Reprint from the ST. LOUIS CLINIQUE of June, 1893.



# Air and Contact Infection.

Translated from Schimmelbusch's "Aseptische Wundbehandlung," with permission of the Author.

BY FRANK J. THORNBURN, M. D.,

*Demonstrator of Bacteriology, Medical and Dental Department University of Buffalo.*

More ancient still than medical science itself, is the belief in the transmission of disease through the air. In surgery the opinion was long prevalent that wound infection was dependent upon an atmospheric influence, and this view became a dogma after John Hunter attributed the invariable absence of fever and suppuration in subcutaneous injuries, such as simple fractures, to the fact of their not having been encountered by the air. When, in former times, cases in a hospital developed fever and suppuration, it was the contaminated air of the ward which the surgeon regarded as the source of all evil. The whole aim of surgery in the recommendations of the so-called subcutaneous method of operating, introducing the instruments through the smallest possible slit-like opening, to divide, in a groping way tissues, tendons, and saw through bone, is in accordance with the endeavor to imitate the character of subcutaneous injuries, and procure wounds to which the air has no entrance.

Against nothing else than the air itself did Lister direct his first endeavors at asepsis—not against the air as a gas, however, but rather against the elements of infection contained in the air which, he supposed, induced in like manner decomposition in the wound's secretions and in the wound itself, as they produced changes and decomposition everywhere in organic material. Thus began Lister in his first communication in the *Lancet*, 1867, regarding a new method of treating compound fractures and abscesses:

"The almost invariable absence of danger in simple fractures stands in striking contrast to the disastrous results we otherwise often have occasion to observe, and the excessive frequency of which is one of the most grave and appalling incidents of surgical practice. Investigating the prime reason why the wound in a compound fracture may prove so disastrous, we find simply as explanatory, the septic changes of the blood which is poured out in greater or

less quantity around the seat of fracture and into the connective tissue spaces, such changes being induced by the entrance of air, the blood losing its mild character to take on the quality of an active irritant and become capable of producing local and constitutional disturbances." As had been taught by the investigation of Pasteur, Schwann, von Dusch and others, organic material, blood and tissues, may be preserved from decomposition by protecting them from contact of the minutest living organisms; so also did Lister in his new method, endeavor to exclude from the wound the germs of decomposition. He irrigated the latter with carbolic acid with the use of which in counteracting decomposition he had had an astonishing experience in the deodorization of the fields over which the contents of sewers were allowed to slowly flow and settle outside the city of Carlisle—in order to destroy the germs which the air had already carried into the wound. He then applied the dressings which were already saturated with carbolic acid, and with the greatest possible care bandaged-in the entire wound, occluding it completely with a layer of impermeable material so that further entrance of germs from the air would be prevented. During the operation and at the subsequent change of dressing, the carbolized spray, in addition, was disseminated over the entire region of the wound, this being intended to place the wound in an atmosphere which would be entirely free from dangerous organisms of every variety.

At the time when Lister made the first practical trial of his new method of treatment, our knowledge of the germs contained in the air was very limited. That they existed as the minutest forms of matter had, it is true, been recognized, but regarding their extent, morphological characteristics and appearance and their requirements for existence, almost nothing was known. It is true Tyndall has shown that they appertain to the sunbeams which become visible when the rays of light fall into a dark room through a crack in the closed window shutter; it is also a fact that Pasteur aspirated air through gun cotton and filtered out the germs, then dissolved the gun cotton in ether and examined it microscopically, and that Pouchet collected the particles of air-dust on moist plates against which the air was blown, but all these investigations have proven of but little avail. From the fact that, in a comparatively short time, we have attained a quite thorough and more or less complete understanding of the extent, size, form, appearance and manner of life of the air bacteria, we are indebted to nothing other than the brilliantly perfected methods of bacteriological investigation for which our tribute of gratitude is due first of all, to Robert Koch.

