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THE QUESTION OF LIVING BACTERIA IN STONY METEORITES

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PREFACE

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The report by Professor Charles B. Lipman that he had recovered bacteria from meteorites and his interpretation of their being of extra-terrestrial origin were received by the layman with philosophical interest and by geologists and bacteriologists with skepticism. The interpretation proposed by Lipman is of fundamental significance and before it is accepted it should be shown to rest on indisputable evidence. As with the proof that a certain micro-organism causes a specific disease, so with the proof that bacteria are brought to earth by meteorites—all chance of bacterial contamination on earth must be excluded or a distinctive bacterium must be found. The difficulties inherent in such determinations are well-nigh insurmountable, and even the closest regard for technique may be insufficient because of the manipulations necessarily involved.

All evidence so far presented indicates that a distinctive bacterium was not suspected, and it therefore remained to be determined that no possibility of contamination existed in the laboratory examinations. The bacteria described by Lipman appear to be those most frequently met as contaminants in laboratories; this fact throws even more burden of proof upon the modern sponsor of extra-terrestrial origin of life.

The significance of Lipman's theory is of such a fundamental nature that a repetition of the laboratory tests and a statement of another's interpretation of the findings are most timely. This has been done by a member of the scientific staff of Field Museum, Mr. Sharat Kumar Roy, whose laboratory results and argumentation follow. The unique combination of an intensive geological experience, a bacteriological training, and a technical patience and skill, together with the availability of meteorite specimens, is enjoyed by few men. I have followed this work with interest and feel that the interpretations offered by Mr. Roy are justified.

Under the present circumstances of bacteriological analysis in the laboratory, evidence other than bacterial seems essential before the theory of extra-terrestrial origin of life can be accepted.

INTRODUCTION

Lipman (1928) reported the finding of living bacteria in three samples of rocks, two from the Pre-Cambrian and one from the Pliocene. The organisms found in the Pre-Cambrian were said to be different from those found in the Pliocene samples, but in general they were spore-bearing bacilli occurring in chains. The question as to whether the organisms had gained relatively recent access to the interior of the rocks or had always been there was left by Lipman as a problem to be determined by further investigation but no other paper on the subject has since appeared.

Three years later the same investigator (Lipman, 1931) reported the finding of bacteria in anthracite coal. This time he claimed that these bacteria had existed in the coal ever since it was formed, some 250 million years ago. Following this announcement, Farrell and Turner (1932) attempted to verify Lipman's findings, but failed to do so except in coal that was fractured and thus was exposed to the ingress of bacteria through surface seepage. Further, the bacteria (a staphylococcus and a Gram-positive spore-forming rod) found in this fractured coal were plentiful in the mine and surface waters and mine soils, and similar to those described by Lipman. No bacteria were found by Farrell and Turner in coal that was not fractured or cracked.

In a third paper Lipman (1932) reported the finding of living bacteria in aerolites (stony meteorites). He claimed that stony meteorites had brought down with them from somewhere in space "a few surviving bacteria, probably in spore form but not necessarily so, which can in many cases be made to grow on bacteriological media in the laboratory." This very ambitious interpretation which directly hinted at the extra-terrestrial origin of life on earth has aroused much interest and controversy in geological and biological circles, and because of its spectacular nature has gained wide publicity.

The present writer, with the view of confirming or controverting this announcement, undertook to repeat Lipman's experiments, closely following his technique and culture media so that the two results might be comparable. Four meteorites were used for the purpose and the experiments were carried on in the Department of Hygiene and Bacteriology of the University of Chicago. The work was started in the spring of 1933 and was completed in the summer of 1935. The results obtained are given in the following pages.

EARLIER WORK

The probable occurrence of bacteria in ancient rocks, in cosmic space, and in meteorites has been suggested before. Galle (1910–11), Schroeder (1914), and von Lieske and Hoffman (1929) carried on various experiments to determine whether the bacteria found in ancient rocks were responsible for the production of coal gas in the mines and at what depths of the earth's crust bacteria might actually be recovered. Bastin (1926), Gahl and Anderson (1928), and Bastin and Greer (1930) believed that the presence of hydrogen sulphide in oil wells might be the result of the reduction of soluble sulphates by certain anaerobic bacteria. Richter speculated on the possibility that micro-organisms pervaded all space. This speculation assumed the form of a hypothesis in the mind of Arrhenius, who reasoned that under certain favorable conditions the pressure of light could drive spores from space to our planet and thus could seed it with life. Von Helmholtz and Kelvin suggested that meteorites might have been responsible for bringing the original forms of terrestrial life to the earth when the azoic stage was passed. Lipman appeared to raise this suggestion to the dignity of a fact by his announcement that he had found living bacteria in the interior of stone meteorites, thus proving experimentally that life existed beyond the earth.

