FIG. 61.—Annular Scleroderma of the Little Toe Preceding Spontaneous Amputation. (Case of Ainhum; service of Dr. R. Matas, Charity Hospital, New Orleans, La.)

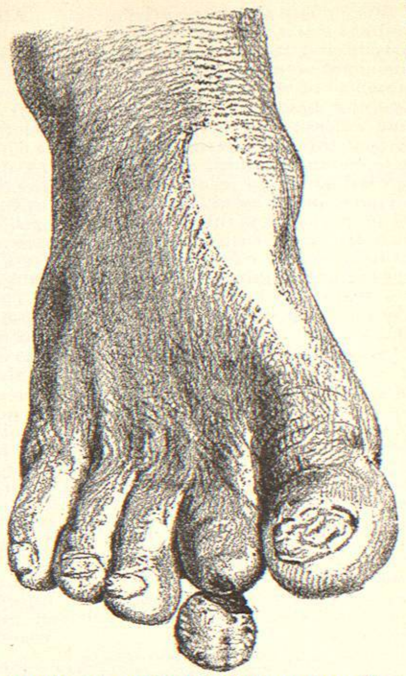

FIG. 62.—Diseased Foot Before Operation. (Case of Dr. C. Peña, Córdova, Republic of Mexico.)

there is a distinct odor, of a nauseous character, resembling that of the neurotic ulcer. The pedicle, or base, heals kindly. The process lasts months—even years in some instances.

PATHOLOGY.—Unna believes the condition to be "a ring-formed scleroderma with callous formation of the epidermis, leading to secondary total stagnating necrosis, resembling artificial snaring of tumors. There is a primary inflammation with marked hypertrophy of the epidermis, the papillæ being narrowed and elongated. In the papillary body there is cellular infiltration; the vessels are dilated. The tumefaction of the toe indicates a stagnation of lymph and fat, which gradually causes degeneration of all of the constituents of the cutis, a rarefaction of the bones, and the disappearance of the phalanges." In this most observers agree, the latest contribution (see Figs. 64, 65, and 66) indicating the above process.

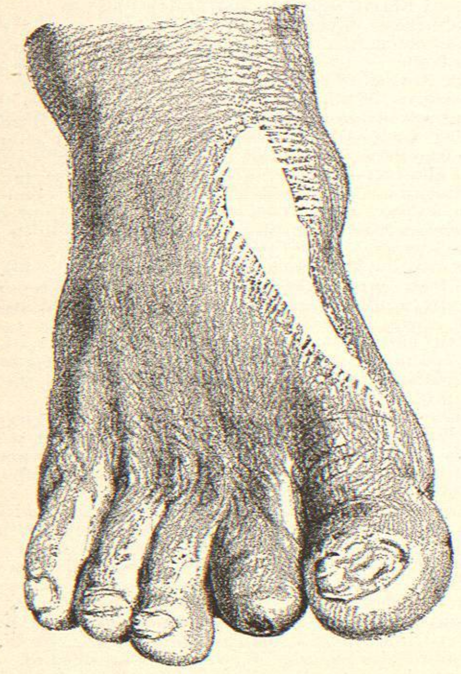

FIG. 63.—The Same After Operation. (Case of Dr. C. Peña.)

DIFFERENTIAL DIAGNOSIS must be made especially from Raynaud's disease, from paronychia, from the neurotic ulcer, and from leprosy.

Raynaud's disease is nearly always painful, occurs seldom on the lower extremities, is quite common on the upper extremities, and the trophic change is evidenced most often by the occurrence of preliminary lesions, *e.g.*, vesicles or bullæ.

Paronychia is inflammatory throughout and occurs on the ungual phalanx always.

The *neurotic ulcer* begins as a callosity, is circumscribed and deep seated, occurs usually on the plantar surface of

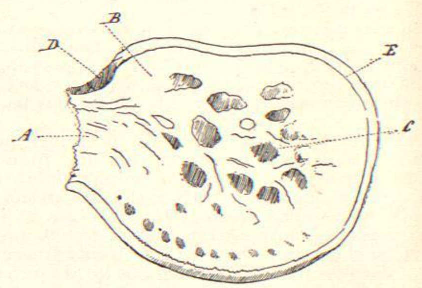

FIG. 64.—Longitudinal Section of the Amputated Toe. *A*, Section of the pedicle; *B*, fibrous fasciculi or bundles; *C*, collections of fatty tissue; *D*, remains of the nail; *E*, epidermis. (Case of Dr. C. Peña.)

the heel or great toe, and is never located just at the digito-plantar fold of the fifth toe. It is characterized almost from the start by the loss of the central tissue and by a persistent slough, exulcerating and discharging freely.

