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ABOUT A UNIQUE BEHAVIOR OF FRESHWATER BACTERIA

EXPERIMENTAL DATA

Inspecting a hanging drop containing material collected from drainage water poured into a pothole dug into the ground, it was noted that the majority of the microorganisms always migrated and accumulated in the same direction, even after the plate of the microscope was rotated around. When the material was set on a covered glass slide, it was still possible to observe the unique behavior. The experiment was repeated changing environment and sample material (drainage basin sediments, permanent potholes, bogs, ponds, morasses, morass bottoms of abandoned caves, small, closed, shallow lakes with little water), but the same behavior was repeatedly found, as if the microorganisms were always attracted by something in the that direction.

Randomly inspecting a sample at noon with the sun overhead, it was observed that microorganisms present in the biological sample were migrating toward the arm of the microscope. The eyepiece lens was taken off the arm and attached to another support, but the result was nevertheless the same with various samples. A microscope arm was built of wood, with a wooden stage, and a tube made of cardboard, but no significant change was noticed in the behavior of the bacteria compared to that seen using a traditional microscope made of metal. The conclusion was that the microorganisms were migrating toward geomagnetic north. The goal was to confirm these observations and verify whether the same behavior could be seen outside the particular biological environment of the sediment sample. So two hanging drops were placed next to each other, one drop to the south containing the biological sample and the other drop to the north containing sterilized "spring water". The microorganisms moved into the drop of spring water and behaved as described. Subsequently, this particular procedure was used to separate the microorganisms attracted towards the magnetic north from others that do not possess such characteristic behavior, and from unknown materials contained in the sample.

Microscopic enlargements of about 100 X (objective lens 8.8X and eyepiece lens 11X) were sufficient to detect the phenomenon, which was also studied in dark environment. With gradually greater enlargements up to 3000X (objective lenses 42X, 64X, 105X water and oil, 130X oil; eye pieces from 5.6X to 25X) it was possible to distinguish the microorganisms as spirilli, bacilli and cocci. There was a possible indication of similar behavior in some algae.

The suspicion that the bacteria, predominantly anaerobic, were being attracted by the geomagnetic north pole was confirmed when a magnet was placed near a slide prepared with a thick sediment layer, with the pole facing the layer the one that attracted the north-pointing pole of a magnetic compass needle. If the magnet was powerful enough, the bacteria moved towards the magnet, no matter what position it was in relative to the geomagnetic north pole. An electromagnet was built and energized with up to 750 volts DC and a current of 1 Ampere with a power-pack set far from the biological preparation. The direction of the current was such that on the coil face closest to the microscope was the pole that attracted the north-pointing pole of the magnetic compass needle. More powerful electromagnets were later prepared.

If the electromagnet used were placed at geomagnetic north, the bacteria migration would increase in speed, but if the intensity passed a certain level (undetermined level due to a lack of equipment), the bacteria stopped and some changed their path.

This indicated that the excess local magnetic flux had changed the polarity of the apparatus responsible for the unique behavior of the microorganisms. All this could mean that the bacteria under study possess a type of internal compass that could consist either of a biological power generator or of a magnet inserted in their cellular structure, necessarily of a shape more or less elongated in order to be itself a magnetic needle. This latter hypothesis appears the most probable because Magnetosensitive Bacteria (as it is suggested to denominate them) killed either with formaldehyde or with heat using pasteurization or sterilization, were seen to spin following as the magnetic field produced in loco was rotated, even when the bacteria were obviously not motile.

When, in fact, the drop of material examined containing the killed bacteria was placed next to a drop of spring water, the bacteria would orient themselves according to the magnetic field, but would not migrate into the drop of water.

