If the material is centrifuged four or five times, a majority of the ova present can be recovered. If much solid material comes to the surface with the ova, it may be necessary to refloat the ova in saturated salt solution a second or even a third time in order to get rid of the foreign material. This method is tedious and time-consuming, but if the feces of a *heavily* infested dog are used, large quantities of ova can be obtained almost entirely free from fecal material.

Ova collected by this method can be sterilized by treatment with a 5 per cent. antiformin solution in 10 per cent. formalin. From 10 to 50 per cent. of the ova remain viable after this treatment. The ova are washed several times with sterile distilled water and are then ready for inoculation onto the agar cultures. During the process of sterilizing and washing, the ova are best kept in a sterile 50 cc centrifuge tube closed with a cotton plug.

Cultures were made up in 250 cc Erlenmeyer flasks stoppered with cotton plugs, and consisted of 20 cc of ordinary bacteriological agar which had been diluted with three parts of water. The flasks were autoclaved and inoculated with bacteria twenty-four hours before the ova were introduced. Since at ordinary room temperature the ova do not hatch for an additional thirty-six hours, there was a heavy growth of bacteria in the cultures by the time the larvae were ready to begin feeding. The sterile ova were introduced into the flasks in 1 cc portions of an aqueous suspension, several thousand ova usually being put in each flask. In every experiment, 1 cc portions of this suspension were also inoculated into control broth cultures both before and after the inoculation of the experimental flasks. In this way the sterility of the suspension of ova could be checked. In addition, at the end of each experiment, in order to detect any possible contamination during the process of inoculating the flasks, subcultures in broth were made from the growths in the experimental flasks and after twenty-four hours examined by a Gram stain. When proper precautions were observed, only occasional contaminations occurred, and these flasks were discarded from the experiment.

In the experiments so far carried out larvae have grown to the infective stage in the normal period of about seven days on pure cultures of *Bacillus coli, B. subtilis, B. prodigiosus, B. lactis aerogenes, Staphylococcus aureus, Spirillum metchnikovi, S. rubrum* and *Micrococcus citreus.* Ova which were put on plain agar without bacteria hatched normally and lived for as long as ten days, but did not grow. If bacteria were then introduced into the flasks, the larvae grew to the infective stage. These experiments demonstrate that hookworm larvae in growing to the infective stage are able to utilize bacteria as their sole source of food.

Not all bacteria are suitable food for hookworm larvae, since they failed to grow on cultures of *Bacillus pyocyaneus* and *Sarcina lutea,* and growth was very much retarded on cultures of *B. cereus* and *B. megatherium.* Larvae, however, grew normally on a mixed culture of *Bacillus cereus* and *B. coli.* In all experiments quantitative methods were employed for counting the number of ova which were introduced into each flask and the number of larvae which developed.

The recovery of hookworm ova free from fecal material according to the procedure outlined above can be applied to obtain material not only for experiments on the food of the larvae but also for exact studies of the factors influencing their development. Almost all observations on the biology of the free-living stages of the hookworm have been made upon eggs and larvae in fecal cultures. Studies of the eggs and larvae free from feces in a controlled environment will make possible more definite knowledge concerning the influence of the various factors upon their development.

The conclusions drawn from the experiments in this report do not exclude the possibility that other substances than bacteria may serve as food for hookworm larvae. In fact, it is quite probable that other organic material may contribute to their nourishment. Various substances are being tested in this respect. But the experiments do demonstrate that certain bacteria may alone furnish adequate food for the growth of hookworm larvae to the infective stage.

OLIVER R. MCCOY

THE EXCITATION OF LUMINESCENCE BY THE AGITATION OF MERCURY IN GLASS AND TRANSPARENT FUSED SILICA TUBES AND VESSELS

IT is well known that when an exhausted glass tube containing a small quantity of mercury (leaving a partial vacuum, which must not contain even a trace of moisture) is held horizontally and given a reciprocating motion, static electricity is generated by the contact of the mercury against the glass, and the electrical discharges through the residual gas produce light. This is one of the most direct methods of producing electrical light by the expenditure of mechanical energy. As explained by Professor Elihu Thomson in an exceptionally valuable contribution,[1] "the electrification of the glass, by the running of the mercury over the surface, would, in neutralizing itself, together with the charge which the mercury acquired, illuminate the interior of the tube in much the same way that the Geissler tube is illuminated by the passage of an electric discharge."