Leprosy of the mutilating type has points of resemblance to ainhum, especially when the latter disease is well

advanced. Leprosy, however, has no preference for the negro, and it is not a tropical disease. The trophic lesions of leprosy are found on any toe or any finger. These are almost invariably associated with other present or past manifestations. The initial evidence of mutilating lep-

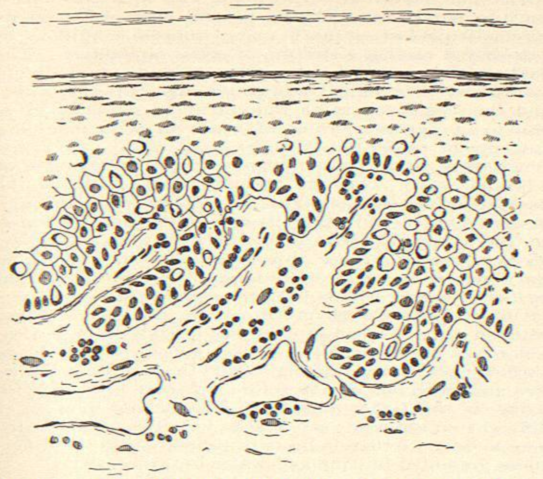

FIG. 65.—Section of the Skin. Moderately enlarged. (Case of Dr. C. Peña.)

rosy is a macule, excoriation, or bulla on the site of the destruction. The initial evidence of ainhum is a callous furrow, without inflammatory redness.

Zambaco Pacha (*loc. cit.*) elaborately argues this point of resemblance, arraying a large number of observers in confirmation of his opinion, but the burden of proof rests with him.

TREATMENT.—All observers agree that perpendicular and free incision of the circular bands may arrest the

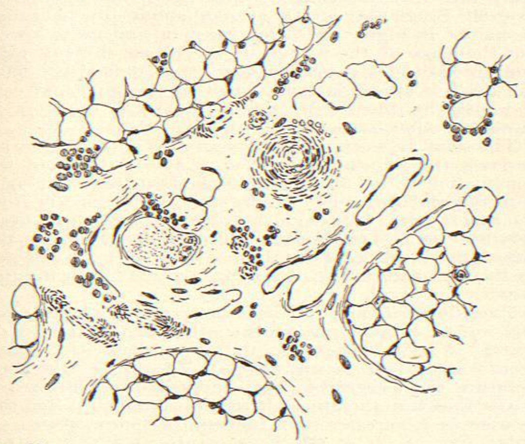

FIG. 66.—Section of a Blood-Vessel and of a Nerve. Moderately enlarged. (Case of Dr. C. Peña.)

process, but that usually the course of spontaneous amputation is completed, unless artificially or surgically produced.

Isadore Dyer.

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AIR.—To appreciate the various sanitary relations of the atmosphere, the subject must be studied from the physical as well as from the chemical standpoint. In considering the physical aspects of air, attention must be given to the subjects of atmospheric pressure, light, heat, humidity, and electrical condition.

The air is an invisible gaseous ocean. In it, as in all gases, there is no cohesion between the molecules. They are apart from one another, and their tendency to spring farther apart and occupy more space is so great that a restraining force is needful to prevent expansion and attenuation. Air at the sea level, the bottom of the aerial ocean, is compressed by the weight of the superincumbent air. This weight expresses the influence of gravity on the air as a whole, or the influence which the earth exerts on the molecules of its atmosphere to keep them from escaping into limitless space or from being whirled away by the centrifugal force of the diurnal rotation. The pressure of the atmosphere at the sea level balances a column of water 34 feet high. It forces water up the cylinder of a pump in proportion as the air pressure within the cylinder is lessened by the working of the piston, but the raising power of the pump is limited by the height mentioned. Similarly at the sea level the atmospheric pressure balances a column of mercury 29.92 inches, or 760 mm., in height (at 45° N. latitude), and as this number of cubic inches of the liquid metal weighs 14.75 pounds, or 1 kgm., to the square centimetre, the air pressure on every measure of surface becomes known. Generally, however, air pressure is expressed in inches of mercury as being more convenient than a statement of the actual weight on a given area. The pressure on a surface of one square foot amounts to nearly a ton. The average man has a surface of about 15 square feet, but the 15 tons of air pressure under which he moves are unfelt because of the fluidity of the atmosphere. The freedom of movement possessed by its molecules transmits their pressure in all directions. Air permeates all porous bodies, and the internal pressure in bodies so permeated counteracts the external pressure. Noticeable effects of air pressure are seen or felt only when there are local disturbances, as when the tissues are pressed by the weight of the atmosphere into the rarefied air of a cupping glass.