If we review the results of our most recent investigations into the bacteria of the air, we find a conformity to exist throughout, and this conformity has greater significance in view of the varying methods of investigation employed by the different observers.

Practically every form of germ-life which we comprise under the common name micro-organisms, is found in the air to a widely varying extent of distribution; bacilli, cocci, yeast fungi and schizomycetes are usually all present at the same time. As well in the extent of their dissemination as in their multiplicity are there extreme variations, but these variations have a decidedly peculiar similarity and are always dependent upon similar circumstances. For instance, in dwelling-houses, the schizomycetes, bacilli and cocci predominate over the mold fungi, while in the open atmosphere, more of the mold

spores are present. The number of germs varies from a few to many thousand per cubic centimeter.

The air of large cities contains a greater number of bacteria than does country air, in damp weather the number of bacteria in general is less than in dry weather, in winds greater numbers are present than in still air. In the middle of the Atlantic Ocean, and upon mountains in the Alps range which are continuously covered with snow, the air is practically free from bacteria.*

Land winds usually contain more bacteria than do sea winds; for instance, the winds which blew from the land towards Catania as found by Condorelli-Mangere, always contained more bacteria than the wind which blew from mid sea to Catania. The same conditions with reference to land and sea winds were found by Uffelmann in Rostock and Ciorgio Roster on the Island of Elba.

Many of the older writers, for instance, Loewnhoek, we find to have maintained that all bacteria originated from the air and that from this source organic material is infected and its decomposition induced. The same line of thought also made itself very manifest in Lister's first writings. With this opinion, i. e., that the air is the natural habitat of the micro-organisms, and that from this source organic material is infected secondarily, we must, with our present knowledge of the requirements of the bacteria for existence, positively disagree. It is not the air which, par excellence, broods and harbors the deadly organisms and acts as the source of infection of everything else, the conditions are rather the reverse; it is in the organic material that the germs exist; only exceptionally do they from here gain entrance to the air. All the requirements for growth and multiplication of micro-organisms, viz.: warmth, moisture, and a nutrient media, are not present in the air, and, as for the schizomycetes, yeast fungi and mold spores, the air is anything but a favorable place of maintenance.

Then there are bacteria, the so-called anaerobic organisms, which are antagonized in their growth by the air as a gaseous medium—among this class we have the bacillus of tetanus to include — and there are presented by the air, especially by a clear atmosphere, a number of factors, as dryness, diffused daylight and sunshine, which are now known to exert an unfavorable and directly damaging influence upon the micro-organisms.

Only transitorily do germs gain entrance to the air from their essential habitat, the warm, moist and organic material of the earth's surface, and this furthermore under only one condition, i. e. when they are disseminated as dry dust. Naegeli, as early as the year 1870, showed theoretically and experimentally, that the micro-organisms only as dry dust can become mixed with the air, and that never do they gain entrance to the latter from fluids. Yet even to-day it is difficult for an individual who inhales the nauseous vapors of a decomposing fluid to reconcile himself to the belief that with the fumes,

* Upon the fact of the absence of bacteria in the air of mid-ocean I convinced myself in a recent transatlantic voyage. While still in the harbor of Antwerp, bacilli were present in the air varying in number from three to five hundred per cubic meter, as determined by aspirating the air through large glass tubes. Sailing down the Schelda River the number decreased to two or three hundred, and in the North Sea almost no germs were present. Upon entering and sailing through the English Channel the observations continued, revealed the presence of bacteria in the air varying from one to three hundred, per cubic meter although in the wider parts of the Channel the number detected on exposed gelatine and agar plates was much less. Beyond the Scilly Islands the bacteria gradually diminished and in the Atlantic Ocean from five to forty degrees west longitude no germs at all were present.

germs from the contaminated fluid are not inhaled, not-with-standing that all investigations have proven the incorrectness of this opinion. Air offensive in odor frequently contains fewer bacteria than that which we inhale as pure and agreeable, and the stinking air of out-houses, sink holes and canals, has always been found purer bacteriologically than the air of the streets, of dwelling-houses and of gardens.

