# Biological Impact of Small Air Ions

## Despite a history of contention, there is evidence that small air ions can affect life processes.

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If one were to search deliberately for a long-tenured controversy, he could not do better than to choose the question, "Are small air ions biologically active?" Air ions were unknown until the end of the 19th century, when Elster and Geitel (*1*) in Germany and Thomson (*2*) in England independently discovered their existence. Promptly thereafter, biologists and physicians began to explore the possibility that air ions might influence physiological processes, and over the years hundreds of papers detailed their findings. While the general trend of the experimental data was affirmative, a considerable segment of the scientific community, with some reason, has continued to withhold acceptance and the subject remains undecided. It is our purpose here to assess the validity of the arguments advanced to certify that air ions are without biological significance and to present evidence derived from two specific examples, which we believe is sufficient to support the conclusion that air ions can affect life systems. These examples are (i) air ion action on microorganisms and (ii) air ion–induced alteration of serotonin metabolism in mice, rats, and humans. Since serotonin is a powerful neurohormone, the ultimate impact of air ions can be considerable, as is apparent with those individuals living in the Near East who succumb to the atmospheric ion imbalance that precedes by 24 to 48 hours the dry wind and high temperature of the *sharav* weather complex. Additionally, we shall describe how air ions (or their lack) alter the course of influenza in mice and shall speculate about the potential roles they may play under conditions that prevail in our modern environments. We begin with an account of ion production and composition.

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### Nature of Small Air Ions

When alpha, beta, or gamma emissions from a radioactive source displace an electron from a molecule of one of the common atmospheric gases, the molecule is left with a positive charge. The displaced electron is surrounded by $2.7 \times 10^{19}$ molecules per cubic centimeter of air, and under normal conditions it is promptly captured by another molecule, to which it imparts a negative charge. Since the rate of collision of molecular ions with surrounding molecules is about $10^9$ per second, charge transfer is readily accomplished, with the result that the positive charge comes to reside on the molecular species possessing the lowest ionization potential, while the negative charge is kept by the molecule with the highest ionization potential. Under the conditions usually prevailing in nature, water molecules are abundant and in numbers ranging from one to eight they form aggregates around the charged molecules within $2 \times 10^{-7}$ second. The small air ions so produced are not uniform in composition and are subject to further changes during aging, particularly to incorporation of trace gases present in the atmosphere. However, they are uniform in possessing unit charge ($1.6 \times 10^{-19}$ coulomb) and in exhibiting an average mobility of 1 to 2 cm/sec per volt per centimeter (*3, 4*).

Similar sequences also occur when air ions are produced through the application of forces other than radioactivity—for example, by shearing of water droplets as occurs in waterfalls (the Lenard effect), by the rapid flow of great volumes of air over a land mass (the foehn, sharav, or Santa Ana), or by cosmic rays. In all these instances, the events accompanying ion generation—emission of radiation, atomic decay, hot, dry winds, and so forth—prominently overshadow the seemingly innocuous end product. Furthermore, the number of air ions in clean country or mountain air seldom exceeds $1 \times 10^4$ per cubic centimeter, so that they are subject to an enormous dilution factor of at least 15 orders of magnitude. Under ideal conditions, small ions may have a life span of several minutes. However, their numbers are continually being depleted by combination with small or large ions of opposite sign and with uncharged condensation particles. It is this last type of reaction which produces large ions (considered to be biologically inert). Obviously, the degree of air pollution bears an inverse relation to the small ion count.

### Problems, Technical and Conceptual

These special innate characteristics of air ions which postulate the improbability of their participation in biological reactions have been reinforced by considerations of a totally different nature. Probably one of the most damaging elements in the air ion dispute is the very uneven quality of the research that has been reported. Sometimes faulty experimental design permitted the impact of environmental elements other than air ions and the results were erroneously attributed to the ions. Also, there were occasions when no ions at all reached the subject and meaningless negative results were reported. The major factors contributing to errors of observation were:

1) Neglect of ozone and oxides of nitrogen produced by corona discharge ion sources.

2) Failure to monitor and control ion densities, temperature, and humidity.

3) Use of air containing particulates and gaseous pollutants which combine with air ions and lead to widely fluctuating small ion densities.

4) Failure to hold the experimental subjects at ground potential, so that their surfaces developed high electrostatic charges and repelled approaching air ions.