TECHNIQUE, MEDIA, AND RESULTS OF LIPMAN

Lipman's experimental technique (1932, pp. 1–3), and the culture media he used (personal communication, April 22, 1933) were as follows:

GENERAL EXPERIMENTAL TECHNIQUE

"The arrival at the most desirable technique was a matter of evolution, and a number of meteorite specimens had to be sacrificed more or less in the process. The general idea, however, remained the same throughout, viz., an attempt was made to remove from the surface of the specimen all organisms which might be attached to dust or other adhering substances. This was attempted by first washing the surface of the specimen thoroughly with soap and hot water with the aid of a sterile brush. The specimen was then rinsed in distilled water, dried with a paper towel and placed in a solution of bactericide. At first, solutions of $HgCl_2$ (concentration of 1 to 1000) were used, and periods of exposure thereto varied in different experiments from one to one and one-half hours. Later, superoxol, a 30% solution of H_2O_2 was used for periods varying generally from three to six hours. The substitution of superoxol for $HgCl_2$ was made because of the suspicion that $HgCl_2$ reacts with some of the constituents of the meteorites and therefore remains in them and possibly poisons the media into which they are transferred later. After the exposure of the specimen to the bactericide for the desired period, it was transferred to 95% alcohol for half a minute to a minute, grasped with sterile tongs and exposed to a large gas flame until the alcohol had all burned away and for a few seconds more. In the early experiments it was then quickly thrown into a sterile iron mortar and crushed and the powder distributed with a sterile spoon into several flasks of sterile media. In the latter experiments, however, the specimen was dropped directly from the flaming procedure just described into a wide-mouthed flask containing one of the best adapted media in sterile condition. In such media, the specimen remained for periods varying from two or three weeks to four or five months, and, if no growth was evident, the supernatant fluid was plated and poured off, the flask being thoroughly flamed before and after opening, and the specimen dropped into a sterile mortar and crushed as described above. The sterile mortars were prepared and guarded with the greatest care and the technique involved was as described elsewhere [Lipman, 1931, p. 184]. Wherever growth appeared in the small culture flasks of liquid medium into which the meteorite powder from the mortar was introduced, it was studied directly under the microscope and by plating. Practically all of the manipulation involved in those experiments was carried out in an inoculation chamber specially sterilized every time it was used by many hours of fumigation with formaldehyde vapor and steam. Everything used in the experiments was sterilized by the most drastic means. Glassware and tongs were heated for twenty-four hours or more at 165° C. The mortars were heated at the same temperature for several days. Liquid and solid media were sterilized in the autoclave two or three times before using, each exposure being from one to three hours at 20 pounds steam pressure. Except as described otherwise below [Lipman, 1932, p. 15], incubation of cultures was 28° C. in a special incubator room, and all culture flasks during and before incubation were protected against contamination by capping cotton stoppers with filter paper which had been dipped in $HgCl_2$ solution."

CULTURE MEDIA

(1) *Peptone soil extract:*
Soil and water—1:1
1% or 5% peptone

(2) *Na_2S peptone soil extract:*
Soil and water—1:1
1% or 5% peptone
1% Na_2S

(3) *Peptone coal extract:*
Powdered coal
Distilled water
1% peptone

(4) *Jacobson's sulphur oxidizing medium:*
Distilled water—1000 cc.
K_2HPO_4—0.5 gram
NH_4Cl—0.5 gram
$MgCl_2$—0.2 gram
$CaCO_3$ or $MgCO_3$—20.0 grams

A little precipitated sulphur, sterilized by heating in dry heat just below the melting point for a period of seven or eight hours is added after the medium has been sterilized. This is to avoid sulphur melting and forming globules in the autoclave.

(5) *Scale's medium minus cellulose:*
K_2HPO_4—0.5 gram
$MgSO_4$—0.25 gram
NaCl—0.5 gram
$(NH_4)_2SO_4$—1.0 gram
$CaCO_3$—0.25 gram
$MgCO_3$—0.25 gram
Fe—20.0 p.p.m.
Cu—0.25 p.p.m.
Mn—1.0 p.p.m.
Zn—1.0 p.p.m.
Boron—1.0 p.p.m.
Distilled water—1000 cc.

(6) *Bastin's medium:*
K_2HPO_4—0.5 gram
Asparagin—1.0 gram
$MgSO_4$—2.5 grams
Sodium lactate—0.5 gram
$(FeNH_3)_2(SO_4)_3$—trace
Distilled water—1000 cc.
NaCl—2.0 grams per liter

(7) *Bristol's algal medium:*
$Ca(NO_3)_2$—1.0 gram
KCl—0.25 gram
$MgSO_4$—0.25 gram
KH_2PO_4—0.25 gram
Tap water—1000 cc.