Tubes of this kind have sometimes been designated as "mercurial phosphorus" and "Geissler's shaking

[1] "The Nature of Tribo-electricity, or Electricity of Friction, and Other Kindred Matters," *General Electric Review,* 25: 418–421, 1922.

tubes." A form that can also be utilized in demonstrating other phenomena has been described and illustrated by Professor Charles T. Knipp.[2]

The history of these tubes—which had their inception in 1675, when Jean Piquard, a celebrated French astronomer and scientist, noticed that a pale flickering light was playing in the Torricellian vacuum above the surface of the mercury column of a barometer which he was carrying through a dark passageway in the Royal Observatory of Paris—is given by W. S. Andrews[3] in a highly interesting paper. In the same contribution he describes his important researches on improved construction of these tubes and the phenomena exhibited, when he tested neon and various luminous substances in them. He states:

About ten years ago (that is, about 1906) the writer made up some vacuum tubes specially designed to cause considerable mercurial friction when shaken and these tubes emitted quite an appreciable amount of light. These experiments were recently (1916) repeated, the tubes being filled with neon at a pressure of about fifteen mm. and, owing to the high sensitivity of this gas to electrical excitation, the amount of light emitted on shaking them was greatly augmented and it assumed the bright red glow that is the characteristic color of an electric discharge through this gas.

When an air vacuum is used and the exhaustion is carried to a very low pressure, say 0.001 of a mm (1 micron) or lower, the tube will glow with a pale blue light that probably shows a pure mercury spectrum, but this glow may be intensified and changed to almost any color by putting into the tube, before it is exhausted, some suitable fluorescent substance, such as zinc sulphide.

This compound, under different methods of preparation, can be made to fluoresce in a variety of different colors, such as blue, green and various shades of yellow. The writer, by these means, has made "Shaker" tubes, that exhibit many different colors of light.

I correspond with Mr. Andrews, and the information relative to his tubes that he kindly imparted to me and which I give herein is published with his very kind permission.

In one of his letters he states:

Tubes containing air, at a pressure of about 1 mm or less, show a whitish luminescence, and all gases, at suitable low pressures, are similarly excited. The presence of a fluorescent substance, such as willemite, in fine powder, introduced into one of these tubes, intensifies the luminescence, and gives it, in the case of willemite, its characteristic fine green color. If willemite is used, in a tube containing neon, at a very low pressure, the luminescence occurs in streaks or clouds of green and red, intermingled, which present a very beautiful appearance.

[2] "A Simple Demonstration Tube, for Exhibiting the Mercury Hammer, Glow by Mercury Friction and the Vaporization of Mercury at Reduced Pressure," *School Science and Mathematics*, 17: 442–3, 1917.

[3] "The First Electrically Lighted Vacuum Tube," *General Electric Review*, 19: 414, 1916.

The preparation of his synthetic fluorescent willemite is described in another paper.[4] He kindly informed me that in addition to the tubes described in his paper and letter, quoted above, he designed and constructed a large number of different sizes and various shapes, some with and others without an inner tube, such as the standard "shaking tubes" contain, and he found those with an inner tube, containing a number of constrictions and enlargements, to emit the most light. Also, that the enlargements on the inner tube must be located at the proper distance from the wall of the outer tube to obtain the best results. Moreover, the inner tube must be anchored at both ends to the outer tube to prevent its breaking in operation and, especially, in transportation, as the inner tube is subjected to considerable mechanical stress at the point of attachment, if only anchored at one end, and, consequently, sometimes is fractured at that junction.

In one variety the inner tube, instead of being open to the atmosphere at one end, as is the usual practice, was exhausted and then filled with neon at about 10 mm pressure; the outer tube contained a small quantity of mercury only and a partial vacuum. The neon in the inner tube was excited by induction through the glass wall of the inner tube by the electricity produced in the tube, when operated in the regular manner. The result was that when the tube was in operation there was produced a combination of red light from the neon in the inner tube, and pale blue light, from the mercury vapor in the space between inner and outer tubes, in streaks and flashes, and the effect was very pretty. In making tubes of this kind it is essential that the walls of the inner tube be made thin since otherwise the brilliance of the discharge is greatly reduced. Of course, hydrogen, helium, carbon-dioxide or any other gas at a suitable low pressure, or various fluorescent liquids, could be used in the inner tube instead of neon. A small quantity of some luminous substance, in powdered form, could also be placed therein. In this case the gas used in connection with the fluorescent compound would have to be at a very low pressure. Moreover, the outer tube, instead of containing mercury only, could contain, in addition to the mercury, various gases at suitable low pressures and also luminous compounds in powdered form.