It has been suggested that all purported small-ion biological activity depends not on the ions directly, but rather on their capacity to serve as catalysts in the conversion of trace gases into chemical compounds possessing varying degrees of toxicity. Such catalytic reactions between ions and trace gases actually occur, but involvement of the end product as biological mediators has yet to be proved. Inasmuch as trace gases are extremely variable in nature and concentration, depending on a number of factors such as weather and local sources of emission, they can be expected to contribute varying kinds and densities of compounds that range widely in physiological impact. Since this degree of variance cannot be reconciled with the reproducibility of the biological phenomena we shall describe, we have not invoked the ion–trace gas mechanism in interpreting our experimental results.

In the mid-1950's, the field suffered a serious setback when air ion generators were sold directly to the public through intensive advertising campaigns extolling their efficacy in treating a wide variety of diseases. The Food and Drug Administration brought these activities to a halt and since then has prohibited their sale for any medical applications. This unhappy episode gave the whole subject an unsavory reputation.

There are many reasons why these objections to viewing air ions as potential biological agents are no longer tenable. The dilution argument has been laid to rest and our whole concept of the lower limits of biological responsiveness extended by the discovery of the pheromones. For example, Bossert and Wilson (*5*) showed that the male silkworm *Bombyx mori* reacts to as little as $2.6 \times 10^3$ molecules of the female attractant pheromone, provided by a concentration of less than 200 molecules in each cubic centimeter of air. That these phenomena are not limited to one type of response, nor to a single species or genus, is attested by the recent discovery of the alarm pheromone anthopleurine in the sea anemone (*6*). When isolated in crystalline form, anthopleurine had a median effective concentration of $3.5 \times 10^{-10}$ mole per liter of seawater or about 1 molecule to $1.5 \times 10^{11}$ molecules of water. Comparable ultrasensitivity to physical forces has been observed—for example, in the recognition of a quantum of light by the retina (*7*) and the remarkable role played by even less tangible agencies such as magnetic and electrical fields in the orientation of cockchafers (*8*) or in the shape and motility of amoebas (*9*). There is no basis, then, for labeling the potential biological impact of air ions as physically impossible because of the limited magnitude of the stimulus they supply.

While it is true that during the early history of air ion experimentation, much of the work failed to provide incontestable proof that ions were the proximate cause of observed functional changes, this situation has been rectified. Investigators in many parts of the world have conducted experiments with air ions under rigorously controlled test conditions and have demonstrated measurable changes in living forms clearly related to the ion content of the air. In the recent past, these findings aroused a promising renewal of interest in the reactions between air ions and bacteria, protozoa, plants, insects, animals, and humans. Organizations such as the Association Française pour la Recherche sur l'Aéroionisation have come into being and have stimulated research, basic and clinical, by reputable scientists. A number of review papers provide accounts of these developments and the reader is referred to them for details (*10*, pp. 3–167; *11*).

The third major caveat—the shadow cast on the air ion field by the commercial exploitation of 20 years ago—is hardly a valid reason for condemning the whole area of investigation. Historically there have been numerous occasions when the Western medical world discovered merit in remedies of unconventional origin. A classical example is that durable workhorse of generations of physicians—digitalis. If William Withering, foremost of medical botanists (appropriately called the "flower of physicians"), had not been willing to look for the active ingredient in a mixture of herbs which a very nonestablishment Shropshire grandame used to treat dropsy, the benefits of this drug would have remained in limbo for some indeterminate period. A more recent example, acupuncture, at first roundly condemned in the halls of orthodoxy, and surely no stranger to the profit motive, is now reported by competent medical specialists to be successfully applied in anesthesia and in the treatment of certain diseases.

There is reason, then, to suggest that this is an appropriate time to reappraise the biological role of air ions. In support of this suggestion, we cite below what we consider to be substantial evidence that small air ions do indeed influence physiological processes.

## Ion Action on Microorganisms

This field of research was pioneered more than 40 years ago by Tchijevski and his colleagues at the Central Laboratory for the Study of Aeroionification in Moscow (*12*, *13*). In a long series of experiments with agar plate cultures of *Micrococcus pyogenes* [*Staphylococcus aureus* (*Bergey's Manual of Determinative Bacteriology*, ed. 8, 1974)], *Vibrio cholerae*, and *Salmonella typhosa* [*Salmonella typhi* (*Bergey's Manual of Determinative Bacteriology*, ed. 8, 1974)], they found that colonial growth was markedly retarded in atmospheres containing $5 \times 10^4$ to $5 \times 10^6$ negative or positive ions per cubic centimeter. Negative ions were more effective than positive ions. Tests on the natural microflora of the air in enclosed spaces or on artificially created bacterial aerosols showed that ion densities in the same range rapidly reduced the count of viable cells. Similar results were obtained by a number of American investigators who, because of the language barrier, were unaware of this work, and by Russian scientists who carried out additional experiments during the 1960's.