SUMMARY OF RESULTS

Lipman's preliminary and secondary experiments with ten meteorites hardly need to be mentioned here, for it was not definitely known whether the surfaces of the meteorites were sterile or not. In his final experiments he used six meteorites from five different falls. They are as follows:

(1) Modoc. Fell September 2, 1905. Weight, 162 grams.
(2) Holbrook. Fell July 19, 1912. Weight, 252.5 grams.
(3) and (4) Johnstown. Fell July 6, 1924. Weight, 123 and 49 grams respectively.
(5) Mocs. Fell February 3, 1882. Weight, 109 grams.
(6) Pultusk. Fell January 30, 1868. Weight, 117.0 grams.

The first five of the above meteorites yielded bacteria which were of the order of rod or bacillus forms, and cocci. The sixth, the Pultusk meteorite, produced in peptone coal extract an irregular rod mixed with coccus forms. This organism was found to be autotrophic; that is, one which requires neither organic carbon nor organic nitrogen. It is capable of building up both carbohydrates and proteins out of carbon dioxide and inorganic salts.

None of the bacteria except one, *Bacillus megatherium*, found in these six meteorites was identified by Lipman. He dismisses this important phase of his studies by saying: "These bacteria are similar to forms common on our earth and probably identical with some of our forms." Whether he has made any attempt to determine the systematic position of these bacteria is not known to the writer.

GENERAL REMARKS

The four meteorites used by the writer in his studies are (1) Holbrook, (2) Mocs, (3) Pultusk, and (4) Forest City. The first three of these belong to the same falls as three of the five falls used by Lipman in his investigations. How there could be more than one meteorite in a single fall might be asked here by those unfamiliar with meteorites. This is due to what are known as meteoritic showers, which are characterized by the fall of a large number of individuals, sometimes thousands, at one time and place. Opinions as to the origin of these showers differ. It may be that meteorites come as one body and break up on striking the earth's atmosphere. The angularity, the uniform composition, and the narrow distribution of the individuals of a shower, as well as the appearance of meteors in the air as a ball rather than as a swarm of bodies, seem to favor this assumption.

The specimens used were all small, the largest being 8.65 grams. The reason for choosing small specimens is that stony meteorites larger than 10 grams are seldom completely crusted. In studies of this nature, the importance of complete encrustation can not be overestimated, for the crust not only insures retention of the contents of the interior of meteorites in their original form and condition, but also serves as a natural protection against the ingress of bacteria from dust and air. Furthermore, small specimens are more easily handled—an advantage which greatly diminishes the chances of

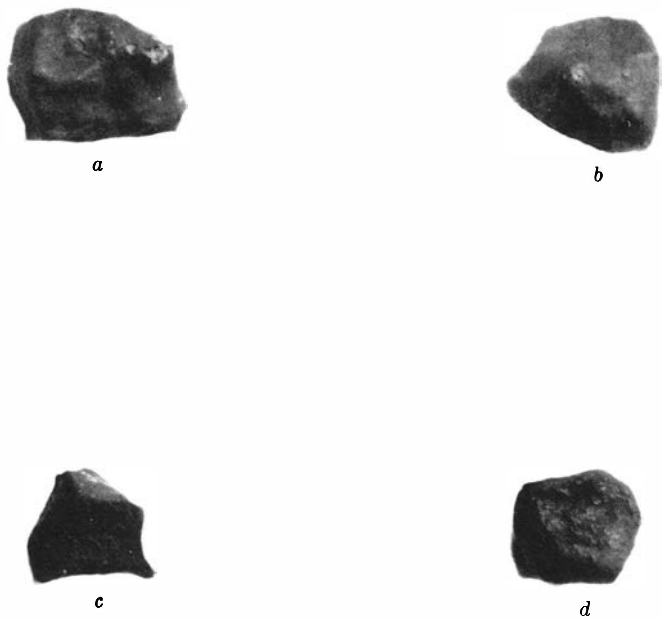


FIG. 40. The four meteorites used in the investigation. *a*, Pultusk. *b*, Holbrook. *c*, Forest City. *d*, Mocs.

their being contaminated. Houston (Report on Chemical and Bacteriological Examinations of Soils, London, Local Government Board, 1897–1898) found uncultivated sandy soils to contain on an average 100,000 bacteria per gram, and garden soils 1,500,000 per gram. This being the case, it would seem that a number of small-sized specimens (if bacteria do perchance exist in meteorites) would be far more desirable than a large one. Here in Field Museum, which houses the largest single representative collection of meteorites in existence, there is not one stone meteorite even one-fourth the size of those Lipman used which is completely crusted.

