Bacteria

Bacteria are ubiquitous *prokaryotic* organisms with a size of **0,3–10 µm**.

General information

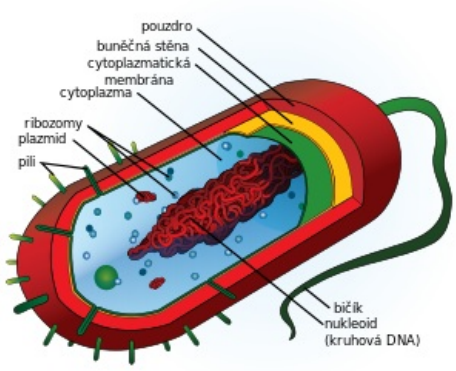
Bacteria belonged to the evolving chain of life on Earth. They originated about **3 billion years ago** and affected both the development of the environment and the development of other species, as infections are important factors in selection. More than **2000 species** of bacteria have been described. **They do not have a nuclear membrane** or **nucleolus**. Transcription and translation take place almost **simultaneously** in the cytoplasm. They have an irreplaceable **role in ecosystems**:

- degrade organic matter and recycle nutrients (**saprophytes**)
- some are able to capture atmospheric nitrogen
- they are extremely **adaptable** – they show a huge diversity of metabolism and the ability to use different energy sources

Bacterial structure

== Cytoplasm ==

The cytoplasm of prokaryotes has a similar composition to eukaryotic cells. However, there are no membrane structures in it. Bacteria lack the classic cytoskeleton.



Bacterial cell.

Ribosomes

Bacterial ribosomes have a different structure than eukaryotic ones. Prokaryotic ribosomes are smaller than eukaryotic ones and their subunits have different compositions. The small subunit consists of **30 S** (1 RNA, 21 protein molecules) and large **50 S** (2 RNA, 34 protein molecules). Together they have **70 S**.

Different ribosome structures can be used in antibiotic treatment. Such antibiotics include, for example, streptomycin, tetracycline, chloramphenicol, erythromycin, etc.

The number of ribosomes is proportional to the cell growth rate (constant translation rate of about 13 amino acids per second). At present, 1 mRNA of its kind (1000 in total) is present in the cell. They have a short lifespan (several minutes), but at the same time they have a quick adaptive response. **Transcription and translation can take place simultaneously.**.

Plasmids

One or more small circular chromosomes that are not essential for the survival and division of the bacterium are called **plasmids**. They are genetic endosymbionts. The plasmid has the ability to integrate into the chromosome. There may be 1-100 plasmids (plasmid number) in the cell. They may contain genes that alter the properties of the bacteria.

- **Tox** plasmids – genes for toxin production.
- **R** plasmids – resistance factor, genes for enzymes that degrade or modify ATB.
  - Often part of a transposon - a bacterial strain can quickly become a carrier of multiple resistance plasmids.
  - They are often conjugative - propagation.
- **Col** plasmids – the formation of bacteriocins (eg. colicins) that kill other bacteria.
- **F-factor** – genes for sex-pili production, attachment of b. F+ to b. F−, E. coli, salmonella.
- **Virulence** plasmids – endotoxin production, colonization factors.
- **Metabolic** plasmids.

The cell itself is not able to create a plasmid - it can obtain it:

- By **conjugation** through fimbriae from another bacterial cell - spread of antibiotic resistance, horizontal transmission of genetic information.
- By **transduction – through the bacteriophage.**
- By **transformation – the transfer of free DNA from the environment to the cell (Griffith's experiments, evidence of DNA as a carrier of genetic information).**

Additional features and uses

Degradation and oxidation of toxic substances, antibiotic resistance, heavy metals, production of antibiotics, toxins, formation of restriction and modification enzymes. They are used for their great replication capacity as **vectors** in genetic engineering.

Inclusion bodies, granules

- Glycogen,
- polybetahydroxybutyric acid droplets - a specific storage substance for bacteria,
- polyphopsphates,
- lipids,
- vacuoles – buoyancy of aquatic bacteria.

Spores

Spores can be found in some bacteria (*Bacillus*, *Clostridium*).

Major circular chromosome (nucleoid)

Bacterial DNA is found freely in the cytoplasm, it is not enveloped by a membrane, so we are not talking about the nucleus. It consists of one circular chromosome. It is in the so-called *nucleolar region* and is attached in one place to the cytoplasmic membrane **(OriC)**. This place is called **mesosome**.

The DNA of the double helix is enclosed in superhelicity - physiological is negative, ie more loose, negative superhelicity is maintained by enzymes topoizomerázami (I – releases, II – produces with ATP consumption). The double helix consists of about 3 Mbp with a length of about 1-2 mm (the degree of spiralization depends on the transcriptional activity of the genes that lie in the section). The size of the bacterial genome is species-specific, ranging from six to eight thousand genes.

