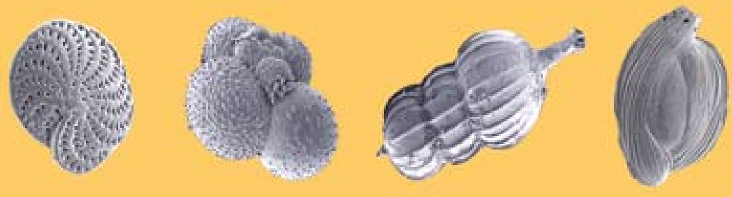
A foraminiferan adventure

Michael Hesemann (Germany)



Two years ago, I joined an evening course on microfossils. I started by learning the proper use of microscopes and observing 4 to 5cm (that is, rather big) fossil otholiths (that is, the ear stones of fish). Soon ostracods, nummulites, smaller foraminifera and diatoms were given to the class and I was amazed by the outstanding and unusual structures I saw. In addition, we also learnt that the Egyptian pyramids of Giza consist to 40% of nummulite tests and that 60% of the world rocks that are derived from marine environments contain the remains of foraminifera.
As a result, I started to collect foraminifera and got in contact with hobby micropalaeontologists. In March 2008, I received a 100g letter containing tiny plastic-bags weighing between 10 to 15g. To me, it was an overwhelming miracle - hundreds of foraminifera from the Pleistocene rocks of Torrente Stirone in Northern Italy.
My foraminiferan adventure had well and truly begun.

What are foraminifera?

Foraminifera are single celled protozoans with an amoeboid internal structure consisting of a nucleus, vacuoles and cytoplasm. The main parts are usually protected by an internal shell called a "test", which consists of one or more chambers. Fine strands of plasma branch and merge from the main opening and, sometimes, through pores to the outside to catch food. The name "foraminifera" refers to the openings (that is, foramen) between the chambers. The test size usually ranges from 0.1 to 1.5mm, but it may be as large as 15cm in some cases.
About 4,000 recent and 55,000 fossil species have been recognised. The taxon is under permanent review, as it is based on the tests and, therefore, is defined morphologically rather than genetically. The tests may be agglutinated, that is, made of particles cemented together as seen in the Textularia (see fig. 18). They may be also solely calcareous in different ways such as transparent, porcellaneous or microgranular. The test and cement is secreted and the wall may be single or multi-layered, perforate or solid. The test-morphology varies enormously from single to numerous chambers, and is extremely diverse, as is shown in the accompanying pictures.
Today, foraminifera inhabit all parts of the oceans, from the poles to the equator and from the shallow intertidal regions to the deep sea. They live in great numbers and play a significant role in the food chain, the economy and balance of the biosphere. For example, planctonic members of the *Globigerina* genus live drifting in the ocean, whereas benthic species of the *Pyrgo* genus (see page 18) are sea-floor dwellers.

Feeding and reproduction

Quite different feeding strategies have been observed, including diets consisting of algae and zooplankton, omnivorous and parasitic diets, and even cannibalistic feeding. In fact, foraminifera inhabiting the photic zone often live symbiotically with photosynthesizing algae such as diatoms and dinoflagellates.
Studies of about 30 recent species have revealed different reproduction cycles in what is a typical and complex alternation between sexual and asexual generations. These two generations may differ quite substantially in size and test-shape, and some larger foraminifera are thought to have three forms. A single individual may have a lifespan from a few weeks to as long as five years.

Palaeoecological significance

The oldest tests have been found in Cambrian rocks that are 550 million years old. These Textulariina were simple, agglutinated tubes and still exist today (see fig. 18). They became more abundant in the Ordovician and multi-chambered forms appeared first in the Devonian - the Fusulinacea. This suborder died out at the end of the Palaeozoic (250mya) but, in the meantime, other suborders had emerged - Involutina,

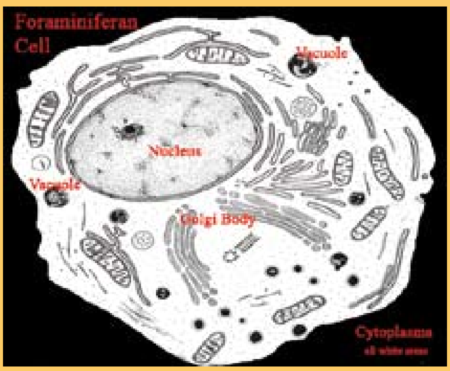
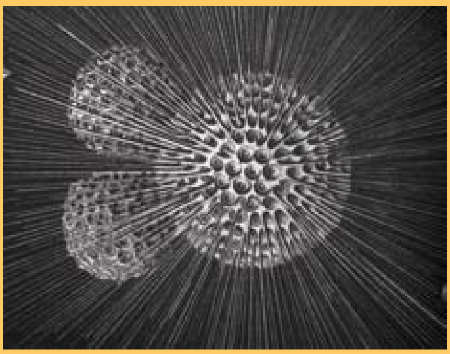


Diagram of a foraminifera cell structure.