Small bottles of liquid sediment samples left by themselves were found to be an excellent enrichment culture ground, so utilizing this scenario to increase the bacterial concentration in the medium was thought to be feasible. Later, the bacteria were placed in solutions poor in minerals, or even demineralized, and a noticeable, statistically significant, decrease in the magnetosensitivity of the microorganisms was observed, up to the complete loss of their peculiar behavior. By periodic addition of various mineral salts, it was observed that iron in a soluble organic form in doses up to 3 mg per liter was able to restore the magnetosensitivity. This might mean that these microorganisms are able to synthesize the biomagnetic material necessary for the orientation organ. Moreover, this hypothesis is confirmed by the fact that increasing the quantity of iron or other elements does not increase the average capacity of orientation or the translation speed of the bacteria. It really seems that the iron compounds are responsible for restoring the capacity of magnetic orientation in the bacteria.

If the microorganisms under study are magneto-sensitive and if they migrate toward geomagnetic north, changing the direction of the magnetic field should cause these microorganisms to change their swimming direction. Following this hypothesis, impulses of opposed magnetic fields were applied to the material being examined, by simply alternatively presenting the opposite poles of a magnetic bar, or changing the direction of the current in the coil of the electromagnet. With this expedient, it was possible to observe that the Magnetosensitive Bacteria changed the direction of their swimming in the liquid medium every time the magnetic pole was changed, as long as it was of adequate intensity. A further experiment was conducted submitting the biological material to demagnetization by introducing it inside a coil with alternating current and slowly moving it away from the magnetic field. In this case, disarray in orientation was observed in both the live and the dead bacteria: some of the microorganisms changed their orientation in a statistically significant manner, but sure cases of demagnetization were not observed.

DISCUSSION

By definition, the direction of a magnetic field is the one toward which the north-pointing pole of a magnetic compass needle points. It appears likely that the bacteria being studied are migrating along the lines of force of the magnetic field. If this is the case, similar microorganisms in the southern hemisphere should move towards the geomagnetic south pole. The supposed biomagnetic compass seems to direct the microorganism exclusively depending on the angular component of the forces exerted by the inner bacterial magnetic field as well as that of the geomagnetic field. Increasing the intensity of the local magnetic field increases the speed of migration of the microorganisms, with the limitations previously discussed. The behavior of these predominantly anaerobic bacteria, could force them to move away from the liquid surfaces, or more oxygenated semi-liquid ones, to sink into the silt, as the geomagnetic field is oriented, toward the bottom in the northern hemisphere

It seems possible that the biomagnetic apparatus has a magnetic dipole moment oriented opposite to the flagellar apparatus but not directly connected to it. Indeed, in the *anfilofotrichi* there is the same unipolar movement. Therefore, one must assume that the orientation has nothing to do with the flagellar apparatus, so the bacterial "compass" must be located inside of the cell and not in the pili or in the flagella.

Since these magnetosensitive bacteria were detected in the sediments (not in shallow waters) of more or less limited basins, their constant swimming towards the north sooner or later takes them to the northern limit of the basin, where they obviously have to stop. As it seems above all unlikely that the magnetosensitive microorganisms must move in the direction of the magnetic north until they reach it and, particularly, without a precise reason for this natural predisposition, one can ask if the magneto-dynamic property of these bacteria isn't rather a temporary condition in relation to determined states or to contingent functional moments of the bacterial cell. One is also led to think that the microorganisms in question are habituated to the use of substances that, in the environment in which they live, gather towards the magnetic north; or that instead of possessing only one magnet, they possess an entire series of them. In this latter case it doesn't appear so imaginative to think that using the magnetization of single segments, or in their reciprocal alignment, the bacteria manage to form magnetic couples that, although preserving the magnetic pole as reference, allow them to follow environmental or physiological stimuli in various directions, such as upwards or downwards. Most likely this latter movement could be conditioned by the quantity of oxygen present in the environment.

The research conducted thus far on the orientation of bees and of other insects should be reviewed in the light of the experimental observations reported here. On the same level, the process of cellular division could be subject to magnetic attractive and repulsive forces.

SUMMARY

Some anaerobic bacteria ever go toward the magnetic North Pole. The A. propose the denomination "Magnetosensitive Bacteria" and suppose that in their body exist a biomagnetic compass.

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