The higher we ascend into the atmosphere the less is the pressure, because there is less overlying air to affect us by its weight. Heights are measured by the decreased pressure, and balloonists calculate their distance from the earth by the fall of the mercurial column in their barometers. At the sea level, under a pressure equivalent to that of 29.92 inches of mercury, a cubic foot of air weighs 536 grains. Air is increased in bulk as pressure is diminished. At the height of one mile, the barometric column falls to 24.5 inches, equivalent to a pressure of 12.04 pounds to the square inch. Under this lessened pressure, a cubic foot of sea-level air would expand, other things being equal, to $29.92 \div 24.5$, or 1.22 cubic feet, and one cubic foot of this rarefied air would weigh only 439 grains. The pressure at two miles being equivalent to only 20 inches of mercury, one cubic foot of sea-level air would expand to $29.92 \div 20$, or 1.49 cubic feet, and the weight of a cubic foot of this expanded air would be 360 grains. With increased height there is diminished density, but as the elastic force which separates the molecules becomes lessened by their separation, there may be a certain condition of tenuity in which this force is unable to overcome those which operate in restraint. The depth of the atmospheric ocean has been estimated variously at from 45 to 350 miles or more.

Light from the sun or other sources passes through the air without illuminating it. Were it otherwise we should be able to see the air. We see things by the light which they emit or reflect, but the air merely transmits. We speak of atmospheric glows and beams of light, of the blue of the firmament and the radiance of morn, but these phrases relate to the visibility of substances in the air. Light is transmitted in straight lines, with the exception of some refraction in the denser strata near the earth's surface; but as more or less of the light is refused a lodgment by every substance on which it falls, and is reflected from one object to another at all angles and hence in every direction, the whole of the air is filled with rays which illuminate objects that are not exposed directly to the source of the illumination. Molecules of watery vapor and minute particles of dust suspended in the air give rise to the apparent diffusion of light in the atmosphere. These account for the dawning light of morn, and the twilight after sundown.

Associated with solar light are actinic and heat rays. The latter are of the highest interest, as being the cause of the tides, currents, and local movements in the atmosphere. Heat rays pass through the atmosphere without warming it. The air of high mountain regions is cold, although the same rays pass through it which may give a tropical warmth to the plains below. It is usually said that the temperature falls 1° F. for every 300 feet of altitude, or about 134 metres for 1° C. This, although not accurate, is useful. If the temperature, average or actual, of a given locality be stated, an approximation to the corresponding temperature of a neighboring plateau may be calculated. Glaisher, during his balloon ascents, found the temperature on a cloudy day lowered 4° F. for every inch of a barometric fall of 11 inches; and the further ascent was marked by a more rapid refrigeration. As 11 inches of mercury indicate an elevation of 12,000 feet, the average ascent for the Fahrenheit degree was about 270 feet. On a clear day the thermometer fell 5° for each of the first 4 inches of barometric fall, 4° for each of the next 9 inches, and 13.5° for the last 3 inches of his ascent. The cold is proportioned to the lessened pressure, 4° F. for each inch; but as the height to be ascended for each inch of fall increases with the ascent, the height for each degree of temperature increases correspondingly.

Air, in expanding under lessened pressure, has its expansion restricted in some measure by the loss of heat attending the expansion, for the volume of a gas is contracted by cold. Air expands $\frac{1}{460}$ of its volume at 0° F. for each degree of increased temperature ($\frac{1}{273}$ in the case of Centigrade). Hence 460 cubic inches or feet or, in general terms, volumes, at 0° F. expand at 60° to 250 volumes, and conversely by a reduction of temperature from 60° F. to 0° 520 volumes contract to 460. On these data is based that which in dealing with air and gases is called the "correction for temperature." The molecules of a cubic foot of dry air weigh, at the sea level, 536 grains. Under the diminished pressure, at 16,000 feet, these molecules would occupy a space of two cubic feet, each foot containing 268 grains; but the coincident reduction of temperature would so modify this that the cubic foot of air would weigh 303 grains. The rarefaction of the atmosphere in mountain regions is thus seen to be somewhat less than we should be led to expect by a consideration merely of the barometric pressure.