From *Ernst Haeckel: Kunst-formen der Natur, 1899-1904, Plate 2.*

Residue on a sample plate.

Fig. 1. . *Ammonia beccarii,* Torrente Stirone, Pleistocene.

Fig. 2. *Ammonia beccarii*, Crete.

Fig. 3. *Amphicoryna scalaris*, El-Alquian/Spain, Miocene.

Fig. 4. *Bulimina* sp., Torrente Stirone, Pleistocene.

Fig. 5. *C. spengleri* inside view.

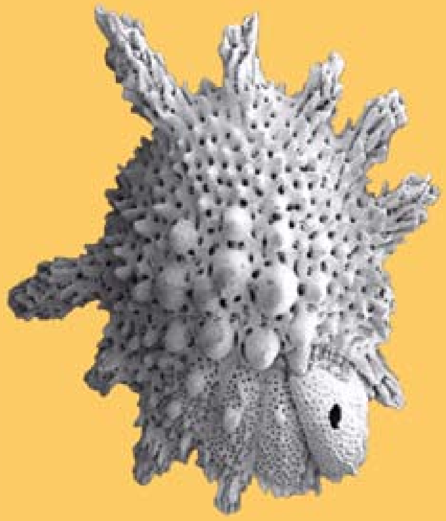


Fig. 6. *Calcarina spengleri,* SE Australia, recent.

Fig. 7. *Dentalina* sp.*,* Spitsbergen.

Fig. 8. *Discorbis* sp.*,* Alquian/Spain, Miocene.

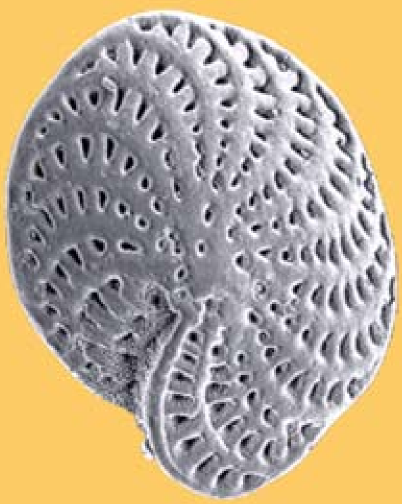


Fig. 9. *Elphidium crispum,* Torrente Stirone, Pleistocene.

Fig. 10. *Lagena* sp.*,* Spitsbergen.

Fig. 11. *Lagena* sp.*,* Kobrow, Germany, Oligocene.

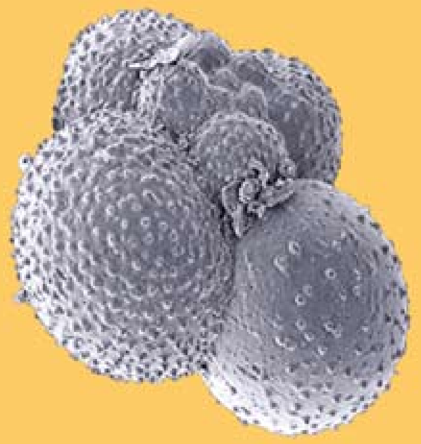


Fig. 12. *Globigerina* sp.*,* Torrente Stirone, Pleistocene.

Lagenina and Miliolina (see fig. 20). Important Mesozoic events included the appearance of Rotaliina, complex Textulariina and the first planktonic Globigerinina. At the K/T boundary, 75% of species died out. However, due to their remarkable ecological flexibility, foraminifera soon radiated out again to fill the world's oceans.

Biostratigraphy

Eocene nummulite found sliced in matrix near Schwerin, Germany.

As hundreds of specimens may be found well preserved in small chips of rock, foraminifera are extensively used for biostratigraphy from the Upper Carboniferous onwards. The focus is on correlating and assigning relative ages of rock layers by using the foraminiferan assemblages contained within them. The first and last occurrence of marker species is used for fine biozonation, even at a regional scale. In fact, the oil industry has long regarded foram-faunas as a cheap and reliable means for palaeontological correlation and monitoring well drillings (see Cushman 1928). Single layers may be identified down to a width of 10cm and it is possible to work out a precise framework for an oil exploration site. However, absolute age estimates can only be made if the fossils encountered in a sample can be related to the global zonation schemes that exist today.