According to investigations made by Hesse and Petri, the open air in the interior of Berlin always contains from several hundred to one thousand bacteria per cubic meter, and that of dwelling houses from six to ten thousand, while Petri alone found that the air in the canal below Potzdamer Place showed none at all, or only a few scattered germs.

In fact, the air below Potzdamer Place is, bacteriologically, the purest in the whole city of Berlin, and even at the top of the Court House tower an individual would inhale a greater number of germs, as here according to Hesse eight hundred per cubic meter are present. It has been experimentally proven that even through powerful current of air passed over the upper surface of fluids containing bacteria, germs are not disseminated, that is to say the solution only is stirred up and then settles, carrying down with it also the bacteria.

The sun which pours its hot rays upon stagnant pools swarming in micro-organisms, of course vaporizes the water and generates foul odors, but never are bacteria liberated from the solution, and even though the drops of rain and hail stones the size of a walnut which were showered over St. Petersburg in a storm, revealed the presence of bacteria (Foutin), we are not to infer that these germs arose from the water as it evaporated, but that later the dust particles in the atmosphere became enveloped by the precipitation.

The presence of greater numbers of bacteria in dry and moving, than in moist air, is a sequence of the excessive circulation of dust which isinduced by dryness. The reason why there are fewer bacteria in the air after, than before, a rain, is the fact that the water in falling carries down with it the germs, and especially explanatory is the saturation of the earth's surface caused by a protracted rain, preventing temporarily the rising of dust. The absence, furthermore, of micro-organisms in the air upon icebergs and in mid-ocean, is due simply to the fact that here there is no dust containing bacteria which can be stirred up by the motion of the air, and that the glaciers as well as the sea water have the property of holding down the bacteria contained in them. Condorelli-Mangeri found in Catania, that during the great assemblage of the multitudes at the time of earthquakes, the air contained more bacteria than otherwise. The air of stalls in which small animals are kept and move about, as for instance, in the pens in the Hygienic Institute, Berlin, is, according to Petri, very rich in germs; it contains upwards of thirty-four thousand bacteria and about seven thousand four hundred mold fungi per cubic meter. In the air of work shops the number of bacteria increases rapidly as soon as the work is begun, and in barracks, hospitals and dwellings, the number of bacteria in the air is found to be always greatest shortly after the rooms have been swept and dusted.

In the operating room of the Billroth clinic, the number of bacteria in the air is always greatest while the clinic is in progress, after entrance of the students, and according to Hess the number of germs in the air of a school room increases from three thousand per cubic

meter to twenty thousand during the sessions and to forty thousand during the exit of the pupils. All these observations only illustrate further the effect of the rising of dust on the bacterial contents of the air. Very general in the medical profession as well as among the laity is the belief of the infectiousness of the breath, and this sentiment finds vivid expression in the fictitious narratives of very ancient times, which attributed to a vigorous exhalation of the monsters, the property of destroying everything it encountered. It is surprising that at the beginning of the antiseptic era special importance was not attributed to expired air as a source of wound infection, for it is not difficult to understand, *a priori*, that from the views in vogue a variety of suspicions might have been formed by operators.

Exact bacteriological study has, however, dispersed these views, and even though the air of an over-crowded room rapidly deteriorates and becomes irrespirable in the process of respiration, it is to be emphasized that germs, comprising the bacilli and mold fungi, do not participate to any appreciable extent in this deterioration, and that the latter, as in case of tunnels, pertains more especially to the gaseous constitutents. Since Tyndall discovered that the breath of man is entirely free from bacteria, a variety of investigations have been made into the exhaled air, and, concordantly, they have shown that micro-organisms instead of being given off from the respiratory tract are rather taken up from the air and filtered out.