The amount of protein around the chromosome is non-constant and depends on the intensity of proteosynthesis (these are mainly DNA and RNA polymerases). The proportion of RNA around the chromosome depends on the number of genes currently transcribed. The rate of cell division depends on the frequency of replication initiations (a new one can start during another ongoing one).

During division, DNA attaches to the mesosome. DNA duplication is subject to negative regulation - dilution of the replication inhibitor in a growing cell volume. When DNA is damaged, the SOS regulatory system is activated. There is only one haploid chromosome in the resting non-growing cell, mRNA unmodified - high transcription rate.

Bacterial wall

The bacterial wall is made up of several layers. Because the cytoplasmic membrane is an essential component of all bacteria, other components of the bacterial wall may or may not be present. Their presence may **increase the pathogenicity** of the microbe.

Cytoplasmic membrane

It consists of a phospholipid bilayer permeated by transmembrane proteins and glycoproteins. It does not contain cholesterol and at lower temperatures there is a higher proportion of unsaturated fatty acids. It has the function of transmembrane transport, the respiratory function (it represents the mitochondria), it anchors the rotor of bacterial flagella.

Cell wall

The main components of the bacterial wall are **peptidoglycan polymers (mureins)**, composed of long disaccharide and shorter peptide chains, which together form a kind of *lattice*. The wall ensures the **shape** of the bacteria and allows them to survive in a **hypotonic environment**.

Its composition depends on whether the bacteria appear to be **G+** nebo **G-**.

- Bacteria with lipopolysaccharides and part of proteoglycans are **gram-negative**.
- Bacteria with only peptidoglycan walls are **gram-positive**.

It is present in most bacteria, it does not occur in mycoplasmas and **L-forms of bacteria**.

Information on the structure of the bacterial wall is essential for the choice of **antibiotics** in the treatment of bacterial infections.

Movement and adhesion organelles

They occur only in some bacteria. Their structure and function differ from eukaryotic locomotor organelles.

Function of adhesion molecules (adhesins)

- **Adherence** – interactions between structures on the surface of bacteria.
  - Tissue tropism of bacteria, **specific binding** to certain structures on the cell surface.
  - The need for proper orientation (negative charges of adhesins and receptors).
  - Adherence is not unique to pathogenic microbes.
- **Biofilm formation**.
- Knowledge of the chemical structure of receptors → the possibility of blockade for bacteria.

Extracellular polymers (glycocalyx)

Extracellular polymers only occur in some bacteria (eg. *E. coli*). The presence may be **a determining factor in the pathogenicity** of the microbe (*Haemophilus influenzae*). Formation is influenced by the environment. Glycocalyx has a **polysaccharide** character (pneumococci, klebsielly, hemophilia...). *Bacillus anthracis* is made up of polypeptides. It is shown by negative coloring (**ink**). Colonies have a mucous appearance.

Function

- **Adherence** (function of adhesins) – host colonization, bacterial coaggregation.
- **Biofilm formation**.
- **Resistance** to phagocytosis.
- **Antibiotic resistance**.

Types

1. **Capsule**
   - Clearly separated from the environment, it clings firmly to the cell wall.
   - Structural integrity (well condensed polymer).
   - Antigenic properties, virulence and invasiveness factor.
2. **Slime** – loose amorphous mass.
3. **S-layer** – a squamous glycoprotein on the cell wall surface.

Capsule

Only in some bacteria. It consists of polysaccharides. It has a protective function.

Fimbria (pili)

- They allow the adhesion of bacteria to the host cells and to other bacteria (sex pili).
- Short rigid hollow fibers, made of **pilin** protein, brittle.
- **Only in G-**, tens to hundreds.
- **Adhesin** function – ability to colonize the host.
- Binding to membrane glycoproteins and glycolipids.
- Very **numerous**, mostly evenly on the surface.
- The formation of fimbriae is often coordinated with the formation of other tools of pathogenicity (toxins).
- High specificity, typical for each type of bacterium.
- Very fragile - constant formation of new fimbriae - virulence factor – **change in antigenic composition of pilin**, escape from IgA antibodies (anti-adherent).
- Mannose-sensitive and manno-resistant adherence (if possible inhibition by D-mannose).
- *E. coli* (P-fimbria – pyelonephritis), *N. gonorrhoeae*, *Pseudomonas aeruginosa*, *Bacteroides*, *Vibrio*.

