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BACK TO OUR ROOTS

It was cold and clammy, but it changed the rules of life for ever. **Helen Pilcher** goes in search of the ancestor of all animals.

From the family album: sponges are probably the closest living relative to the first multicelled animal.

Some geneticists have all the luck. While most are slavishly chained to the bench pipetting liquid, Werner Müller from the University of Mainz, Germany, gets to ponder the origins of life as he dives for sponges in the Adriatic Sea. His favourite spot is a 30-metre-long cave off the coast of Croatia, where sponges at the grotto's entrance are bright yellow, a hue bequeathed to them by the bacteria they contain. Sunlight pours through a hole in the ceiling. "It's a beautiful place," he says.

Müller hopes that his bounty will shed light on one life's biggest mysteries: how did animals come into being? Their birth is still shrouded by the mists of time, but scientists do know something special happened in the ocean around 600 million years ago when a group of single-celled creatures joined forces to form the first ever animal body, or 'metazoan'. Clubbing together allowed the cells to share the labour of living and paved the way for the evolution of specialized cell types, such as muscle, nerve and stem cells. This ancestor of all animals, known as the urmetazoan, would have needed a genetic blueprint for its structure or body plan. And this plan was the raw material that evolution acted on to give us the dazzling variety of animals we see today (see key examples in Graphic, opposite).

So it's no surprise that Müller and others want to find out more about this extinct animal. They want to discover how single cells took the pivotal step to make that first body, why animals evolved the way they did, and what it was about that early environment that kick-started animal life.

But with the urmetazoan dead for more than half a billion years, studying it is something of a challenge. No fossils have been found, so there are no physical clues to its appearance. As a result, scientists are studying its closest living relatives: sea sponges and single-celled animals called choanoflagellates. By comparing these with each other — and with more complex animals such as mammals — they hope to build up a picture of the urmetazoan's genetic make-up and physical characteristics.

Simple blobs

Researchers have long regarded sponges as the most primitive form of animal life. As such, they are likely to be the most similar to the urmetazoan. At first glance, sponges seem simple. They have no gut, no brain, no obvious front or back, left or right. Adults pump water through a system of canals and cavities to extract food. "But they're much more sophisticated than the amorphous blob you see in the bath tub," says Müller.

For example, sponges are made of many different cell types. They have collar cells that beat their whip-like tails to create a water current inside the sponge's body, drawing food in and washing waste away. Stem cells give rise to sperm and egg, and epithelial 'skin' cells provide a protective barrier from the outside world[1,2]. Cellular variety like this is the essence of multicellular life. And, just like in sponges, specialized or 'differentiated' cells would have allowed the urmetazoan to feed and reproduce simultaneously, making it more efficient than its unicellular neighbours, who could do only one job at a time.

Genetic comparisons between sponges and younger members of the animal tree provide more insight into how these cells all worked together. Sponges, for example, have proteins called integrins on the surfaces of their cells. These tether the cells in place by sticking to another protein called collagen, which surrounds the cells[3]. Such proteins are found in more complex metazoans, so it is likely that the urmetazoan used a similar cellular adhesive.

But the cells also have to communicate. They have to organize themselves into a body with multiple cell types, so strategies are needed to tell the cells where and what they should be. Like more complex animals, sponges solve this problem by using specific molecules to guide differentiation and migration as the cells develop in their embryos.

Animal magnetism

Six hundred million years ago, singletons had the Earth largely to themselves. Its oceans teamed with single-celled organisms such as choanoflagellates and bacteria.

But some 10 million to 50 million years later, the fossil record documents a series of early 'experiments' in multicellularity. The Doushantuo Formation in southern China contains fossils of dividing embryos. A mishmash of strange animal-like creatures known as the Ediacaran fauna (such as the *Dickinsonia* pictured right) made an appearance.

What prompted single cells to get together? Geological records suggest that global oxygen levels rose dramatically about 600 million years ago[10]. The new 'breathable' concentration allowed oxygen to diffuse across

