ceiling, the warm air will pass out above the window, while the cool, fresh air will enter below it. The inclination of the window will cause the air to flow toward the ceiling at first, where it will be warmed and scattered so that it cannot produce drafts upon the heads of the listeners. The addition of an opening in the center of the ceiling for the escape of the warm air forms an efficient mode of ventilation.

Hot air registers both heat and ventilate a room, if care is taken to admit fresh air to the pipes. The hot air passes up from the furnace because it is lighter. An opening in the window or into the chimney is needed to allow the air of the room to escape, so that the warm fresh air can enter.

Since on a cold day the air inside a room is much warmer than the air outside, a current of air will rush through every crack, so that good ventilation will be secured by a very small opening. Since on a warm summer's day the air inside and outside is nearly of the same temperature, large openings are necessary to effect the change of air.

400. Forced ventilation. — In large buildings, such as factories and theaters, warm fresh air is forced into the rooms by rotary fans, and the impure air escapes through openings in the ceiling. Thus the amount of heat and air admitted can be exactly regulated.

Another way of ventilating large houses is to suck out the impure air by rotary fans, while fresh warm air is admitted through small openings near the floor, thus preventing drafts. This method is being adopted in large buildings to the exclusion of other methods.

401. Filtration of air. — In forced ventilation the air is conducted through a large box, which has partitions arranged so as to break the air current and allow the dust to settle. In some, the air is passed through a layer of cotton. Cold air contains less moisture than warm air, and unless the air is given more moisture before it is sent to the rooms, it will be very dry. So a pan of water should always be kept inside the air box of a furnace.

402. Schoolroom ventilation. — Children are especially susceptible to unhealthful surroundings, and the air of a schoolroom, in which they spend the greater part of the day, should be kept pure. Pure air means clearer brains and better lessons, and may determine whether or not a child shall gain a sufficient knowledge to assure his success in life. In every half day of school it is well to allow a short recess in which windows and doors can be thrown wide open and the pupils sent out to get deep breaths of oxygen during play.

The upper sashes of all the windows on the side of the schoolroom away from the wind can be kept open a space so as to produce a gentle outward current of foul air.

If the upper sashes cannot be lowered, the lower one can be raised and a board inserted under it so that the only opening left is between the two sashes.

If registers or special means of ventilation are provided, they should be watched and regulated according to the needs of the air.

403. Purification of the atmosphere. — Although it is continually receiving impurities, the atmosphere as a whole never becomes foul, for the process of purification never ceases. First, the wind scatters the impurities to a height miles above our heads and over the seas to arctic and uninhabited regions, and thus dilutes the impurities. Second, rain washes out dust and germs and soot, and foul gases, and carries them into the earth. Third, sunlight destroys living germs floating in the air, and dries up stagnant sources of impurities. Fourth, plants, both on land and in the sea, absorb carbonic acid gas and restore the oxygen to the air. By these means the composition of the air is kept always the same.

SUMMARY

1. Air is essentially oxygen diluted with four times its volume of nitrogen.
2. When the amount of oxygen is diminished there is shortness of breath.
3. Exhaled carbonic acid gas is not poisonous in itself, but if present in great amounts it may keep oxygen out of the lungs.
4. Foul-smelling vapors, carbonic acid gas, moisture, and the contamination by fire and lights make the air of crowded rooms oppressive.
5. Coal gas inhaled may unite with the hemoglobin in the red blood cells so that they will not carry oxygen.
6. The main thing to be feared in close air of crowded rooms is the disease germs which may be breathed into it.
7. The air of a room should be changed often enough to allow 4000 cubic feet of fresh air to each person each hour.
8. Breathed air is warm, and tends to rise and pass out of cracks and openings in the upper part of the rooms, while cold, fresh air enters by lower openings.
9. In large buildings the foul air is either forced or drawn out by rotary fans, and fresh warmed air enters to take its place.
10. The atmosphere is purified by winds, rain, sunlight, and plants.

DEMONSTRATIONS

93. The harmlessness of carbonic acid gas can be illustrated by soda water, which is water in which a large amount of the gas is held under pressure. Open a bottle and inhale the liberated gas. Notice its pungent odor and taste.

94. Hold a candle or lighted match near each crack of the room and notice that usually the flame is blown towards the inside from cracks near the floor, while it is blown outward in cracks higher up.

95. Clap two blackboard erasers together to make a small cloud of dust, and watch the movements of the particles in a ray of sunlight, so as to detect the direction of the air currents in the room.

96. Show methods of ventilation by lowering the upper sash; by raising the lower and inserting a board in the opening. Show and explain the methods of ventilation adopted in the school.

REVIEW TOPICS

1. Give the composition of the air.
2. Describe ozone; argon; nature's method of removing dust from inspired air; and the dangers of inhaling dust in certain trades.
3. Tell how much oxygen is needed in the air to sustain life, and give a simple test to determine whether sufficient is present.
4. Give the effects of rarefied air, and air under increased pressure.
5. Give the effects of carbonic acid gas.
6. Describe foul air and its effects.
7. Discuss the meaning and the effects of bad odors; of sewer gas; of night air; and of cellar air.
8. Describe *malaria*.
9. Show how fire and lights contaminate the air.
10. Describe coal gas poisoning.
11. Show that foul air may contain disease germs.
12. Calculate how much fresh air should be admitted into a given room for a given number of persons.
13. Describe how ventilation naturally goes on, and tell some ways of assisting nature in ventilation.
14. Tell how a schoolroom may be ventilated.
15. Tell how the atmosphere is purified.

CHAPTER XXV

HEAT AND CLOTHING

404. Temperature of the body. — During health a man's body has a temperature of $98\frac{1}{2}°$ F., which does not change either upon the warmest day in summer or the coldest day in winter. The body is warmed by the oxidation of its own cells and of digested food.

405. Change of heat to energy. — The power which the body puts forth in performing work is derived from the heat of oxidation. The work of the heart requires the use of $\frac{1}{16}$ of all the heat produced in the body; the respiration requires $\frac{1}{60}$; digestion and absorption require a smaller amount. An ordinary day's work requires $\frac{3}{16}$ of the total amount of heat. So nearly three fourths of all the heat produced is used simply to heat the body.

406. Uniformity of temperature. — In some parts of the body oxidation is many times more active than in others. Probably most of the sugar is oxidized in the liver, and most of the fat in the lungs. As fast as heat is developed it is carried all over the body by the blood, so that there is scarcely half a degree's difference between the temperature in any two parts. Only the surface of the skin is cooler because it comes in contact with cooler air.

407. Fever. — When the temperature of the body is raised only a degree there is a feeling of warmth and discomfort, which is called a *fever*. The discomfort is worse as the temperature is higher. A temperature of 104 degrees is a high fever, and if continued may cause death.