What's in a cell?

The big picture

A transmission electron microscope in which electron beams go through an ultra-thin specimen. The image is seen through the binoculars or on the screen.

Biologists classify living organisms according to the two-part, five-kingdom system: two parts (Prokarya and Eukarya) with five kingdoms (Plants, Animals, Protoctista, Prokaryota and Fungi). This scheme has gradually changed as we have learned more about the cells of which living organisms are made.

Antonie van Leeuwenhoek was a Dutch microscopist. In 1674, he sent the Royal Society evidence for the existence of single celled organisms. This led to the proposal of the third kingdom, the Protoctista.

Until the 1930s, our understanding of the interior of the cell was limited by the resolving power of the light microscope; this in turn is limited by the wavelength of light. Any object with a diameter smaller than 0.28 micrometres (1 μm = 10^{-6} m or 0.000 001 m) will be blurred or invisible. Things changed with the invention of the electron microscope, which can see objects as small as 1 nanometre (there are 1 000 nm in a micrometre, so a nanometre is 0.000 000 001 m!). This high resolution allows scientists to distinguish between large molecules.

The electron microscope showed clearly that some cells have a nucleus and others do not. This led Copeland in 1938 to propose four kingdoms, with the non-nucleated forms becoming the Prokaryota. Finally, in 1969, Robert Whittaker moved the fungi into a fifth Kingdom.

The electron microscope has revolutionized the way we view cells. Millions of pictures (called electron micrographs) have been taken, often of small parts of cells. The picture on pages 10-11, however, shows two whole cells. They are secretory cells, found in the pancreas and called acinar cells, and they show most of the features that have been revealed as common to cells in the domain Eukarya.

Organelles

A eukaryote cell is one that contains complex structures enclosed in membranes. These structure are referred to as organelles. The full list of organelles found in eukaryotes is :

mitochondria

chloroplasts and other plastids (only in plants and plant-like organisms)