Fuerst (*14*) reported that small air ions of either charge inhibited the germination of spores of *Neurospora crassa*. Using *Penicillium notatum* as the target, Pratt and Barnard (*15*) observed a moderate lethal effect of positive and negative ions, and in the same year Kingdon (*16*) found that air ions killed *Escherichia coli*. Krueger *et al.* (*17*) demonstrated acceleration of the death rate of *M. pyogenes* by small negative or positive ions when the organisms were suspended in droplets of distilled water sufficiently small to provide a high ratio of surface area to volume. This action occurred if the cells were brought to the air-water interface through agitation of the suspension with a microstirrer. Steps were taken to avoid the following potential sources of error.

1) Direct action of radiation on the cells. The ions were produced by sealed foils of $^{210}Po$ or $^{3}H$, placed well beyond the maximal ranges of alpha or beta radiation.

2) Agglutination of bacteria resulting in reduced viable cell count. Direct examination revealed no cell aggregates. Further, the lethal effect was reversed by exposing the cell to intense light of the visible spectrum, a reaction typical of many instances of cell damage and one which does not occur in simple agglutination. Finally, the time required to inflict cell death was much less than the minimal time for agglutination predicted by the von Smoluchowski equation (*18*).

3) Bactericidal action of ozone produced by the ion sources. Under the conditions prevailing in our experiments, no measurable amounts were generated by either radioisotope.

At the All Union Conference on Aeroionization in Industrial Hygiene, convened in Leningrad during November 1963 (*19*), several papers supplied further confirmation of the effectiveness of air ions in reducing the viable cell count of bacterial aerosols. Boyko and Sverchkov reported that an aerosolized culture of *M. pyogenes* had no survivors after treatment of the air for 60 minutes with high concentrations of negative ions. Yaroshenko found that concentrations of negative ions ranging from $5.2 \times 10^4$ to

$9.5 \times 10^4$ per cubic centimeter reduced the viable population to values averaging 7 to 15 percent of the control population. Similar experiments by Voytsekhovskiy with smaller concentrations of negative ions revealed the same trend. Phillips *et al.* (*20*) in the United States exposed *Serratia marcescens* in aerosol droplets of diameter $< 5$ $\mu$m in a 365-liter chamber. The exponential decay rate was 23 percent per minute with untreated air, 54 percent per minute with positive ions, and 78 percent per minute with negative ions. They concluded that the increase in total decay rate occurring with positive ion treatment was due largely to physical forces, whereas negative ions caused a significant amount of biological decay as well. In 1970, analogous but more dramatic lethal effects were obtained by Biró and Sváb (*21*), who studies the action of negative air ions on aerosols of *M. pyogenes* and four types of bacteriophages.

It is not at all surprising to find that small air ions affect the dispersion of aerosolized microorganisms quite apart from any direct lethal action. Most aerosols, whether produced by natural or artificial means, are electrically charged and sometimes are highly charged. When high concentrations of ions are introduced into an aerosolized cloud, they materially alter the stability of the aerosol. The net space charge that develops is responsible for high charge concentration gradients, strong electrical fields, and resultant precipitation of ions and aerosols (*22*).

Some evidence indicates that negative ions form a radical on contact with water, and from time to time consideration has been given to the potential lethal role of this theoretical compound. That such a complex may exist is suggested by Lotmar's observation (*23*) that oxygen consumption of liver tissue is increased when the tissue is exposed directly to negative ions or treated with an aqueous medium that previously has been so exposed. While these data point to the probability that negative ions form a biologically active radical with water, it seems clear that it is not concerned with the lethal effects on microorganisms, for in a series of tests by Krueger *et al.* (*24*) ion-treated water had no effect on the viable cell count of *M. pyogenes* var. *aureus* suspensions.

To summarize then, the physical mechanism that accounts for the decrease in numbers of cells or virus particles present in an aerosol is readily explicable, but at present there is no explanation for the growth inhibition and lethal action exerted by ions of either charge.