Palaeoecology and Palaeoclimate

The idea that 'the present is the key to the past' is a basic concept in palaeontology. It is commonly used in paleo-environmental studies based on foraminiferan assemblages, but with certain limitations: the older the forams, the bigger the differences that may exist in their lifestyle when compared to extant relatives. Indeed,

***Textulariina: Rhabdammins abyssorum*, recent, bottom of the Greenland Sea.**

warm water species of today may have coldwater ancestors. However, with passage back in time, the fossil faunas are increasingly different from present ones. So, the reconstruction of past environments becomes more difficult. However, for the Neogene, Palaeogene and the Cretaceous, salinity, depth (and, therefore, sea-level), water temperature and oxygen/methane content at different depths, the reconstruction of water currents and masses, seasonal variation, marine bio-production and much more information can all be derived from fossil foram assemblages. The scale may be global, regional or restricted to specific localities. Archaeologists have also used the foram-record to reconstruct ancient harbour-developments.

For example, the coiling of recent *N. pachyderma* (figs. 13 and 14), is correlated with ocean-surface temperatures. Dominantly left-coiling populations occur in polar/sub polar waters, whereas right-coiling specimens prevail under more temperate conditions. The change of dominance in coiling coincides with a 7.2°C surface temperature. In April, the 7.2°C isotherm runs in the northern Atlantic from southern Canada to Iceland and down to the Shetlands. Therefore, coiling ratios of *N. pachyderma* in sediment cores are widely used to infer ancient environments.

Classification

Species of organisms are commonly distinguished by their DNA and ability to interbreed to produce fertile offspring. However, foraminifera are commonly distinguished by their morphology: wall composition and structure, chamber shape and arrangement, aperture and ornamentation. For recent species, DNA analysis and life-cycle studies have led to some new taxational views and, in the future, a major revision may be possible. However, for the fossil record, the morphological approach will remain, as only the fossilised tests are left.

Wall composition

Agglutinated, porcellaneous and hyaline tests can easily be distinguished. Agglutinated ones are built of extraneous material cemented together by secretions. Quartz grains, various heavy minerals, clay, mollusc fragments and organic debris, including sponge spicules, and even the tests of other foraminifera, are commonly used. Porcellaneous tests are mainly found in the suborder Miliolina. However, most species have hyaline tests allowing a more or less good view through the wall inside.

Only experts can usually recognise details such as the type of cement, micr511granular tests or how many layers the wall is made of. However, the ornamentation of the test surface and a tooth in the main opening may be more easily visible (see, for example, the bifid tooth below).

***Miliolina: Pyrgo* sp. recent, Greenland Sea.**

***Quinqueloculina* sp. Oligocene, Germany.**

Fig. 13. ***Neogloboquadrina pachyderma.***
Weddell Sea, Antartica.

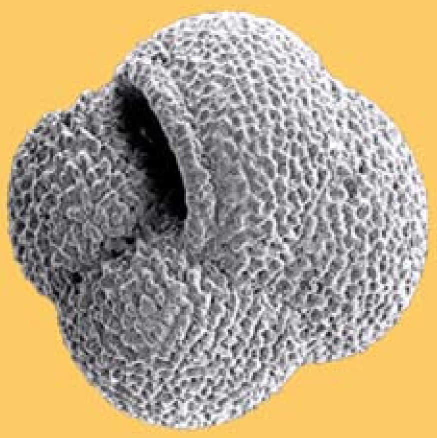


Fig. 14. ***Neogloboquadrina pachyderma.***
Weddell Sea, Antartica, left coiling.

Fig. 15. ***Peneroplis,*** **Crete, recent.**

Fig. 16. ***Planorbulina mediterranensis,***
bottom view, Crete, recent.

Fig. 17. ***Planorbulina mediterranensis,***
top view, Crete, recent.

Fig. 20. ***Miliolina: Quinqueloculina*** **sp.,**
Torrente Stirone, Pleistocene.

Fig. 18. ***Textularia*** **sp., recent, found on the**
beach of Malia/Crete in Greece.

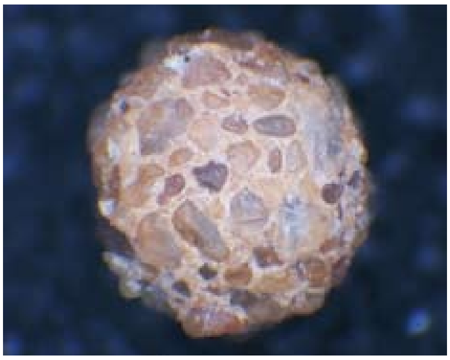
Fig. 19. ***Spirillina vivipara,*** **Spitsbergen.**

Fig. 21. ***Nonionellina*** **sp., Spitsbergen.**

Fig. 22. ***Triloculina*** **sp., Torrente Stirone,**
Pleistocene.