In the air of sick rooms very rich in bacteria, of six hundred germs inhaled, not more than one is found in the exhaled air. Cadeac and Malet placed healthy sheep opposite to others affected with anthrax and sheep pox and allowed them to breathe for long intervals through tubes 0.30 to 1.50 meters in length, varying their experiments in a number of ways, but never were they successful in infecting through the breath of diseased animals, those which were healthy. The lungs do not give up bacteria from their moist alveolar surfaces but rather have an opposite effect, working as filters, and is it only possible for expired air to act in the transmission of germs when sputum, mucous secretion, or tissue shreds, are expelled from the expiratory tract in paroxysms of coughing. As correctly stated by Strauss the bacteria contained in the air of an over-crowded apartment must be diminished by the act of respiration, and it may be of consolation to a clinical lecturer, whose auditorium becomes filled with listners, entering in the raising of dust, to know that each individual brings with him in the capacity of his lungs, a filter apparatus and that with each act of respiration he renders about five hundred cubic centimeters of air free from germs. A surgeon need not fear that he will infect a wound with his breath, nor that a patient suffering from sepsis in the act of respiration can fill the air of a ward with infectious organisms.

The more our bacteriological knowledge has been extended, the more frequently the true source of bacteria has been investigated, and the more we have endeavored experimentally to transmit the wound diseases, so much the more have our fears of an infection through the air diminished, and so much the less appears to be the danger of disease being communicated in this way, as compared with that by direct contact of infectious materials. The simple consideration of the number of bacteria which can gain acces to a wound, on the one hand, through the air, and on the other hand through contact, is suffi-

cient to reduce our fears of the so-called air infection. It is true it appears large when we think of a cubic centimeter of air containing 1000 or indeed 20,000 or 40,000 germs, but what are these numbers as compared with the bacteria contained in decomposed organic materials. The Spree River water in Berlin, for instance, contains in each cubic centimeter, i. e., in the millionth part of the above quantity of air, as many thousands of bacteria, and the number of germs in a drop of pus or other extensively decomposed fluid amounts to millions. Let us take to illustrate these proportions, a frequent instance in practice: The germs of the atmosphere which gain access to a wound settle upon it from air moderately in motion, by reason of gravity. By repeated investigations in the Von Bergmann clinic, we have proven, in the operating room with the auditorium occupied, that the number of bacteria which settle upon the surface of the wound a square decimeter in extent in the course of a half hour amounts to about 60 to 70; the number which deposit from the open air in the vicinity of the clinic being, however, much in the decrease.

The Spree River flows just past the clinic, and the number of bacteria which it here contains according to investigation in the Hygienic Institute, varies from 3200 to 15,000 per cubic centimeter; the average number is 37,525. Let us consider now the not infrequent instance of a ship hand on the Spree receiving a wound and suppose it happens to be a wound a square decimeter in extent – the individual coming to the clinic with the wound open and undisturbed, although exposed to the action of the air, would receive upon its surface in the lapse of one half hour before application of the dressing, at most, from 60 to 70 germs which, furthermore, are scattered loosely and very superficially over the blood clot. If, in accordance with the usual custom, the wound be now irrigated with a liter of Spree water, slowly and thoroughly for the purpose of cleansing it may readily be estimated that over 37,000,000 micro-organisms would be brought in contact, and it defeats all efforts at calculation as far as numbers of bacteria are concerned, when, in addition, the part is wrapped in a dirty cloth to which is adherent usually in mass decomposed material rich in bacteria.

Lister was of the opinion that the bacteria of the air which produce changes and decomposition in organic substrata are also those which cause wound infection. Modern investigation has long since demonstrated the incorrectness of this opinion, however, and shown that the germs of wound infection are entirely different from those of ordinary putrefaction scattered over the earth. The direct examination of the air for the now recognized cause of the wound-infection diseases in man, has afforded very scant, and for the most part only negative, evidence.