Mr. Andrews experimented with neon at pressures from 5 mm to 20 mm, but he believes that the best results were obtained when the pressure was from 10 to 15 mm. He found that at a pressure less than 10 mm the red color of the neon glow became weaker,

[4] "Notes on the Preparation of Some Fluorescent and Phosphorescent Compounds," *The American Mineralogist*, 7: 19–23, 1922.

and at over 15 mm it also seemed to lose color. He found that the most important thing to attend to in making these tubes was the careful exclusion of water vapor by heating the tube under exhaustion with a gas flame.

A small speck of a radium salt in a shaking tube containing neon increased the ionization of the gas and made it glow more brightly.

Upon rubbing one of his shaking tubes with a warm dry piece of silk a faint glow was discernible, but the intensity was very low compared with the light emitted by the interior excitation, by mercury against the glass.

Dr. W. A. Darrah investigated the operation of one of these tubes containing neon.

In a letter to me (published with his very kind permission) he stated:

> I was particularly interested in noting that, on agitating the tube slowly, the glow always comes from the portion of glass wall and mercury which has been separated, and never from the parts which are approaching. This, of course, is what you would expect, from the ordinary laws of frictional electricity, except that I should have anticipated that the charge would have been distributed widely over the metallic surface.

Mr. Andrews and the writer have verified Dr. Darrah's discovery, which is a valuable addition to the information contained in the explanation given by Professor Thomson and quoted above.

Transparent fused silica can also be used instead of glass in the construction of single and double shaking tubes.

PRODUCTION OF LIGHT BY ROTATING VESSELS OF GLASS OR TRANSPARENT FUSED SILICA

Mr. Henry Schroeder, in his "History of the Electric Light,"[5] describes Otto von Guericke's electric machine (1650) in which a ball of sulphur was rotated, electricity being generated when it rubbed against the hand. There is a charming illustration on page 2 of his monograph which depicts, in addition to the artistically constructed electrical apparatus, ladies and gentlemen attired in the quaint costumes of that period. Francis Hawksbee's (1709) with its hollow glass globe which could be exhausted is likewise described. The exhausted globe when rotated at high speed and rubbed by hand would produce a glowing light and this "electric light," as it was called, created great excitement when it was shown before the Royal Society in London.

This suggested to me the production of light by the rotation of glass or transparent fused silica vessels containing mercury and a partial vacuum, or mercury and various gases and luminous substances.

[5] Smithsonian Miscellaneous Collections, 76: No. 2, Pub. 2717, published by the Smithsonian Institution, Washington, D. C., August 15, 1923.

On February 6, 1925, I communicated my ideas to Mr. Andrews, suggesting the construction of several shapes of vessels, including spherical and tubular, and, in compliance with my request, he very kindly undertook such research.

He also made some vessels, indented, corrugated, etc., in accordance with his own ideas for modifying their shape to increase the intensity of light produced.

He attached Edison electric incandescent lamp bases to the vessels and a keyless Edison incandescent lamp socket to the horizontal shaft of a variable speed electric motor, the center line of socket being aligned with the center line of shaft. The different vessels could then be screwed in socket on shaft and rotated at various speeds.

He found that the best speed to use for the small vessels tested, when they contained a small quantity of mercury and neon at 10 to 15 mm pressure, was 700 to 800 r. p. m. for a plain smooth spherical vessel and 400 to 500 r. p. m. for a corrugated one, with the corrugations parallel to the horizontal axis of rotation. The neon in the plain vessel then emitted a bright red light, and the effect produced in the corrugated one was much brighter and exquisite.

Naturally, a lower speed of rotation must be used for the corrugated vessel, to avoid its destruction by the violent agitation of the mercury contained therein. However, this danger could probably be eliminated if thicker glass was used in its construction, thus permitting higher speed of rotation and consequently increase in intensity of light emitted by neon, etc. He did not have the opportunity to test luminous substances in such vessels.