Heat, like light, is absorbed in varying proportions by everything on the surface of the earth, and that which is not absorbed is reflected at various angles, so that the air in its lower strata is filled with reflected rays which become manifest only when they are absorbed and increase the temperature of the absorbing substance. Absorbed heat is radiated to cooler bodies in the neighborhood, for the tendency in nature is to an equable distribution. Hence, besides reflected rays, the air may be filled with rays of radiant heat, but in all this there is merely transmission, with no appreciable influence on the air itself. When, however, absorbed heat is distributed by convection the air assumes an active part in the process. A warm substance communicates part of its heat to the air molecules in immediate contact with it. The air thus heated expands and is floated upward by the inflow of colder and heavier air beneath it; and it is thus raised until by admixture with the general mass of the air its rarefaction is lost, or until under unusual conditions of placidity it reaches a stratum of equal rarefaction. The cold air that replaced it in contact with the heated substance becomes similarly warmed and borne upward; and this continued in an uninterrupted sequence gives rise to an upward current of warm air with inflowing currents of colder, heavier air on all sides. We sometimes seem to see this upward current by the side of a heated stove, when its varying density disturbs the passage of the rays of light from objects seen through it, and gives a quivering movement to their outlines. In the sandy districts of southern Arizona and New Mexico, trees and other objects at a little distance from the observer are often tremulously distorted to his sight by the upward currents from the sun-heated surface.

Objects that absorb much radiate much, and those warmed rapidly by absorption cool quickly by radiation. Color has an influence on these movements, for black surfaces absorb and radiate better than white. Radiation and reflection are therefore different processes, for white is the better reflector. The radiant powers of different substances vary much, but it is unnecessary here to do more than indicate in general terms the differences presented by land and water in this regard.

As compared with water, land heats quickly and cools quickly. The heat does not penetrate but accumulates in and immediately beneath the surface. Children know how cool is the underlying sand turned up on the seashore in their holiday play. The surface is hot by day and cool by night, but at a depth of three feet there is no diurnal increase of temperature, and even the heat of a prolonged summer penetrates only about seventy feet, for well water at this depth has the same temperature summer and winter.

Masses of water, on the other hand, heat slowly and cool slowly; the rays penetrate to the depths. The temperature of the surface waters of the ocean is never over 80° F. (26.6° C.) in the tropics, and its diurnal range is small. In higher latitudes the temperature is lower, but the mass of the waters of the ocean, in both high and low latitudes, is never below 39° F. (3.9° C.). Thus the air is warmed intermittently by the land and continuously by the ocean, and its molecules are kept in motion by the convection which is in progress.

The solar rays are the only source from which the air derives its warmth, for, although animal life and the combustion of fuel develop heat, the heat thus developed is merely the liberation of energy derived originally from the sun. Again, although the earth has an internal heat, this heat is not transmitted through the crust, for the superficial strata to a depth of seventy feet are affected by the seasonal warmth of the sun, and not by the interior heat.

The effects of heat on the atmosphere are multiplied and varied by the phenomena attending its action on water. Vapor, invisible as the atmosphere itself, rises from water at all temperatures. The higher the temperature the more rapid the evaporation. Thus vapor is absorbed into the atmosphere, and the amount that can be absorbed increases with increase of temperature. A cubic foot of air at 32° F. is saturated with moisture when it contains 10 cubic inches or about two grains of vapor of water; but at 100° F. (37.8° C.) the cubic foot of air can absorb about 100 cubic inches, or nearly 20 grains. The molecules of the vapor find place for themselves in the intermolecular spaces of the air, but not without crowding aside the air molecules to such an extent that saturated air is lighter than dry air. Air is known to be saturated when the slightest lowering of its temperature causes a deposition of moisture. We call such a deposition cloud when in the air above us, fog

or mist when in the air around us, and dew when deposited at night on vegetation and other highly radiating surfaces. The *dew point* may be found by noting the temperature at which moisture appears on the outside of a test tube, cooled by the evaporation of ether in its interior. Usually an approximation to it is obtained by the wet bulb thermometer, from which the actual dew point may be calculated or gathered from Glasher's tables. Moisture in the air is expressed as *relative humidity* on a scale of which 100 is the point of saturation. Absolute figures give no satisfaction. With two grains of moisture in a cubic foot of air the air, as we have seen, may be very moist or very dry. If the temperature is 32° F., the air is saturated; if it is 100° F., the air is so dry that it is ready to take up 18 grains more before it becomes saturated.