In addition, large specimens are seldom without cracks, which, needless to state, provide an easy means for the bacteria to gain entrance into the interior from such transporting agents as air, dust, and water. Furthermore, if these agents contain sufficient food for bacterial life, the cracks, when sealed over, might serve as harbors for the organisms to multiply.

Of the several culture media described (p. 183), only the following three which were found to be the best adapted were used in the present investigation. The reason for limiting to Lipman's media was to adhere as closely as possible to repetition of his technique. The formulae for these media (Nos. 1–3) are given on page 183. Their preparations are as follows:

Peptone soil extract.—Soil (fertile and nearly neutral) suspension in tap-water sterilized for one hour per day for four days in the autoclave at 19 pounds steam pressure. Filtered through Berkefeld candle (ordinary filtering left the extract still cloudy). Filtrate again sterilized for same length of time and in the same manner before filtering. Peptone (5%) added and heated until peptone was dissolved. Filtered again. Medium distributed to sterile flasks and sterilized for two one-hour periods on successive days.

Na_2S peptone soil extract.—Na_2S (1%) added to above-mentioned peptone soil extract medium before the final two hours of sterilization.

Peptone coal extract.—Powdered coal in distilled water sterilized in autoclave for one hour per day for eight days. Filtered. Peptone (1%) added and heated until peptone dissolved. Filtered again, and distributed to previously sterilized flasks and sterilized for two one-hour periods on successive days.

PRELIMINARY EXPERIMENTS

These experiments were conducted with glacial drift pebbles mainly to get acquainted with the technique and incidentally to determine whether bacteria that have gained entrance into stony meteorites could find sufficient food to survive in them. It has been known and later experimentally proved that water with bacteria can seep through stony meteorites (p. 196) when they are in contact with the earth. Accordingly, four pebbles having the average texture of stony meteorites used in the final experiments were selected. The texture was determined by comparing thin sections of similar pebbles and meteorites of the same falls as those experimented on. The pebbles consisted of three peridotites and one basalt, which of all terrestrial rocks correspond most nearly in structure and composition to stony meteorites. None of the specimens exceeded 10 grams in weight, and none showed surface cracks when examined under the microscope (60 ×).

Treatment.—The specimens were scrubbed with hot water and new antiseptic soap (a sterile brush was used), rinsed thoroughly in sterile water, dried with sterile cotton, and placed in a beaker of superoxol. They were left there for four hours, then removed with sterile tongs into 95% alcohol, flamed until the alcohol had all burned away and then each specimen was dropped into a separate large bore test tube containing sterile peptone soil extract. The pebbles were incubated aerobically for three weeks at 28° C., then anaerobically for six weeks at 37° C. The medium in each tube remained perfectly clear. The specimens were then crushed in a sterile chamber separately in a sterile mortar and the powder from each was distributed with a sterile flamed spoon into two tubes, one containing peptone soil extract, the other peptone coal extract. Incubation was carried out aerobically for two weeks at 28° C., then anaerobically for six weeks at 37° C.

One control plate was exposed in the inoculating chamber.

Results.—Growth developed in two of the eight tubes. The control plate developed three different types of colonies and one mold colony. The two tubes showing growth, however, were apparently contaminated, for the organisms found therein were identical with those of the control plate.

Remarks.—The results obtained from the foregoing studies led the writer to believe that the possibility of bacteria surviving in stony meteorites is very small. This was later confirmed by the negative results obtained when terrestrial bacteria, both bacilli and cocci, were inoculated in a culture medium consisting of meteorite powder and distilled water.

FINAL EXPERIMENTS

A peculiar problem was met while attempting to free the surface of the meteorites from bacteria. On four successive occasions after the surfaces of the specimens were sterilized as mentioned above and left to be incubated, a heavy precipitate simulating growth of certain types of bacteria was observed at the bottom of every tube after it had been in the incubator for periods varying from seven to fifteen days. Each time the sediment was cultured but no growth developed, nor could any bacterial structure be recognized when it was examined under the microscope. The precipitate was then analyzed chemically and found to be the result of hydrolization of basic iron salts giving free hydroxide, the iron having been in solution as chloride from the mineral lawrencite (a mixture of iron and nickel chlorides) in the meteorites.

PULTUSK METEORITE

Name and place.—Pultusk, Warsaw, Poland. No. Me 1585 Field Museum (fig. 40*a*).

Description.—Angular; length 23 mm., width 18 mm., height 14.9 mm., weight 8.65 grams. Completely crusted. Fell 7 P.M., January 30, 1868. A shower of stones estimated at over 100,000 pieces varying in weight from 9 kilograms to 1 gram. One of the most remarkable falls on record. Over 200 kilograms are listed as scattered throughout the various collections of the world.