I believe that further researches on the size, shape and contents of single vessels should be made; and on use of glass of various compositions and also of glass containing various impurities for the construction of single and double vessels. Variation of the size and shape of both inner and outer vessels, some inner vessels of similar shape and some dissimilar to outer vessels, should be tried; the optimum spacing, between inner and outer vessel, should be determined; the thin inner vessel should be anchored at both ends to the outer vessel, to insure mechanical strength in operation and transportation; filling the inner vessel with different gases should be tried, and also placing therein a small quantity of luminous substances in powdered form and exciting these by induction, in the manner used for the shaking tube constructed by Mr. Andrews and described earlier in this paper; various fluorescent liquids could be used in the inner vessel, but *not* in contact with the mercury in the space between the vessels, because of the deleterious effect of the presence of moisture. However, various gases and luminous compounds, in powdered form, can be used there.

By using transparent fused silica vessels for such experiments and a spectrograph with quartz prism and lenses, all the visible and invisible radiations produced in the vessels, when they contain mercury and various gases and luminous substances, could be investigated. The effect of a minute quantity of a radio-active compound in increasing the intensity of the luminescence (discovered by Mr. Andrews and previously referred to) should also be thoroughly studied, in all types of vessels and all varieties of contents.

Tests of this kind would be of great scientific interest, and, eventually, possibly lead to results of practical value.

W. L. LEMCKE

FRANKLIN, PA.

THE INORGANIC CONSTITUENTS OF MILK

RECENT investigations have shown the importance of even minute traces of certain inorganic constituents in the normal growth of plants. Manganese, boron and zinc appear to be essential, and copper may also have an important function. Investigations of the elements essential for animal growth are beset with far greater difficulties, since we rely on natural foodstuffs for the main bulk of experimental rations, and these will bear considerable quantities of the lesser recognized elements as impurities.

If one excepts its low iron content, whole milk has until recently been held to provide an "adequate" diet for the growth of the young of the same species, and it is permissible to assume that a study of the inorganic constituents of milk will give some indication of the elements essential to animal growth. No data are available which give full analyses of the inorganic constituents of milk, either qualitative or quantitative.

During the past year, samples of cow's milk have been obtained from various parts of the United States and of Great Britain, and qualitative examinations have been made of the ash constituents of these samples by spectrographic analysis. The samples were milked straight into glass bottles. They were evaporated to dryness either in silica or in platinum dishes and ashed at low temperature in an electric muffle furnace. Spectrograms of the ash were prepared with the aid of a quartz spectrograph by placing the ash in an arc between two pure graphite electrodes. Examinations of the spectrograms were made between λ 2,400 and λ 4,600 angstroms.

Samples from the following localities were examined: *United States,* New York State, New Jersey, Wisconsin, Michigan, Missouri and California; *Great Britain,* Somersetshire, Derbyshire and Aberdeenshire. The spectrograms obtained from all these samples were qualitatively identical, and from them it has been possible to determine the elements normally occurring in milk.[1] The results may be summarized as follows:

Elements previously identified, and confirmed by spectrographic analysis		Elements not previously identified but now found to be present
Large quantities	Traces	Traces
Calcium	Iron	Silicon
Magnesium	Copper	Boron
Potassium	Zinc	Titanium
Sodium	Aluminum	Vanadium
Phosphorus	Manganese	Rubidium[3]
(Chlorine)[2]	(Iodine)[2]	Lithium
		Strontium

It should be noted that the newly recognized elements are present in small *but definite traces.* Whether they are significant in nutrition remains to be determined. Two of the samples examined deserve special mention. With one sample the spectrogram indicated more than the usual amounts of copper. On reference to the records this was found to be a sample of dried milk. With the second sample the analysis indicated more than the usual amounts of zinc. On reference to the records, it was found that this sample had been obtained from cows pasturing in the neighborhood of the zinc smelters at Franklin, N. J. Such results give ground for placing considerable reliance on the spectrographic analysis, while the occurrence of zinc in more than usual quantity in the milk from the neighborhood of zinc refineries indicates that in some cases the quantity of an element may be directly influenced by its concentration in the soil.

In conclusion, the method of spectrographic analysis as applied to biological materials appears from this work to warrant more attention. The method may well be applied to biological material both qualitatively and semi-quantitatively.

NORMAN C. WRIGHT

THE HANNAH DAIRY RESEARCH INSTITUTE, SCOTLAND

JACOB PAPISH

DEPARTMENT OF CHEMISTRY, CORNELL UNIVERSITY

[1] See, however, footnote 3.

[2] This element can not be confirmed by the spectrographic method employed, but its presence has been adequately confirmed by other methods.

[3] In a sample of milk ashes recently examined by one of us (J. P.) the presence of rubidium could not be established with certainty.