Evaporation aids radiation and convection in cooling a warm, moist surface. The soldier in a summer camp moistens the outside of his canteen and hangs it on a branch that the passing breeze may cool its contained water. Even the surface of the water of the tropical oceans is cooled slightly at night. It is, however, not so much by the production of a local coolness as by the transference of heat from one place to another that the chief influence of evaporation is exercised. From the surface of the ocean, particularly in the warmer latitudes, evaporation is going on at all times. An upward movement of moist, warm air is continuously in progress. Partial condensation occurs by the time this air reaches a stratum of its own density, but the clouds there formed are usually hurried by air currents to other and colder regions of the globe before the particles of condensed vapor become aggregated and fall as *rain*. The heat gathered from the tropics is thus distributed to other parts of the earth, the air of which is warmed by condensation above as well as by convection from below. Moreover, the clouds absorb heat radiated from the surface of the earth, thus preventing its dissipation into the ether beyond. Every object on the surface is thus kept warmer than it otherwise would be. Clouds act as a blanket to keep the air and the earth under them warm. Any roof, however flimsy, even the spreading branches of a tree in foliage, is a protection against the cold of radiation into space. The great heat of the direct rays of the sun at high altitudes, where the surrounding air is intensely cold, is attributed to the freedom of the air from intercepting moisture.

Electricity pervades the atmosphere. It is generated by the evaporation of water, the friction of the wind on the surface, and of the molecular constituents of the air each on the other; but its relations to these constituents are not clearly understood. It is greatest in cold, dry weather, but the greatest electrical disturbances are associated with condensation and rainfall.

Our knowledge of the effects of heat and moisture enables us with but little effort to recognize the causes of many meteorologic phenomena that have important bearings on the well-being and comfort of the human race. Meteorology is probably the oldest of the sciences, for man, even in the earliest days of his racial existence, found it necessary to study the probabilities; and the weather wisdom of every nation is embodied in proverbial expressions. The co-operative work of modern times, made possible by the use of the telegraph, has enlarged our knowledge and broadened our views of these phenomena, so that we now have a useful understanding of the general as well as the local movements of the atmosphere.

Extending for a few degrees on each side of the equator is a region of calm and light variable winds, known to sailors as the doldrums. Here the uprising of the moist, warm air leads to condensation in the higher strata. Heavy rains fall, and the heat liberated during the condensation rarefies the relatively dry air of the upper regions and develops a swell on the surface of the atmospheric ocean which divides or flows over, one-half to the north, the other to the south, while an inflow in the lower strata restores the aërial equilibrium. The inflowing currents do not come from the poles; they reach only from the 30th parallels, and their motion is more or less obliquely from the east on account of the diurnal revolution of the earth. A belt of variable winds is found about the 30th parallels. Here the upper current from the tropics impinges (in the northern hemisphere) on a northeast upper current from the Arctic circle, and the swell of their meeting occasions an increased pressure at this point. Escape for the accumulated air is found below, southward constituting the trade winds and northward constituting the regular southwest winds of the north temperate zone. At the Arctic circle is another doldrum belt into which flows the wind last mentioned and a surface current from the northeast. These, warm and cold intermingling, produce condensation and rainfall and an expansion or swell which overflows into a northeast upper current over the temperate zone, and a southwest upper current toward the pole. The surface currents affect the air to a height of 16,000 feet, involving about one-half of the weight of the atmosphere, and their velocity averages about 15 miles an hour. This constitutes the general circulation of the atmospheric ocean, but there are many secondary currents, as that between land and sea. In fact innumerable causes of greater heating at one place than at another give rise to local currents.

The resultant of all the meteorological conditions constitute climate; but temperature, as being the most notable condition, is usually adopted to give formal expression to the character of a climate. Temperature depends on latitude, altitude, and the presence of large bodies of water to reduce the daily and seasonal ranges. One of the first discoveries by those who collated the meteorological observations of the medical officers of the United States Army was the climatic importance of the great lakes. In New England the influence of the ocean was found to modify the mean temperature. In the interior of New York, the daily range increased and the seasons were strongly contrasted. Farther west, near the great lakes, a climate similar to that of the seaboard was again found, but in the interior beyond them, extreme changes again became the rule. Water tempers the winds which blow over it and loads them with vapor for subsequent condensation and warmth. The regular southwest winds of the temperate zone reaching Europe from the Atlantic and California from the Pacific Ocean give these shores a climate markedly different from that of the Eastern coast or interior of the United States. The air of continental interiors is dry and the solar rays beat with full intensity on the surface, while at night there is no protection against radiation into the cloudless skies.