**Serotonin Hypothesis of Ion Action**

The second air ion phenomenon to be discussed here—the serotonin hypothesis of air ion action—does not have as sizable a background of individual testing as is the case with the experiments previously discussed. However, it is based on a considerable body of experimental data and perhaps is more relevant because it bridges the gap between purely laboratory observation and a possible role of ions in the natural environment.

Serotonin, 5-hydroxytryptamine or 5-HT, is a very powerful and versatile neurohormone. For example, it is capable of inducing profound neurovascular, endocrinal, and metabolic effects throughout the body. It is concerned with the transmission of nervous impulses and occurs in considerable quantities in the lower midbrain, where it plays important roles in such basic patterns of life as sleep and our evaluation of mood. It has the further advantage of being subject to assay in microgram amounts by a sensitive and accurate spectrophotofluorometric method (*25*).

In 1959 we found, by direct measurement, that negative air ions reduced the amount of free 5-HT normally present in the tracheae of mice and rabbits (*26*). When we exposed guinea pigs to negative ions and collected all the urine, we observed a considerable increment in the amount of 5-hydroxyindoleacetic acid, an inactive end product of the oxidation of 5-HT. These data suggested that negative ions lower tissue levels of 5-HT by accelerating this enzymatic oxidation process. Such a mechanism is consistent with the evidence of earlier experiments indicating that negative air ions can affect tissue oxidative reactions. When we exposed tissue homogenates in vitro to large doses of negative ions the rate of conversion of succinate to fumarate was notably increased (*27*). This demonstrates the ability of negative ions to promote one phase of the aerobic metabolism of carbohydrates in the Krebs cycle which produces the lion's share of energy for all organisms that use oxygen in respiration. Similarly, treatment of the reduced form of cytochrome c with negative ions speeded up the formation of the oxidized form. Later it was observed in experiments with plants that air ions increased the uptake of iron, promoted production of cytochrome and other iron-containing enzymes, and enhanced oxygen consumption (*10, 11*).

Many tissues contain the enzyme monoamine oxidase. Because the chief metabolic route for removing serotonin depends on oxidative deamination by monoamine oxidase, we advanced the hypothesis that small negative ions stimulate while small positive ions block monoamine oxidase action, thus producing, respectively, a drop or rise in the concentration of free 5-HT present in certain tissues and eliciting a corresponding physiological response. The probable validity of this hypothesis was established in extensive experiments conducted over a period of 16 years, with a genetically uniform strain of mice exposed at ground potential to preselected concentrations of small air ions in pollutant-free air under controlled conditions of temperature and humidity. High concentrations of positive ions raised blood levels of 5-HT, while high concentrations of negative ions had the opposite effect (*28*). We also found that the brain content of free 5-HT was responsive to the concentrations of air ions in the air (*29*). (In the course of this work, we have performed spectrofluorometric analyses on more than 12,000 brain and 36,000 blood samples from controls and ion-treated mice.)

This general mechanism of air ion action has been confirmed by other investigators, who have pursued several different approaches to the problem. Gilbert (*30*) used quantitative methods to study the effect of small negative air ions on the emotional behavior and brain serotonin content of rats. Continuous ion treatment produced statistically significant reductions in emotionality and serotonin levels. Olivereau (*31*) conducted extensive experiments on the endocrine systems and nervous mechanisms of rats treated for various periods of time with air ions. Employing sophisticated and elegant biochemical, histological, histometric, and histochemical techniques, he surveyed air ion action on the hypothalamus, the hypophysis, the adrenals, the thyroid, brain metabolism, behavior, eating, activity, psychomotor performance, and adaptation to stress. He concluded that air ion–induced alterations in blood levels of 5-HT account for very significant physiological changes in the endocrine glands and central nervous system. These, in turn, substantially alter basic physiological processes. An interesting and significant facet of Olivereau's research is his observation that negative ions exert a measurable anxiety-reducing effect on mice and rats exposed to stressful situations, a phenomenon noted by several other workers (*32, 33*). This response parallels that which follows administration to animals or humans of the drug, reserpine, used in treating hypertension. Reserpine and negative ions have in common the ability to reduce the amount of serotonin in the midbrain, and apparently this accounts for their tranquilizing action.

Other experiments concerning the effects of negative ions on rats have not included assays of tissue levels of serotonin, but have yielded physiological results compatible with the serotonin hypothesis. For example, Frey (*32*) taught rats to press a lever in order to receive a reward of food. Once this behavior was established, a conditioned emotional response was imposed by periodically sounding a buzzer, which terminated with an electrical shock to the animal's tail. The rate of lever pressing was suppressed because of anxiety when the buzzer sounded. Next, separate trials were made of the ability of the tranquilizer reserpine and of negatively ionized air to neutralize this inhibition; both were effective and again both are known to reduce the content of serotonin in the midbrain.