Composition.—Light-gray chondritic mass containing grains of iron and pyrrhotite in a groundmass composed of olivine, enstatite and some diallage.

Treatment.—The specimen was scrubbed with hot water and new antiseptic soap (a sterile brush was used), rinsed several times in sterile water, dried with sterile cotton, and immersed in superoxol. After four hours the meteorite was removed with sterile tongs, dipped in 95% alcohol for a minute, flamed until the alcohol had burned away and for a few seconds more, then dropped into a six-inch large bore test tube containing sterile peptone soil extract. It was incubated aerobically for twelve weeks at 28° C., then anaerobically for sixteen weeks at 37° C. The medium remained perfectly clear to the end of this time. The specimen was then crushed inside a sterile chamber in a specially devised mortar (fig. 41D), which was previously sterilized inside a metal container (fig. 41A,B). The container itself had served as a separate sterile chamber. The powder was then distributed with a thoroughly flamed sterile spoon into single tubes of the following media: peptone soil extract, Na_2S peptone soil extract, and peptone coal extract. The tubes were incubated aerobically for two weeks at 28° C., and anaerobically for eight weeks at 37° C.

A control plate was exposed by passing it through the atmosphere of the inoculating chamber four times.

Results.—Growth to be described later developed in peptone soil extract within twenty-four hours and not in the other media. The control plate showed two distinct types of colonies, and three mold colonies.

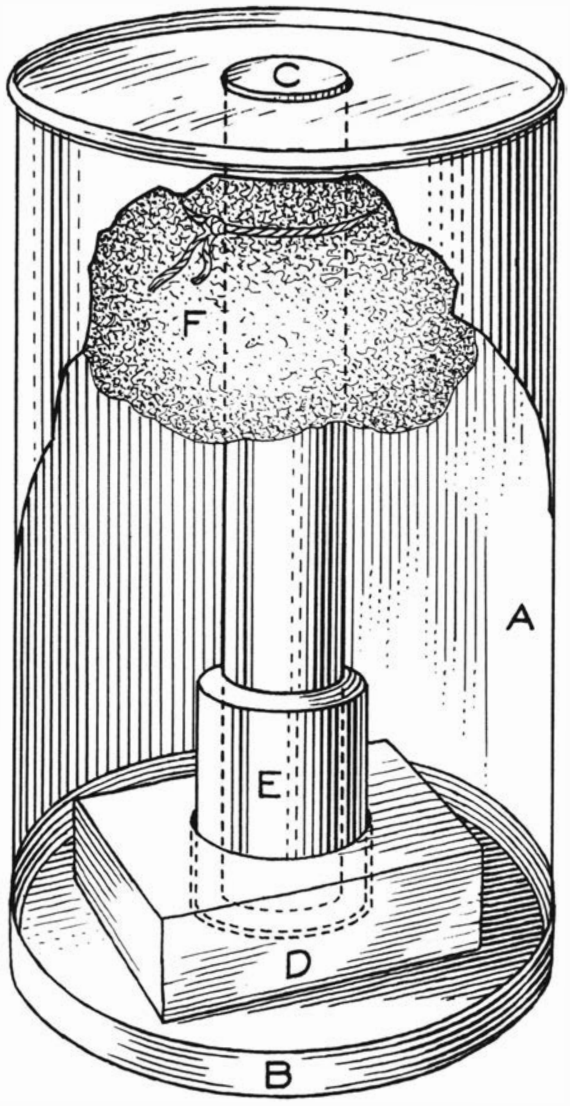


FIG. 41. Specially devised mortar and pestle shown inside metal container (sectioned). A= removable upper part of metal container; B=base of metal container; C=pestle; D=mortar; E= removable collar of pestle; F=cotton tied around top of pestle.

The apparatus is wrapped in brown paper and sterilized in dry heat at 165° C. for 24 hours. It is then placed in sterile chamber. A is slightly raised from B, exposing the mortar and pestle. E, which lifts the pestle with it, is removed and the meteorite is placed in the mortar. A is then replaced and the specimen powdered by hammering the pestle through the opening on the top of A. The cotton protects against bacterial ingress from above.

HOLBROOK METEORITE

Name and place.—Holbrook, Navajo County, Arizona. No. Me 801 Field Museum (fig. 40*b*).

Description.—Angular; length 20.5 mm., width 17.5 mm., height 14 mm., weight 6.13 grams. Completely crusted. Fell 7.15 P.M., July 19, 1912. The shower numbered more than 14,000 separate pieces, which weighed from the fraction of a gram to 6,000 grams.

Composition.—Light-gray chondrite showing very little metal, but comparatively numerous nodules of troilite. Olivine with monoclinic and orthorhombic pyroxenes and a small amount of maskelynite.