1. **Sex fimbria**
   - Wider and longer than ordinary fimbriae.
   - Coded by a so-called fertile plasmid.
   - DNA transfer between bacteria (**conjugation**).
2. **Curli**
   - Clusters of slender and wrinkled fibers.
   - On the surface of some **escherichia and salmonella.**.
   - Serum proteins binding (**sepsis**).

Non-fimbrial adhesins

- **Protein F** (binds fibronectin, *Str. pyogenes*).
- They can also act as hemagglutinins (yersinie, bordetely, mykoplasmata).

Flagellum

- They are made of the protein **flagellin**, they have a simpler structure than eukaryotes. The movement of bacteria is caused by their rotation, which is caused by a ring of proteins in the plasma membrane around the flagellum → the ring responds by changing the conformation to a change in the gradient of H^+ ions.

- Longer than the whole cell – up to 20 µm, thickness 20–30 nm.

- 3 parts - filament, hook and basal body:
  1. Flagellin **filament** (hollow, globular protein, species specific).
  2. (**Hook**) – strengthening and connection to the basal body, by 90°.
  3. **Basal body** – anchored by rings into the wall (stator) and cytoplasmic membranes (rotor), differ in G+ a

G- (different cell wall structure).

Distribution of bacteria according to flagella

1. Monotricha – one on pole – *Vibrium*.
2. Lophotricha – bundle at one pole – *Pseudomonas fluorescens*.
3. Amfitricha – bundles at both poles – *Spirillum minus*.
4. Peritricha – flagella all over the surface – majority (*Proteus*, *Escherichia*).

- Representation by **silvering**, indirect identification by motion detection.
- **Axial fibers** – a structure analogous to a whip, but placed below the surface of the cells - the movement of **spirochetes**.
- Spirochetes move by changing their shape. Myxobacteria move by the produced secretion.

Bacterial reproduction

Bacteria multiply by **asexual division**, very fast. The length of one reproductive cycle is 20–150 min (the more favorable the conditions, the shorter the cycle). Reproduction is regulated by the amount of nutrients and concentrations of bacterial metabolism products. Asexual division begins with cell elongation and replication of the bacterial ring chromosome. Replication begins at the **OriC** – the site of attachment of the chromosome to the plasma membrane. The genetic identity of clones (daughter cells) is limited by random mutations. The formation of a new section of membrane between these two attachments pushes the newly formed daughter chromosomes apart. Thus, there may be a situation where the cells move away sufficiently and a septum is formed, or the two daughter cells separate from each other - the so-called plate division.

Bacterial DNA replication

It runs in both directions against each other, it is semi-conservative. Synthesis and repair are controlled by **DNA-polymerase**. **Leading strand** leads from the 5 'to the 3' end, synthesis continuously. **Lagging strand** – the synthesis of **Okazaki fragments** – they are connected by ligase. The enzymes involved in bacterial DNA replication are:

- helicases - untangling
- topoisomerases – release tension in the resulting DNA
- gyrase - removal of excess threads

Gene expression

RNA transcription

The DNA-dependent RNA polymerase binds to the sigma factor promoter.

Translation

Ribosomes are smaller and structurally different from eukaryotic ribosomes (antibiotics act selectively only on bacteria), so it is very fast – ribosomes attach immediately to unfinished mRNA

Gene expression control

Bacteria have the ability to adapt to environmental change (intrusion into the host), which is a two-step process – sensor > activator / represor

Mutations

Bacterial mutations are point or larger changes - deletions, inversions, insertions. Many mutations lead to disruption of the metabolic pathway – **auxotroph** (does not grow on a culture medium where the product is missing). There is also the **possibility of beneficial features** – the ability to withstand bacteriophages, chemicals or ATBS. Mutations are divided into spontaneous and induced mutations

- base analogs, alkylating agents, intercalating agents
- **The Ames test of mutagenity** – the more auxotrophic strains back mutated - the more they grow on the medium - the more mutagenic the medium

Plasmids

They are small, circular DNA molecules **independent** of the bacterial chromosome with separate replication. They carry several dozen genes that are not essential for the bacterium:

- **episome plasmid** – can also exist integrated into the chromosome
- **conjugative plasmid** – genes for sawing, during conjugation they can transfer their copies to other bacteria

Recombination

Recombination is the interruption and reconnection of DNA with the exchange of its segments. May be:

1. Heterologous

New genes are introduced and exchanged between a pair of homologous DNA sequences. We distinguish here transposons, integrons.

Transposons

Movement within the genome and from the plasmid to the chromosome, is called „jumping genes“. By moving tr. certain genes can be started and stopped. They differ from the virus in that they lack a reproductive cycle, from the plasmid's inability to self-replicate and exist outside the chromosome. After incorporation – mutation, may carry stop codons, termination sequences, promoters.