***Nonion*, recent, Skagerrak.**

***Haynesina*, recent, Skagerrak.**



Agglutinated *Psammosphaera fusca*, recent, bottom of the Greenland Sea.

Chamber arrangement

The simplest and earliest chamber architecture is represented by single chambered tests, which are referred to as being “unilocular”. They may be tubular, radial branched, globose, irregular or flask-shaped, as in the recent *Lagena* sp. from arctic Spitsbergen seen in fig. 10.

Multilocular tests may be grouped into forms with serial, spiral or milioline arranged chambers. The *Dentalina* sp., shown in fig. 7, is uniserial. Bi and tri-serial foraminifera have two and three alternating rows of chambers. Examples of a milioline structure are seen in the genera *Pyrgo* and *Quinqueloculina* shown in fig. 20. Spiral tests may have identical sides, as is seen in *Spirillina vivipara*. These are referred to as “planispiral”. Where material is added in a helical coil, the test is called “trochospiral”, as in *Ammonia beccarii*.

If foraminifera are attached to algae or other substrate, one side will resemble the substrate, as seen in the bottom view of *Planorbulina* in fig. 16.

Hints for collecting

Start by collecting living examples of foraminifera from the beach at low tide. Take different sized write-on bags, a pencil, a spoon (to pick up samples) and a magnifying glass with you. Look for stripes of visible small shells, which are laid down by the waves at high tide. Trenches around spur dykes are also good places to look. However, do not dig. Instead, take the material from the surface. Also, take samples from different spots on the same beach in 20 to 50g write-on bags. Note the localities immediately, not at home, in case you forget the details.

To get fossil foraminifera, start with clay or marly material, or chalkstone. You can carefully crumble it in water and washing-up liquid, either by hand or with a mortar. Cracking, by freezing and heating may be of help, but can also damage bigger tests. Chemicals are not needed for such a material.

Technical equipment

A stereo-microscope, with light from above and at least 20x magnification, will be sufficient to observe most foraminifera. For example, a model of the sort is a good starting point and can be purchased for less than £50. If you want to intensify your studies, you can use this type of (portable) microscope in the field. At home and for taking photographs, you will need a trinocular microscope with three tubes.

The material must be separated by being washed in water into finer and finer portions, using sieves of 100, 500 and 1,000 microns or similar to wash away the debris. Cheap sieves are available in shops selling aquariums or more expensive ones are available from more specialist suppliers (such as UKGE).

UKGE sells all of the equipment featured.

Dry the resulting material and store it in a separate write-on bag or glass jar. Then, spread 2 to 5g on a professional sorting tray or any flat surface, such as the lid of a jam jar. If well spread out, the forams can easily be picked out with a fine brush or mounted needle and placed onto microfossil slides. These are commonly used for storage and fit into special boxes or trays. In fact, a shoe box can hold a whole collection of 100,000 foraminifera! The accompanying material should also be kept, but will need more space.

A more difficult task will be the identification of your finds. There are several good sources of information on foraminifera and I have included some of these in a list of further reading below, or you can use my own website (www. foraminifera.eu), which has some information on it.

My foraminiferan adventure goes on, as there is so much stuff waiting to be explored and discovered. Are you ready too for a foraminiferan adventure?

Acknowledgments

All SEM foraminifera images have been created by Dr. Rosenfeldt, Karl-Otto Bock and the author at the SEM of the Microbiological Society of Hamburg (www. mikrohamburg.de). The optical images were taken by the author. Most samples of rock, beach-sand or unsorted foraminifera were sent to the author by family members, friends and also by micropalaeontologists, who have stumbled across my webpage: www.foraminifera.eu.

Send me your material. I will publish pictures of it online! Contact me at info@foraminifera.eu.

Michael Hesemann, Hamburg, Germany is a member of the Microbiological Society of Hamburg.

Further Reading

Armstrong/Brasier: Microfossils 2nd ed., 2005.

Cushman, Joseph A.: Foraminifera, their classification and economic use, 1st ed. 1928/ 4th ed. 1959.

Loeblich and Tappan, Treatise on Invertebrate Palaeontology, Part C Vol.1+2, 1964.

John Murray: Ecology and Applications of Benthic Foraminifera, Cambridge Univ. Press 2006.