Treatment.—Same as No. Me 1585 (p. 188).

Results.—Growth in twenty-four hours developed only in a tube of Na_2S peptone soil extract.

MOCS METEORITE

Name and place.—Mocs, Cluj (=Klausenburg, Kolozsvar), Transylvania. No. Me 1448 Field Museum (fig. 40*d*).

Description.—Angular; length 16 mm., width 14 mm., height 11.5 mm., weight 4.50 grams. Completely crusted. Fell 4 P.M., February 3, 1882. A shower of some 3,000 stones of a total weight of 300 kilograms. The largest single individual weighed 56 kilograms. This is one of the most widely distributed falls, portions of it at one time being found in more than one hundred collections.

Composition.—Gray chondrite, olivine, enstatite, diallage, a plagioclase feldspar, chromite, pyrrhotite, metallic iron, and an amorphous black undetermined substance.

Treatment.—Same as No. Me 1585 (p. 188).

Results.—No growth in any of the media.

FOREST CITY METEORITE

Name and place.—Forest City, Winnebago County, Iowa. No. Me 340 Field Museum (fig. 40*c*).

Description.—Angular; length 17.5 mm., width 14 mm., height 11 mm., weight 4.33 grams. Completely crusted. Fell 5:15 P.M., May 2, 1890. A shower of five large and more than five hundred smaller ones of a total weight of 125 kilograms.

Composition.—Spherical chondrite. Nickeliferous iron, troilite, and silicate soluble and insoluble in HCl.

Treatment.—Same as Specimen No. Me 1585 (p. 188).

Two control plates were exposed in the inoculating chamber after all inoculations had been made, one for one minute, the other by being passed through the air of the inoculating chamber three times.

Results.—Within twenty-four hours growth developed in peptone soil extract, the other tubes remaining clear. Of the two control plates, the one which was passed through the air of the chamber also developed several colonies of two distinct types, and one mold colony.

DISCUSSION OF RESULTS

In the foregoing experiments bacterial growth appeared in a total of three of the twelve tubes of media inoculated with meteorite powder. Stained smears of these growths showed two types of organisms, a rod and a coccus. This was confirmed by plate culturing which developed two types of colonies, one made up of bacilli and the other of cocci. The systematic position of the organisms was then determined by observing their morphology, as well as their cultural, staining, and fermentation reactions. These tests established the rod to be *Bacillus subtilis* (fig. 42*a*), and the coccus, *Staphylococcus albus* (fig. 43*a*).

Since the presence or absence of living bacteria in meteorites was the fundamental object of the present investigation, the tests which led to the identifications of the two aforesaid organisms will be given here.

Bacillus subtilis (Ehrenberg) Cohen. Fig. 42.

Morphology.—Medium-sized rods with rounded ends, mostly straight, a few curved ones occurring singly and in short chains. Motile; about ten peritrichate flagella. Spores centrally and subterminally placed.

Staining reaction.—Gram-positive.

Agar plate.—Colonies irregularly circular, raised, yellowish-gray. Surface granular.

Gelatin stab.—Saccate liquefaction.

Fermentation reaction.—Acid in glucose and sucrose; nitrate reduced to nitrite.

Staphylococcus albus Rosenbach. Fig. 43.

Morphology.—Small spherical cells, in grape-like clusters. Nonmotile.

Staining reaction.—Gram-positive.

Agar plate.—Circular colonies with smooth borders, convex, smooth, and white.

Gelatin stab.—Partial liquefaction.

Fermentation reactions.—Acid in lactose, mannite negative; nitrate reduced to nitrite.

It has been noted before that two of the three control plates exposed in the inoculating chamber developed two distinct types of colonies. These were studied in stained films, showing one of the colonies to consist of rods, the other of cocci. The organisms then were subjected to an appropriate series of tests and were found also to be *B. subtilis* (fig. 42*b*) and *Staph. albus* (fig. 43*b*).

The logical conclusion, therefore, is that growth found in the three tubes inoculated with meteorite powder was the result of contamination with *B. subtilis* and *Staph. albus*. It is needless to mention that the utmost precautions were taken to prevent contamination, but, nevertheless, it apparently occurred in three of the twelve test tubes. Farrell (1933, p. 2) was probably fully justified in stating that "prevention of contamination of the meteorites during the process of crushing alone must appear to trained bacteriologists as an almost insurmountable task." It is, however, convincing to learn that the organisms found were with all probability contaminants, and not "meteorite bacteria."