That climate has a powerful influence on the welfare of man is manifest when we compare the weakness and indolence of tropical races with the strength and energy, mental as well as physical, of those of the temperate zones. Since the earliest ages it has been a favorite theory that diseases come upon mankind through the air. The box of Pandora was opened, and its contents scattered to the winds. A peculiar "epidemic constitution of the air" was formerly accepted as accounting for the unusual prevalence of disease, and even in the medical literature of the present day this epidemic constitution crops up occasionally in instances in which the mode of propagation has not been satisfactorily established. More time and intelligent labor have probably been given to meteorologic observations, with the view of throwing light on this subject, than have been expended on any other line of scientific research. For generations men have been observing and recording, but the collators have been few. Progress has indeed been made, but it has chiefly been by some of the sister sciences invading the domain of medical meteorology and dissipating some part of her clouds and uncertainties. A few years ago cholera was regarded as "obscure in its meteorological relations, modified by such conditions to a great extent, but never controlled by them" (Lorin Blodgett). Many of the agencies of epidemic diseases have been trailed to their haunts, but those of typhus, yellow fever, small-pox, scarlet fever, and measles continue in their old-time obscurity; and the meteorological points connected with them are, briefly: Typhus emanations freely diluted with air are harmless; yellow fever disappears with the advent of frost, and the others have the colder months as their season of prevalence, probably because their contagia are concentrated and correspondingly pernicious in the close, unventilated rooms of that season.

Although the tendency of modern research is to absolve the air from any special complicity in the propagation of epidemic diseases, the charge of influencing the human system unfavorably still holds good in certain other respects. Alterations of atmospheric pressure have been regarded by some medical observers as causing pulmonary congestions, and both compressed and rarefied airs have been used in the treatment of diseased conditions of these organs. In hospitals for consumption, however, where any general influence causing congestion of the lungs would be manifested by an increase in the number of cases of hæmoptysis, careful observation has shown that there is no such increase during the passage of the storm centre. One medical writer of high repute insisted on the influence of air pressure on the healing of wounds, and urged the advisability of adding a portable barometer to the surgeon's equipment, that he might be enabled to perform all operations not of an emergency character, with the mercury at not less than 29.869 inches. The exacerbations of neuralgic and rheumatic pains coincident with alterations of atmospheric pressure have established a popular belief in their relations as effect and cause, which has received some support from a consideration of caisson disease.

The caisson for the Brooklyn tower of the East River Bridge measured 168 x 102 feet, its interior or working chambers being 14 feet in height. It was, in fact, a huge box sunk mouth downward by laying courses of concrete on its upper surface. Compressed air forced into the chambers displaced the water; and relays of men excavated the bottom of the river bed beneath it until a rock foundation was reached. The upper end of each shaft leading to the chambers was guarded by an air-lock to prevent injury to the men by a sudden change of pressure on entering or leaving. Before descending, compressed air from below was admitted gradually into the lock chamber, and only when the density was equal to that in the caisson was the descent made. Correspondingly, before leaving, a gradual transition from compressed to ordinary air was effected. On exposure to air under a pressure of three or four atmospheres, the skin became pale and shrivelled and the countenance shrunken, as the blood was forced from the superficial vessels to those of the bones and the cavity of the skull. The heart's action increased in rapidity to overcome the impediment to the circulation; but after a time the system accommodated itself to the altered conditions, and generally no bad effect was manifested until the men returned to the colder and relatively rarefied air of the surface, when many suffered from pains in the bones, giddiness, faintness, numbness, and even paralysis. A longer time in the lock chamber, to permit of accommodation to lessening air pressure, would no doubt have prevented these injurious effects.

The diminished pressure at high altitudes is described by travellers as causing *soroche*, or mountain sickness, which is characterized by restlessness, sleeplessness, gasping respiration, anxiety, vomiting, and fainting. It is experienced at a height of ten or twelve thousand feet when the individual is expending energy by climbing, but in balloon ascents the effects of diminished pressure are not felt until twice this distance has been reached.

Heat relaxes the tissues and depresses the vital energies. Cold stimulates these energies to make good the loss of animai heat; but if excessive it benumbs and paralyzes and ultimately destroys by freezing. When local in its application it disurbs the circulation of the blood, causing a congestion of some internal organ when the surface of the body is chilled and its vessels are contracted.

Air at 50° F. (10° C.) saturated with moisture is colder to the feel than dry air at the same temperature; it chills by contact. Above 50°, however, it is warmer, as it prevents evaporation from the body. At high atmospheric temperatures it is oppressive and induces heat exhaustion or sunstroke. As evaporation is stopped, the system is unable to keep down its heat to the normal of 98.4° F. (36.9° C.), and when the blood becomes heated higher than this, dangerous symptoms are developed.

The progress of cases of consumption is so manifestly affected by atmospheric changes that the disease until lately was regarded as originating in them. When it is fully established, the duration of life depends on the equability of the climate. Insular climates in warm latitudes are preferred; and the moist warm air of Florida and Southern California is much recommended by medical men. On the other hand, recovery is now generally conceded to be probable, if in the stage of invasion the patient will submit to live in an equable climate, with active exercise in the open air, preferably on horseback. The tablelands of the west and the mountains of New Mexico and Arizona have many records of recovery from consumption in its earlier stages.