These responses to air ions would appear to be solely of academic interest, not only because they are limited to mice and rats, but because they involve high dosages of ions. It is especially interesting, then, to learn that analogous reactions occur in other species with the relatively low ion densities found in nature. Seventy years ago, Czermak (*34*) found that a common characteristic of certain weather fronts, such as the foehn, was the development of abnormally high concentrations of positive ions. He thought that this might be the cause of illness in weather-sensitive people, and others have since pursued the same theory. In the Near East such a weather complex is the sharav, whose most striking features are a sudden rise in temperature, a drop in humidity, and an accompanying wind. The sharav produces illness in about 30 percent of the exposed population. Robinson and Dirnfeld (*35*) studied the phenomenon and noted that weather-sensitive individuals began to suffer just at the time the total air ion count rose with a disproportionate increase in the number of positive ions; this was 24 to 48 hours before any other changes occurred in environmental parameters such as wind velocity and direction, solar radiation, temperature, and humidity. Sulman *et al.* (*36*) confirmed the observations of Robinson and Dirnfeld and also conducted intensive clinical and biochemical studies of the sharav patients. By judicious application of Ockham's razor they eliminated the more unlikely explanations of the origin of the sharav malady and indicted the only physical factor that had changed—that is, the number of positive ions in the air. They designated the cluster of signs and symptoms (migraine, nausea, vomiting, amblyopia, irritability, hyperperistalsis, edema, conjunctivitis, congestion of the respiratory tract, and so on) the serotonin irritation syndrome, first, because the picture is compatible with hyperactivity of serotonin in the midbrain and second, because the patients excrete abnormally large amounts of serotonin in the urine. The sequence then is: elevated density of positive ions, increased production of serotonin in the exposed subject, resultant evolution of the clinical syndrome, and rise in renal excretion of serotonin. The probability that this series of events is connected in a meaningful way is corroborated by two further observations of Sulman *et al.*: the disease is successfully treated by inhalation of air containing large numbers of small negative ions or by administration of serotonin-blocking drugs. While air ion imbalance evidently supplies the essential conditions for initiating the serotonin irritation syndrome, the hot dry wind undoubtedly has a major part in its subsequent maintenance and progression. It should be pointed out that other "winds of ill repute" besides the foehn and sharav occur in many parts of the world and have similar meteorological characteristics—the chinook of the Rocky Mountain States and the Argentine zonda, for example.

## Ion Effects on Mouse Influenza

It may be of interest to describe another air ion phenomenon that has been the subject of intensive investigation in our laboratory, but to the best of our knowledge has not yet been studied by other workers; namely, the role played by air ions in determining the course of influenza in the mouse. We challenged specific pathogen-free mice intranasally with measured doses of influenza virus after they had been exposed in a controlled and monitored microenvironment to various concentrations of small air ions for 48 to 72 hours. The animals were then returned to the initial environment and were observed for rate of death. When they were compared with animals maintained in air having "normal" air ion densities, the most significant findings were these: unipolar high concentrations of positive ions or ion-depleted air increased the cumulative mortality rate; unipolar high concentrations of negative ions decreased the cumulative mortality rate (*37*).

Treatment with positive ions also had a detrimental effect in two other diseases of mice produced by intranasal instillation of measured numbers of arthrospores of the fungus *Coccidioides immitis* (*38*) or of vegetative cells of the bacterium *Klebsiella pneumoniae* (*39*); that is, the cumulative mortality rate was increased. There is good evidence that small positive and negative ions penetrate to and impinge on the mucosa of the upper portions of the respiratory tract and that the physiological changes produced in this zone account for the alterations in rate of death following intranasal challenge with each of the three agents cited. This general concept is supported by experiments conducted in human adults and infants, which demonstrated that high concentrations of positive ions produce congestion of the nose and pharynx (*40*) and, when prolonged, similarly affect the bronchi. If the upper respiratory tract is bypassed by administering influenza virus as an aerosol of particles 2 $\mu$m in diameter, most of the virus reaches the smaller passages of the respiratory tree and the alveoli, with the result that treatment with either negative or positive ions has no influence on the cumulative mortality rate (*41*).