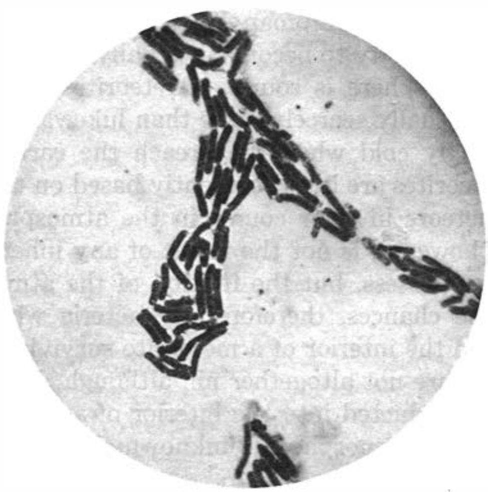
CONCLUSIONS

Under the heading "General Discussion of the Study" Lipman (1932, pp. 17–18) in an attempt to strengthen his conclusions submits a series of anticipated criticisms (Q) with answers (A). Some of these are quoted below. The writer's remarks follow each answer.

> Q. Stony meteorites contain very little organic matter for the support of saprophytes.
>
> A. Stony meteorites do not contain much organic matter, but they do contain some, as is shown in analyses which have been published in meteorite catalogues in respect to organic carbon. In addition, I am publishing in American Museum Novitates No. 589, concurrently with this paper, some data on nitrogen content of stony meteorites which show them all to contain a little combined nitrogen, probably organic in nature. So far as I am aware, these are the only figures known for nitrogen in meteorites.

Only a small percentage of meteorites contain carbon and these only in amounts of less than one fifteen-hundredth of one per cent, a quantity apparently inadequate to sustain bacterial life. It may be also said in this connection that there is no evidence that any of the carbon compounds found are of organic origin. Competent

a



b

FIG. 42. *Bacillus subtilis.* *a,* Isolated from control plate. 48-hour culture. × 1000. *b,* Isolated from growth in sodium sulphide peptone soil extract medium inoculated with Holbrook meteorite powder. 48-hour culture. × 1000.

students of meteoritics believe that they were formed in an inorganic way by union of elements. Lipman's findings of "probable organic nitrogen" have not yet been corroborated in other laboratories.

Q. The heating of the meteorite in its descent through our atmosphere would destroy bacteria.

A. Geologists generally have advised me that meteorites do not have an opportunity to become heated internally while traveling through our atmosphere. They burn externally but remain cold internally.

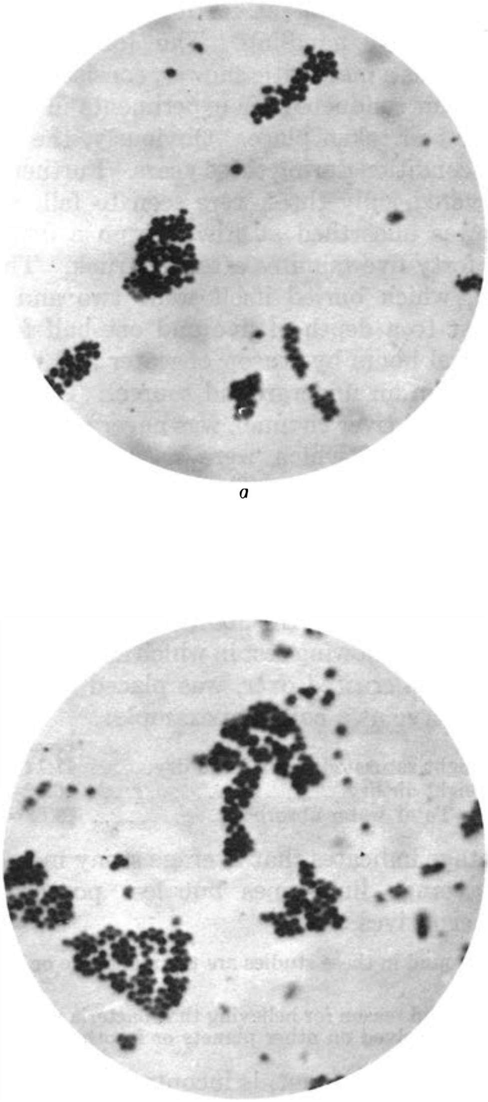
The above answer of Lipman's would seem to be a glaring contradiction, for, referring to his Specimen No. 388, which he had flamed for twenty seconds in a large gas flame, he states (Lipman, 1932, p. 12): "The conductive properties of the meteorite are very high because of the large amount of metallic substance therein, and hence some organisms in the specimen must have been destroyed before the stone was crushed." Any statement as inconsistent as this must necessarily lead one to believe that Lipman was arbitrarily creating a condition to suit his conclusion. How could bacteria, if any, in a meteorite be destroyed by heating it twenty seconds in a gas flame when they are not supposed to be destroyed by the intense heat which literally fuses the surface of the meteor during its passage to the earth?