- insertion sequence – the simplest type of transposon, it carries only the gene for trasposase and inverted repeats
- compound transposons – at least one gene in addition to IS, (genes for virulence factors, for ATB resistance)

2. Homologous

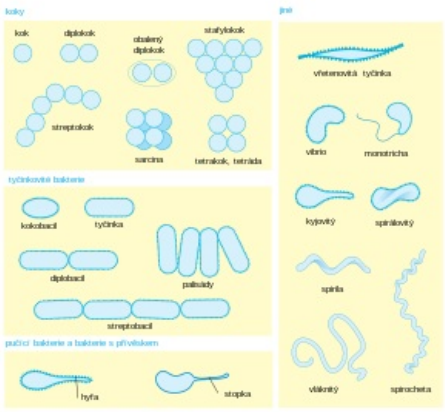
Some bacteria change their properties by rearranging their own genes. We then distinguish between local inversion and gene conversion, eg in gonococci (*Neisseria gonorrhoeae*), when the antigenic composition changes, new serotypes are formed. There are a number of genes for antigens, only one is functional and the others are defective - multiplication and rearrangement of genes → a functional gene becomes defective and one of the defective ones becomes functional.

Interbacterial exchange of genetic information

1. Conjugation
2. Transformation
3. Transduction

The shape of bacteria

- **round** (cocci)
- **rod-shaped** (vibria, spirils, spirochetes)



Different shapes of bacteria.

Types of bacteria and their way of life

Bacteria are equipped with numerous **chemoreceptors** → they respond by *movement* (positively / negatively) to:

- oxygen concentration
- lighting
- chemicals (eg. glucose)
- presence of their own metabolic products

Bacteria are **highly adaptable.**

Heterotrophic bacteria

They act as **decomposers** in the process of recycling substances in nature. It feeds on decomposition products and dead organic matter. As parasites they can cause infectious diseases in plants and animals.

Autotrophic bacteria

They are able to obtain energy through **photosynthesis** or **oxidation of inorganic substances**. **The enzymatic equipment** of bacteria is diverse - it corresponds to the environment to which they have adapted with their development.

Prototrophic bacteria

They are able to live on minimal soil and **synthesize all the substances** needed for life.

Auxotrophic bacteria

Biochemical loss mutations cause bacteria to be able to grow only in an environment that contains a substance that they are **unable to synthesize**.

According to the need of **oxygen** we divide bacteria into:

- **aerobic bacteria**: they need oxygen for their metabolism
- **anaerobic bacteria**: unable to survive in the presence of oxygen. Therefore, they endanger patients with tissue circulatory disorders, eg. after injuries.
- **facultatively anaerobic**: bacteria capable of living in both aerobic and anaerobic environments
- **capnophilic, microaerophilic bacteria**: they grow best in environments with increased CO_2 content

The importance of bacteria in medicine

E. coli is a rod-shaped bacterium that moves with the help of flagella. It is part of the intestinal microflora of all warm-blooded animals. It has its place in the large intestine and the lower part of the small intestine. As part of the intestinal microflora, it is beneficial to humans. It produces a number of substances that prevent the spread of pathogenic bacteria. In addition, it is involved in the production of certain vitamins. Humans have been colonized by this bacterium since birth.

This bacterium plays an **important** role in **insulin production**. (Insulin from pigs for slaughter used to be used for treatment. Due to allergic reactions, insulin production was switched to using genetically modified E. coli.) In addition, it is used in the preparation of human **growth hormone**, **Lyme disease vaccine, amino acid production, parathyroid hormone and calcitonin.** Probiotic E. coli strains can be used to treat infections caused by adherent invasive E. coli and in the treatment of Crohn's disease.

In **genome engineering** bacteria can help us due to the fact that they contain a small amount of DNA – plasmids. We isolate plasmids from the bacteria, attach parts of the DNA from the chromosomes of animals and plants to them, and use them to produce proteins that the bacteria themselves are unable to produce. In this way, for example, insulin and other important substances can be synthesized with the help of bacteria. Abroad, they produce insulin and growth hormone in this way.

Links

- ws:Bacterie

Related articles

- Bacterial structure
- Bacterial reproduction
- Conjugation, Transformation and Transduction.
- Prokaryotes
- Regulation of gene expression in prokaryotes

External links

- Bakterie (Czech Wikipedia)
- Bacteria (English Wikipedia)

Zdroj

- ŠTEFÁNEK, Jiří. *Medicína, nemoci, studium na 1. LF UK* [online]. [cit. 11. 2. 2010]. <https://www.stefajir.cz/>.

References