Liquefaction of Air.—Ordinarily we think of air only as air, but it has been condensed to the liquid form and even solidified. Air becomes liquified at −140° C. (−220° F.) under a pressure of 39 atmospheres; but if the temperature is lowered beyond this, the pressure required to effect the liquefaction will be less. Faraday condensed a number of gases such as carbonic and sulphurous acids under pressure, but failed in all his efforts to liquefy oxygen by not associating a sufficiently low temperature with the pressure employed. Pictet succeeded in liquefying oxygen in 1877 by using the low temperature produced by the rapid evaporation of liquid sulphurous acid to liquefy ethylene, and thereafter employing the ethylene to reduce the temperature of the oxygen. This process was tedious and expensive; but in 1893 Charles E. Tripler, of New York, marked out a process for the production of liquid air on the manufacturing scale, in which the air was condensed to liquidity by the cold produced by its own expansion when liberated from under pressure. The air was compressed first under a pressure of 100 pounds per square inch, and was then passed through pipes surrounded with water to remove the heat liberated by the condensation. It was next subjected to a pressure of 800 pounds to the inch, and the heat developed was removed as before. Lastly, it was subjected to a pressure of 2,000 pounds per inch, and when cooled it was passed into coils of copper tubing which were jacketed with non-conducting material. The pressure within the coils was equal to about 15 atmospheres, while that in the jacket was only one atmosphere, so that when a minute aperture in each coil was opened, the compressed air escaped and expanded. The cold resulting from expansion was such that while two-thirds of the air operated on escaped as air, the remaining third became liquid and collected in the lower part of the cylinder jacket whence it could be drawn off like water from a spigot. It can be thus produced at the rate of two cents, or one English penny, per pound. So far, the study of liquid air has developed no suggestion of usefulness from the medical or hygienic standpoint, although it has proved a valuable instrument in scientific investigations. Mr. Tripler is endeavoring to utilize it commercially as an agent for the production of power, but according to Dr. Hampson in the *Scientific American* (July 1, 1899), it cannot supersede steam: "This pound, or pennyworth, of liquid air, expanding to the volume of thirteen cubic feet of air vapor at atmospheric pressure, will do a certain amount of work in an engine. Half a pound of water will also expand to thirteen cubic feet of steam at atmospheric pressure, and expanding from a smaller volume, will do more work than one pound of liquid air. But half a pound of steam, made in a good steam-raising apparatus, only costs one two-hundred and fortieth part of a penny. For equal quantities of power, therefore, liquid air is

mathematically more than two hundred and forty times as dear as steam, and practically the difficulties of handling it will make it compare more unfavorably still."

Chemical Constitution.—Formerly air was regarded as one of the elements. The advance of our knowledge into the arcana of nature is well illustrated by the progress made in the investigation of air during the past century. It is now known to be a composite substance; the properties of its constituents have been determined, their relations to animal and vegetable life have been discovered, and traces of accidental impurities swept up by its currents from the face of the earth have been detected and studied in their bearing on sanitary conditions. The atmosphere, according to the chemist, consists of a mixture of two gases, oxygen and nitrogen. The former is active in its properties, combining with many susceptible elements, and especially with the carbon and hydrogen of devitalized organic matter, constituting, according to the rapidity of the process, either oxidation or combustion, and, with the same elements in the living tissues of animals, constituting one of the essentials for the continuance of life. A certain small percentage of the oxygen of the air exists in the form of *ozone*, a peculiar modification of oxygen which, although much studied since first discovered by Schönbein in 1840, has yet to have its chemical and natural history fully written. Its nature is uncertain, but it is generally regarded as O_2O. The quantity present in the air cannot be determined, and even its existence is at times indicated with doubt by the iodized starch papers, which have been largely used for its detection, as they are affected by other matters, as nitrous acid and peroxide of hydrogen, occasionally present in the atmosphere. Iodized litmus papers have been shown by Dr. Fox to be of value as a qualitative test, and as indicating comparative quantities when known volumes of the air are aspirated over them. It is certain, however, that ozone has stronger affinities than ordinary oxygen, and that oxidation goes on more rapidly in its presence than in its absence. It undoubtedly destroys the volatile substances which are evolved during the putrefactive process. When foul organic odors are present, ozone is absent. Hence, when the presence of ozone is indicated by the test papers, the air is regarded as free from organic contaminations susceptible of oxidation. Animals exposed to ozone artificially produced suffer from irritation of the lungs. The diseases of these organs prevalent in cold weather have therefore been attributed to it. Not many years ago, medical meteorologists anticipated great practical good from the study of ozone, particularly in respect to influenza and cholera, the one associated with an excess, the other with a deficiency of this form of oxygen, but the discovery of the bacterial origin of these diseases has deprived them of this incentive to a continuance of their labors.