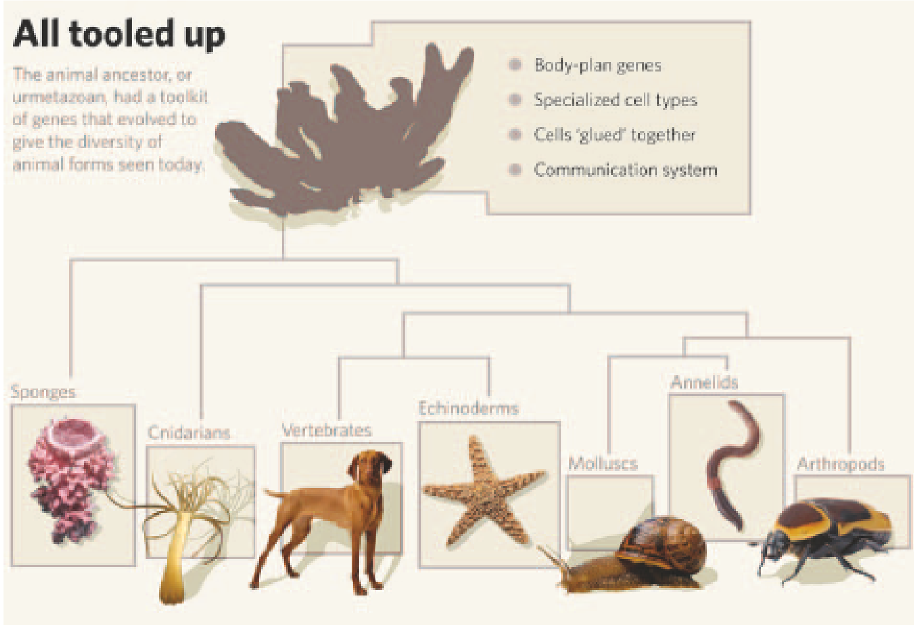
Bernard Degnan, a geneticist at the University of Queensland, Australia, is studying embryos of a sponge called *Reniera* to understand more about how body plans emerged in evolution. *Reniera* embryos contain at least 11 specialized cell types arranged in a particular pattern[4]. Pigmented cells, for example, are initially found on the embryo's surface, but then migrate to one end where they form a dark spot and then a ring.

Degnan speculates that cell migration and differentiation in these embryos is controlled in part by soluble chemicals that diffuse along the embryo's body creating a concentration gradient, a system also used in higher animals. Müller has isolated one such chemical from another sponge, *Suberites domuncula*[5], and thinks that it may influence cell differentiation in both embryonic and adult sponges.

There are signs that many other molecules associated with development in animals also occur in sponges. The Wnt family of proteins, for example, influences how cells become specialized and also helps to lay down the key spatial coordinates of the body plan in complex animals. Sponge cells make the Frizzled protein, a receptor that is activated by Wnt proteins[6]. And they also make a variety of metazoan-like transcription factors — proteins involved in controlling gene expression — that are key players in development[7,8].

The fact that these genes occur during development in all existing animal lineages hints that they were playing a regulatory role in the embryos of the first metazoan. "The urmetazoan was probably quite sophisticated in a developmental and genomic sense," says Degnan. This suggests that it already had the genetic toolkit to direct a body plan containing multiple cell types.

To find out where this toolkit came from, biologists are looking even further back in time, at the single-celled ancestors of the urmetazoan. Their modern-day descendants are choanoflagellates, unicellular creatures that look uncannily like sponge collar cells. Surprisingly, choanoflagellates harbour many of the tools needed for multicellular living.



GETTY IMAGES (WORM); K. PANG (ANEMONE); S. NICHOLS (SPONGE)

Geneticist Nicole King from the University of California, Berkeley, has discovered that choanoflagellates express genes involved in cell adhesion and communication in animals[9]. "This tells us that the molecular machinery for multicellularity was on site before the transition to multicellularity took place," says King.

Parental traits

Like choanoflagellates, the urmetazoan's single-celled ancestors may have used signals relayed by proteins called tyrosine kinases to sense changes in the outside world. Cell adhesion might have helped unicellular organisms to form simple colonies — colonies that may have been an intermediate step between single cells and true multicellularity. The urmetazoan may then have recruited these genes for new purposes. "Evolution is an extremely dynamic system and paradoxically a very lazy one," says palaeobiologist Simon Conway Morris at the University of Cambridge, UK, who studies the origins of metazoans. "It will co-opt whatever it can."

But this raises a puzzling question. If the toolkit was already there, why didn't animals evolve sooner? The answer seems to be that the catalyst for multicellular animal life may not have been genetic but environmental — in the form of rising global oxygen levels (see 'Animal magnetism', below).

Whatever the trigger, researchers hope that the completion of the choanoflagellate genome sequence, expected later this year, will yield fresh insights into the biology of this momentous transition. Genome sequences are also expected for the sea anemone *Nematostella vectensis* and the simplest known living animal, *Trichoplax adhaerens*. *Trichoplax* is just two cells thick, has only four cell types and looks like a giant multicellular amoeba. Its genome promises to be the smallest of any animal yet measured and should define the minimum set of genes needed for animal life. Sea anemones, which have a more advanced body plan, could yield information on the genetic mechanisms underlying body-plan formation.

So it seems that the urmetazoan was a sophisticated creature. But don't expect a photo reconstruction for the animal family album just yet. "At present, its size and shape are pure speculation," says Degnan. ■

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multiple cell layers, giving animals the freedom to become more complex, says biogeochemist John Hayes from Woods Hole Oceanographic Institution, Massachusetts.

No one knows exactly what triggered the rise. Most researchers speculate that it happened when large amounts of organic matter were buried at the bottom of the ocean. This permanently removed carbon from the carbon cycle, upsetting the balance of carbon and oxygen in the water and causing the oxygen concentration to rise. Some suggest that the faecal pellets of tiny single-celled organisms may have caused organic matter in the water to sink. Another theory proposes that the change in oxygen levels was triggered by massive dust storms or the break up of the landmasses or 'supercontinents' that then dominated the globe. **H.P.**

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