lysosomes

nucleus

rough and smooth endoplasmic reticulum

Golgi body

vacuoles

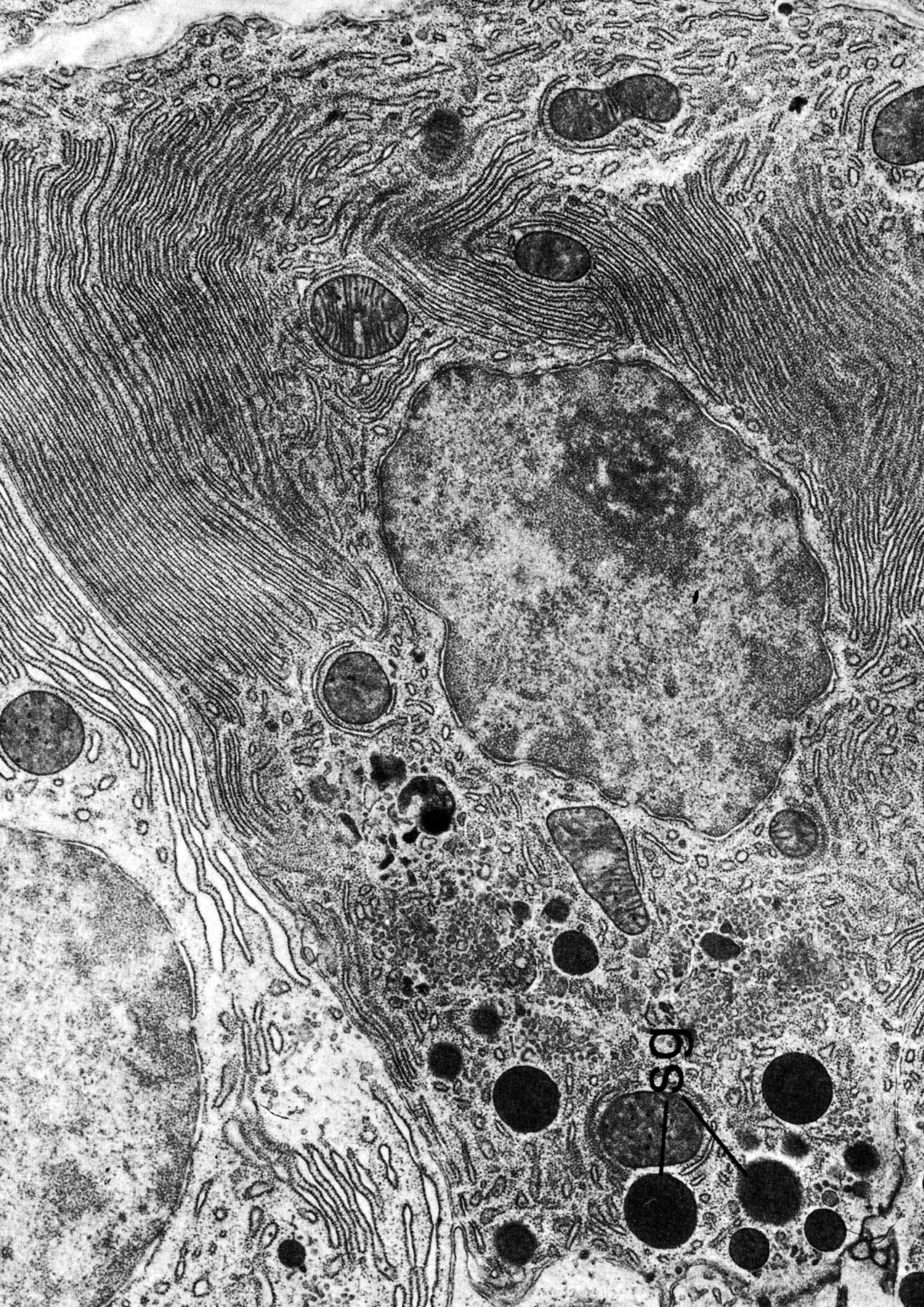
peroxisomes

secretory granules of various kinds

cilia and flagellae (undulipodia)

Most of these organelles are visible in the large picture, although some of them are not very clear (see the labeled diagram on page 13). It should be remembered that a transmission electron micrograph such as this is a picture of a very thin section, and so some things might simply be missed. For example, if you cut many thin slices through a hard-boiled egg, many of them would not contain the yolk. Scientists build up a full picture of a cell by putting together hundreds of such thin slices.

The Big Picture on pages 10-11 shows an electron micrograph of two acinar cells from a pancreas. See page 13 for the key to this image.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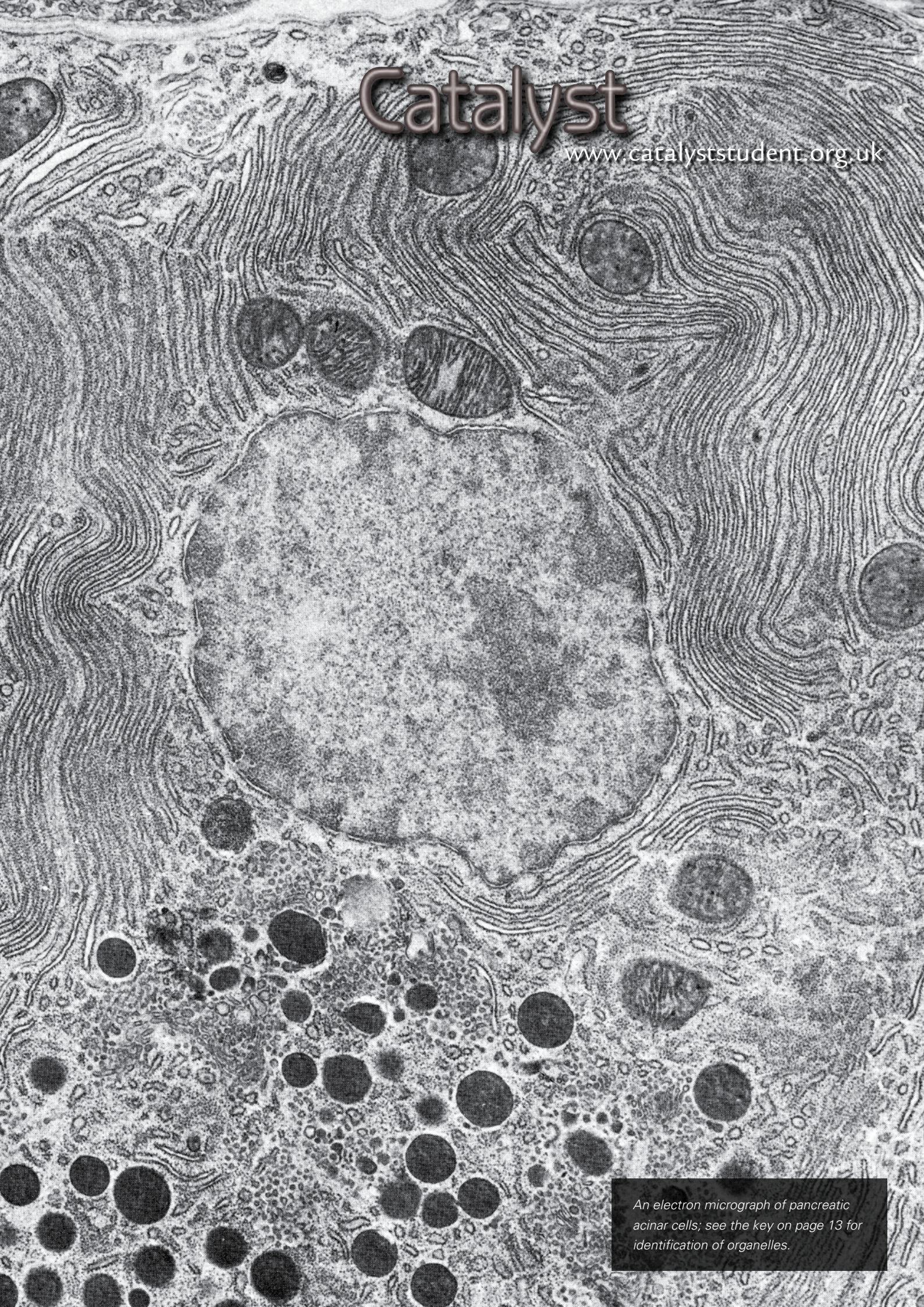