The nitrogen is regarded as negative, or passive, serving merely to moderate the activities of the oxygen by dilution. Mention, however, should be made of the recent discovery of the elementary substance argon by Lord Rayleigh and Professor Ramsey. Argon has characters similar to those of nitrogen; but as its uses in the economy of nature have not as yet been determined, it must be left for the present with the nitrogen, with which it has so long been associated.

In the atmosphere the chemist recognizes also the presence of small but varying quantities of other matters such as carbonic anhydride, ammonia, and watery vapor. The percentage composition of dry air is, by volume, 79 of nitrogen, 20.96 of oxygen, and .04 of carbonic anhydride; by weight the relative proportions of nitrogen and oxygen, are 76.99 and 23.01. Nitrogen is the lightest, carbonic anhydride is the heaviest; yet, on account of the constant motion of the atmosphere and the tendency of gases to diffuse, there is no separation into strata richer in nitrogen above and carbonic anhydride below. This power of diffusion possessed by gases is such that, in places where there is a continuous generation of carbonic anhydride, it does not accumulate unless it is confined as in a room, and even then it is diffused through the whole air of the room and not collected by its weight near the floor. The intermingling of gases by diffusion is shown by Pettenkofer's examination of the air over certain effervescing springs. Samples from the water level contained 70 per cent. of carbonic anhydride; from 40 inches above the water level, 2 per cent., and from 55 inches only 0.5 per cent. Hence little difference is found in the percentage composition of the free air, whether samples be taken from over the land or the ocean, from the sea level or from a high altitude.

The oxygen of the air varies but little from its average percentage, but the quantity of it taken into the lungs varies with the temperature and pressure. Much of the depressing effects of atmospheric heat is probably due to a want of oxygen in the expanded air. A cubic foot of sea-level air at 32° F. contains 132 grains of oxygen; at 100° F. it contains 116 grains, a reduction of 12 per cent. Again, the distress felt by mountain climbers (see page 150) and usually ascribed to lessened pressure, is probably due in great part to the lessened amount of oxygen inhaled. A cubic foot of air, at 60° F. and 30 inches of pressure, contains 124.6 grains of oxygen. The expansion under a barometric pressure of twenty inches, corresponding to a height of two miles, with the coincident contraction by a fall of temperature to 20° F., would reduce the oxygen in a cubic foot to 90 grains, a reduction of 28 per cent.

The carbonic anhydride, or carbon dioxide, CO_2, familiarly known as carbonic acid, is produced by the oxidation of carbon in dead and living tissues, and its percentage in air varies with the local causes which determine its production. Thus it is greater in the alleys and streets of a city than in the open country, and as this gas is soluble to some extent in water, its proportion varies with the hygrometric and other conditions, being greater in a damp atmosphere before rain has fallen than in the air of the same locality after the aqueous vapor has been precipitated. The air currents and the diffusive power tend to equalize the percentage, but as production is constant in some localities, the air of these must always show a relatively larger quantity of this gas than that of others remote from such sources. The proportion in the external air seldom exceeds 4 volumes in 10,000. De Saussure made many series of observations to determine the percentage under various conditions. The present writer, while investigating the ventilation of soldiers' quarters, at Fort Bridger, Wyoming, in 1874, found in the external air a gradual decrease, day by day, from 4.5 to 2.6 volumes per 10,000 as the season advanced, and the surface of the earth became covered with vigorous vegetation.

Carbonic acid is a product of combustion; it will therefore not support combustion. It is a product of respiration, therefore it will not support respiration. In mines, life is in danger when a candle will not burn. Because workmen in soda-water factories suffer no inconvenience in breathing an atmosphere containing as much as two per cent. of carbonic acid, many have supposed that this gas is not poisonous, but that, like water, it drowns fire and life alike by preventing the access of oxygen. Nevertheless experiments have shown it to be actively harmful. Animals breathing it along with as much oxygen as is present in the atmospheric air have the heart's action weakened even to fainting, and when man is the subject of the experiment, dulness of mind culminates in unconsciousness or stupor. This, however, is not of much practical importance, for the sources which furnish carbonic acid to the atmosphere generally yield with it other and more dangerous substances.

Ammonia is diffused from putrefactive processes in progress on the surface of the earth. It is also produced, in traces, from the nitrogen of the atmosphere by electric agency.

Its quantity is variable, but 0.1 mgm. in a cubic metre of air is a not unusual amount. This corresponds to a grain in about 23,000 cubic feet. Rain washes the ammonia from the air to the surface of the earth in