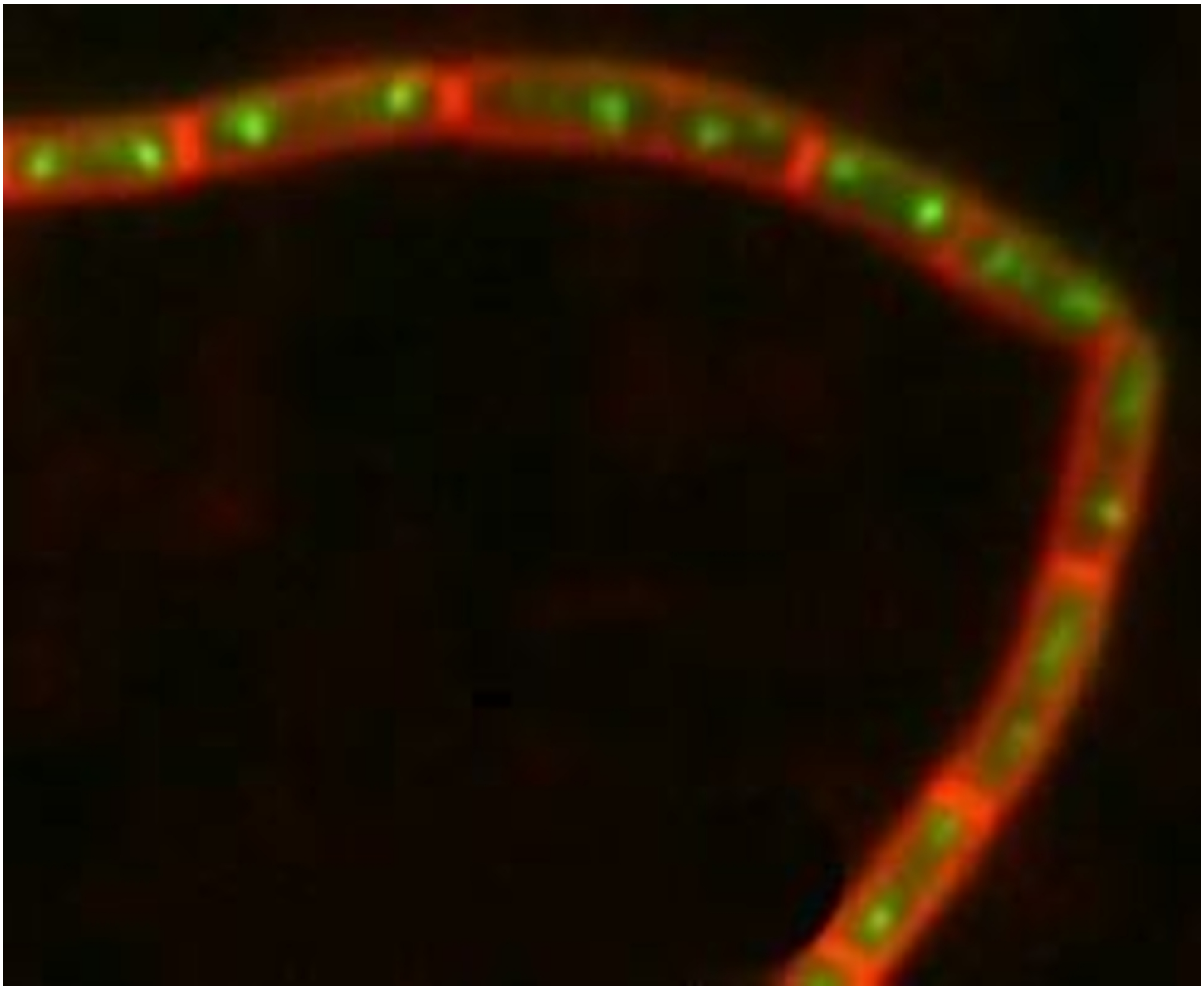
Bacteria cells are highly organised

Consisting of a cell wall, a membrane and a chaotically distributed DNA thread in the cell's interior, microbial cells long gave researchers the impression that they were in a state of complete disorder. However, there is growing evidence that cells are somewhat more organised than previously thought. Prof. Dr. Peter Graumann at the University of Freiburg knows about the controlled distribution of the duplicated hereditary substance to two daughter cells during cell division. Graumann and his team in the Department of Microbiology are investigating the mechanisms that enable this process.

Bacillus subtilis is a rod-shaped bacterium that normally lives in soil. Every so often, the bacteria duplicate their genome and distribute it to two cell halves at the same time as erecting a wall between the two halves that results in two identical daughter cells. Ten years ago, when researchers looked at a Bacillus subtilis culture under the microscope, they saw a cell wall, but no compartments that are found in animal or plant cells. They could perceive a circular chromosome that looked like a cloud, but otherwise there was only chaos. “Since then, modern imaging and genetics methods have enabled them to see completely different pictures,” said Prof. Dr. Peter Graumann, head of a group of researchers in the Department of Microbiology at the Faculty of Biology at the University of Freiburg. “Many bacteria have a cytoskeleton that structures the cell. And we now know that the duplication and division of the genome during cell division is a highly controlled process.”