The advice given to Lipman by geologists that meteorites do not have an opportunity to become internally heated while traveling through our atmosphere is sound. Meteorites, particularly stony meteorites, are usually scarcely more than lukewarm and sometimes even benumbingly cold when they reach the earth. The general belief that meteorites are hot is evidently based on the brilliant light emitted by meteors in their course in the atmosphere. The light phenomenon, however, is not the result of any inherent heat which meteorites may possess, but the friction of the atmosphere against the mass. The chances, therefore, of bacteria which might have gained access to the interior of a meteorite surviving the downward plunge to earth are not altogether nil, although the amount of heat that might be conducted into the interior of a meteorite during its passage through the atmosphere is unknown. It probably is not lethal.

Q. While it was lying on the earth, and before being found, water with bacteria may have seeped into the meteorite.

A. Some specimens studied, notably the Johnstown meteorite, had little or no contact with the earth, being picked up immediately after falling, and hence the argument is not valid.

What these "some specimens" are which had little or no contact with the earth is not known to the writer. In the whole history of



a

b

FIG. 43. *Staphylococcus albus.* *a*, Isolated from control plate. 48-hour culture. × 1000. *b*, Isolated from growth in peptone soil extract inoculated with Pultusk meteorite powder. 48-hour culture. × 1000.

meteorite collecting there is not a single specimen on record which has not been in contact with the earth or which has not been contaminated by extensive handling. The Johnstown meteorite fell in 1924. The fall was a meteoritic shower, consisting of some twenty-six stones. Lipman conducted his experiments in 1932, eight years after the shower had taken place. Obviously, the stones were not kept in a sterile condition during these years. Further, of the twenty-six stones recovered, only three were seen to fall. The first piece (6,832 grams) was unearthed at Elwell from a depth slightly less than two feet, forty-five minutes after it struck. The second piece (23,538 grams), which buried itself some two and one-half miles north of the first to a depth of five and one-half feet, was not recovered for several hours by reason of water and mud that entered the excavation from an underground source. The third, which fell in the muck of an old river channel, was never recovered. The other smaller stones, two of which were used by Lipman, were not picked up for days or months. These facts certainly are not compatible with Lipman's misleading statement that "the Johnstown meteorite had little or no contact with the earth."

The ease with which stony meteorites absorb water leaves little doubt that the individuals of the Johnstown shower were exposed to contamination. The following test in which a stony meteorite (Forest City), three-quarters crusted over, was placed in water for twenty-four hours, may serve as a concrete example:

	Grams
Weight saturated and rubbed dry......	47.14
Weight air dry......................	46.32
Total water absorbed............	0.82=1.77% absorption

This percentage indicates that average stony meteorites are more porous than average limestones but less porous than compact limestones and eruptives.

Q. Organisms found in these studies are too much like or identical with earth bacteria.

A. There is no valid reason for believing that bacteria similar to ours on earth might not have been evolved on other planets or in other systems in space.

This answer, as a statement, is incontrovertible. It is, however, merely a speculation and not an argument or evidence.

It would seem that Lipman could hardly have chosen a more unlikely substance, namely, meteorite, as the basis of his investigations. The composition and structure of meteorites point directly to their igneous origin. Fires must have glowed in cosmic furnaces of some sort in order to impart to meteorites the structure which they present to us. Further, stony meteorites closely resemble terrestrial peridotites and tuffs, and commonly exhibit signs of partial refusion of certain of their constituents—an appearance conformable with the metamorphism produced in terrestrial rocks by intense heat.

It is obvious, therefore, that, unlike sedimentary rocks, meteorites cannot harbor bacteria while they are being formed or being reconsolidated, for neither molten magma nor the heat of metamorphism is inviting to living bodies. Bacterial invasion, if any, must take place subsequent to the formation of meteorites. It is, however, not possible here to surmise how long the organisms could survive after the invasions had taken place. Occasional presence in stony meteorites of a fifteen-hundredth of one per cent of carbon that is doubtfully organic would hardly seem to be sufficient to maintain bacterial metabolism as we know it. These arguments, together with the experimental results obtained by the writer, strongly indicate that the alleged living bacteria in meteorites found by Lipman were contaminants.

The subject of life beyond the earth doubtless offers an interesting field for speculation, but the futility of its discussion beyond that stage can, perhaps, be best expressed by the following statement made by the famed student of meteoritics, the late Dr. George P. Merrill (1929, pp. 77–78): "We should like, with Arrhenius, to think of a world new-born and barren, to which the seeds of life might be borne by a swift-flying meteor; . . . Fascinating as such thought might be, however, it is based upon but flimsy foundations. Not only are our meteorites of material little likely to contain possible animate matter, but the very conditions through which they pass . . . are all against the survival of organic life even if it once existed."

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