By far the greater number of air fungi belong to the innocent germs—the mold spores, yeast plants, and fission fungi, which, for man, are not pathogenic. And when the germs of wound infection have been found in the air, as in hospitals, they have, as compared with other micro-organisms, been greatly in the minority, and we find as the result of all our investigations, that the air which is inherently an unfavorable abode for micro-organisms, allows the bacteria of wound infection, which unavoidably gain access to it, to die very suddenly.

Thus gradually the theories in vogue have been forced to decline, successively, in advance of accurate investigation, and of the original views of Lister

regarding the importance of the bacteria of the air in wound infection, almost nothing remains. In practice, however, there had been experienced by Lister's original views what frequently occurs in case of greatly inaugurated ideas when put into practical application. Uninfluenced by the manner and complicacy with which the method was presented as an established requirement, the good and truth have crystallized out, the non-essential and superfluous have voluntarily remained behind. Thus prior to the evidence afforded through experimental bacteriology, the importance to the physician of air infection had greatly diminished, and from year to year increased stress came to be laid upon contact infection in the avoidance of wound diseases. With timidity, first one operator and then another omitted the use of the spray, and then everywhere it rapidly disappeared, because experience very clearly demonstrated that it was unnecessary.

So, also, will it occur with wound irrigation recommended by Lister for the destruction of infectious germs unavoidably gaining entrance to the wound through the air, and which after discontinuance of the spray by numerous operators, were given increased emphasis as a substitute for the spray.

The results in wound repair which Von Bergmann has attained for years in his clinic without irrigation, and the results which have been attained in the same manner by others who have imitated his example, are plain evidence that antiseptic wound irrigation does not belong to the true character of modern teaching and is only an unnecessary evil. It is not required that we should fill the air of a room with carbolic vapor, we have no occasion to have filtered or heated air poured into the room through ventilators, nor is it necessary that we should deluge our fresh operation wounds with antiseptic agents. We attain favorable results without all these. The individual operating room of the Bergmann clinic is a polygonal building enclosing an amphitheatre constructed of wood which at each clinic hour is filled with several hundred students. Large curtains suspended from the ceiling shut off the sun on one side; a profuse Arabesque lattice work covers a portion of the rear wall of the room, and just over the heads of the operators upon ornamental socles are placed the busts of Von Bergmann's three celebrated predecessors. Still, no one would contend that in these rooms the conditions would be especially contrary to the aggregation of dust, and repeated examinations have shown us that its air contains more bacteria than the air of any other room in the clinic, yet, notwithstanding, all operations here performed are attended with as favorable results as could be desired. In this air the abdominal cavity is quietly opened and major amputations are performed, pauses are made during the operation, the wounds openly demonstrated to the students, and then simply sutured, and in no instance has injury been seen to result from too long exposure to the atmosphere.

The individual precaution which we are required to observe against a possible infection through the air is the avoidance of the excessive clouding of dust. We would not be justified in operating where quantities of dust and dirt are blowing about and can encounter the region of the operation; this requirement, in the operating room, is very easily fulfilled, and affords difficulty only in the open air. It is also well not to clean up a room or to sweep just before a major operation, as we have seen that in this way dust always becomes agitated. Further to be observed is especial precaution in

the handling of dressings saturated with pus. That the spray does not exert a favorable influence over the bacterial contents of the air attributed to it by Lister, is conclusively demonstrated. According to the investigations of Stern, the purifying action possessed by the spray is very unimportant; so also, is it impossible by the ordinary ventilation and airing of a room to effectually diminish the bacteria contained in it. Investigations by Stern showed that after artificial dissemination of bacteria, those which are heavier gravitate to the surface in the course of one-half an hour and the air becomes free from germs, while in case of wool and rag dust, as also with mold spores, a somewhat longer time is required. The most effectual means of freeing the air of a room from its bacteria is to keep the room closed for a number of hours until the germs have settled to the floor. Then we have done all that we are required to do in the avoidance of an infection of wounds through the air. All our further efforts are to be directed against contact infection.