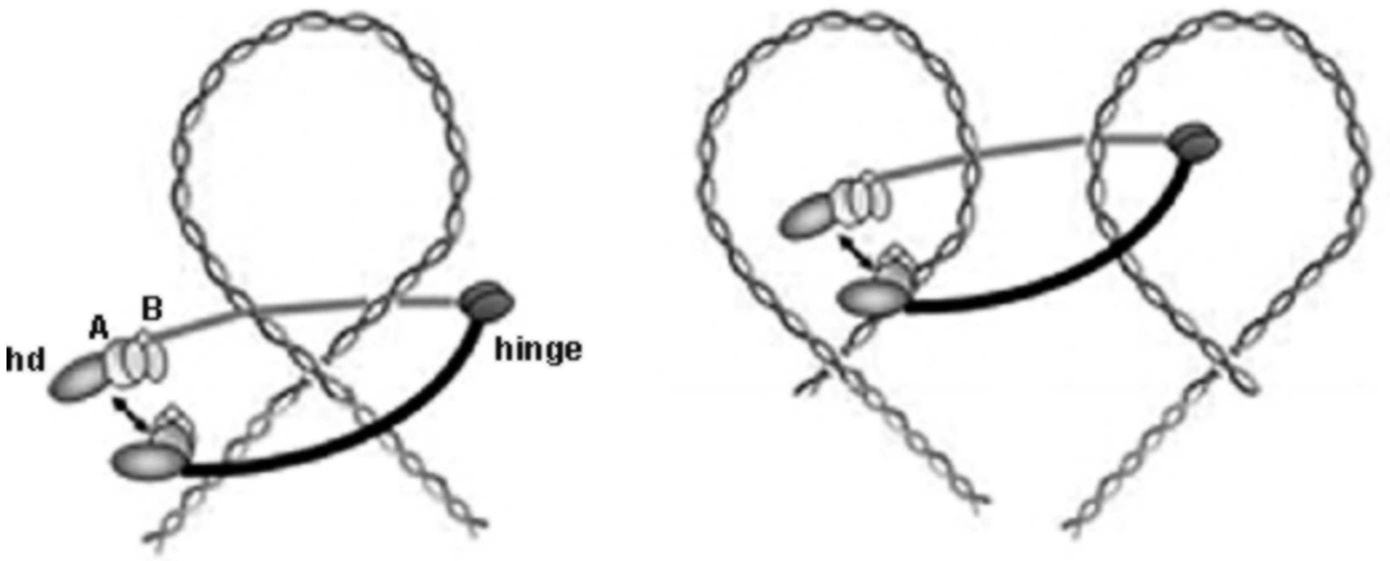
A wire mesh of molecules



Duplicated Bacillus subtilis DNA is located at the two poles of the individual bacterial rods (green dots). (Photo: Work group Prof. Dr. Peter Graumann)

Graumann and his colleagues can track the segregation of chromosomes under a fluorescence microscope. Different areas of the genome can be stained with green fluorescent protein (GFP) and observed. The researchers see a picture of high temporal and spatial resolution: the machinery that leads to the duplication of the DNA is located in the centre of the cell. Previously unknown molecular engines push each of the two freshly duplicated regions towards one of the two cell poles opposite where they will be tightly packaged. The process of segregation is also highly regulated in animal and plant cells. "And some of the molecules involved in the process are very similar," said Graumann.

For example, there are proteins similar to actin, a protein in animal and plant cells that can form long threads and create a type wire mesh. In Bacillus subtilis cells, the proteins similar to actin are located under the bacterial membrane and form the skeleton that leads to the bacteria's typical rod shape. The scientists also believe that the proteins form the skeleton along which the duplicated chromosome moves towards the two poles. If the researchers genetically manipulate the proteins to prevent their synthesis, this also impedes the segregation of the chromosomes. Graumann and his colleagues are currently working on obtaining further insights to see whether the filaments are actually directly involved in or indirectly influence the process of segregation.



The SMC complex looks like a ring and packages the DNA by encompassing it. (Figure: Work group Prof. Dr. Peter Graumann)

Whilst further details are necessary to understand this process, the scientists have already gained important insights into another aspect of chromosome distribution. The SMC (structural maintenance of chromosomes) protein complex ensures that the duplicated areas of the bacterial genome condense at the cell poles to take up less space. The complex, which consists of three different proteins, looks like a ring that can be opened and closed. It encompasses the DNA areas of the bacterial chromosome and introduces supercoils (additional coils) into the already twisted molecule. This results in the compaction of the DNA superhelix.

Proved its value during evolution

"The inactivation of the genes encoding the three proteins of the SMC complex prevents the distribution of the chromosomes to the two daughter cells," said Graumann. "The complex is essential for the active segregation of the chromosomes and hence for the entire process of cell division." The fact that this process has been kept going as cells evolved over millions of years also highlights its huge importance. The process is also found in other, higher, organisms that have developed during evolution. At present, Graumann and his colleagues are working with different microscopic, genetic and biochemical methods to find out more about the mechanisms and molecules involved in the process.

For example, they would be very interested in finding out more about the force that makes the genome move towards the cell poles. It is assumed that molecular engines are present in all groups of bacteria; if the microbiologists are able to find out more about their function, they will potentially be able to modify the proteins. This will also enable the development of drugs that have an effect on the duplication and division of bacteria. The prevention of bacterial cell division might prevent the development of diseases.

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