## Influence of Ion Depletion

Long ago, Tchijevsky (*13*) found that the life span of mice kept in an ion-depleted atmosphere was substantially shortened. This fact, added to our observation that ion depletion promotes the rate of death of mice infected with influenza virus administered by the intranasal route, may lead one to speculate about the possible ecological implications of ion deprivation. The current growth of world population and industrial activities function to produce large-scale atmospheric pollution, and the combination of air pollutants with small (biologically active) air ions yields large or Langevin ions and leads to small ion depletion. That this progression has attained significant magnitude is evidenced by many meteorological observations. Beckett (*42*) measured the densities of small and large air ions over a 4-day period in an industrial area near the San Francisco end of the Bay Bridge. As air pollution developed during the working day, the total small air ion count averaged less than 80 per cubic centimeter, or 10 percent of that in a residential district; in addition, the duration of life of a small air ion in the air at sea became appreciably shorter as air pollutants drifted out from the land.

Very few human activities add small

ions to the air, while many of them lead to ion loss. In consequence, we suffer both the direct toxic effects of the pollutants we generate and long-continued exposure to air in which the normal total ion concentration of about 2000 to 3000 per cubic centimeter (as found in the relatively clean air of open country) is reduced to barely detectable levels. Should we live in the congested area of a typical city, toil in a factory, or work in an ordinary office, we spend most of our time in a Faraday cage which, with varying degrees of efficiency, insulates us from the electrical and ion-generating phenomena of nature. The pervasive gaseous and particulate pollutants react with whatever small air ions are present to ensure that the air surrounding us is ion-depleted. The micrometeorological data of this scenario are well established—the biological sequellae are hypothetical. However, it is noteworthy that ion depletion has been shown to affect plants as well as animals. Seedlings of *Hordeum vulgaris* grown in a chemically defined medium and supplied with air containing about 30 positive and 30 negative small air ions per cubic centimeter displayed a significant reduction in growth as measured by integral elongation and fresh and dry weight; further, the leaves were very soft and the plants lacked normal turgor (*43*).

We have pointed out (*44*) that although the early results of ion depletion very likely will be unimpressive compared to the immediate and dramatic action of known toxic components of polluted air, this alone should furnish little solace. We have every reason to be aware from past experience that adverse effects may follow continued exposure to a small amount of a minor irritant (for example, organic solvents) or the long-term deprivation of an essential metabolic requirement (trace elements or vitamins). The ultimate dimensions of biological changes produced by air ion loss may prove to be as disenchanting as some revealed by Rachel Carson in *The Silent Spring* (*45*).

While ion depletion gives promise of being a threat to the stability of a salubrious ecology, there is good cause to believe that its effects can be minimized. First, the steps now under way to control the emission of pollutants into the atmosphere will permit the natural sources of ion generation once again to prevail and, it is hoped, the air ion levels of urban air will approach those of clean rural air. Second, we can adopt standards of air ion densities for living and working quarters which are comparable to those presently defined for temperature, humidity, and air turnover. The goal will be to maintain air ion concentrations and ratios approximating those existing in nature. Suitable air ion generators already are available and are capable of operating without producing unacceptable amounts of ozone or other toxic gases. Air ion measuring equipment also is in existence. It is expensive, but as demand increases the costs should be lowered.

## Summary

The thrust of the experimental data presented here is that small air ions are biologically active. There is convincing evidence that both negative and positive ions (i) inhibit growth of bacteria and fungi on solid media; (ii) exert a lethal effect on vegetative forms of bacteria suspended in water when opportunity is provided for contact of cells and ions; and (iii) reduce the viable count of bacterial aerosols. Through physical action, ions of either charge upset the stability of aerosolized bacterial suspensions and, in addition, have a direct lethal effect which is more prominent with negative ions than with positive ions. With regard to the serotonin hypothesis of air ion action, the situation is more complex. The essential fact is that mice and rats display a charge-related metabolic response to air ions and this phenomenon also occurs in humans. Because serotonin is such a potent hormone, the ultimate functional changes incident to air ion action are impressive and account for the signs and symptoms of the sharav syndrome. Alterations in the cumulative mortality rate with three experimental respiratory diseases in the mouse also are charge-dependent, positive ions routinely exercising a detrimental effect. Further, in the case of mice infected with influenza virus, ion deprivation increases the cumulative mortality rate. Since ion depletion is a constant concomitant of modern urban life, one reasonably may speculate about comparable inimical effects on humans.

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