An electron micrograph of pancreatic acinar cells; see the key on page 13 for identification of organelles.

Lynn Margulis

Where did all the organelles come from?

In 1905 the botanist Konstantin Mereschkowski put forward the idea of symbiogenesis, suggesting that large complex cells (like the eukaryotes) evolved from the coming together of less complex ones, like the prokaryotes. This idea was not taken very seriously until it was shown that chloroplasts and mitochondria have their own DNA. By this time, DNA had been shown to be the hereditary material of organisms, so it seemed that these organelles might at one time have been separate bacteria, capable of reproducing themselves.

Then, in 1967, biologist Lynn Margulis published a paper entitled *On the origin of mitosing cells* in which she proposed that at least three of the organelles, the mitochondria, plastids (such as chloroplasts) and the basal bodies of flagellae, were themselves once free-living (prokaryotic) cells, and that they had at some time in the distant past merged with or been engulfed by other cells. Again, it took some considerable time for this set of ideas to be widely accepted but it is now part of accepted wisdom amongst most biologists.

As with all such ideas or theories, its acceptance has been won through the accumulation of evidence for it. Margulis's story is, itself, a triumph of determination over orthodoxy, well summed up by evolutionary biologist Richard Dawkins in 1995 when he said:

"I greatly admire Lynn Margulis's sheer courage and stamina in sticking by the endosymbiosis theory, and carrying it through from being an unorthodoxy to an orthodoxy. I'm referring to the theory that the eukaryotic cell is a symbiotic union of primitive prokaryotic cells. This is one of the great achievements of twentieth-century evolutionary biology, and I greatly admire her for it."

Sadly, Lynn Margulis died in November 2011, but perhaps this will prompt someone to write about the epic struggle she had to have her wild theory, as it was seen at the time, accepted. This, in itself, will be a classic example of how scientific ideas change.

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Did some organelles come from bacteria?

Most biologists now believe, as Lynn Margulis did, that mitochondria and plastids were originally free-living bacteria that came to live symbiotically in other cells. Here is some of the evidence for the 'endosymbiont' theory.

Mitochondria and plastids:

- contain DNA that is different from that of the cell nucleus and that is similar to that of bacteria (both in size and circular form);
- are surrounded by two or more membranes, and the innermost of these is similar to a bacterial cell wall;
- are formed only through a process like binary fission seen in bacteria;
- have ribosomes, proteins, enzymes and transport systems similar to those of bacteria;
- are similar in size to bacteria.

This electron micrograph is the same as the larger image shown on pages 10-11. A single acinar cell from the pancreas is outlined in red. You should be able to relate most of the structures in the cell to the drawing of an acinar cell below.