Our Friendly Residents

No one can escape their closest neighbors of all: Some 500 trillion bacteria live on and in the human body. We should look after them.

Text: Mathias Plüss

One might think that man has shone the brightest of spotlights inside himself. The human genome has been decrypted, the brain scanned a thousand times over. We have dissected the pineal gland and shed light on our subconscious drives. No digestive enzyme, no capillary vessel and no auditory ossicle has escaped our notice.

And yet the last few years have revealed an important sphere of the human body that has so far remained almost wholly unknown to us: the life of microorganisms that goes on both inside and upon us. It would be a mistake to dismiss this aspect as a triviality – each fully grown human carries almost 2 kilograms of bacteria around with them, or more than the weight of their cerebral matter. Nor are we in any way dealing with "pests": The majority of the microbes that live in and around us are useful creatures, known by their technical name as "commensal organisms" or simply commensals. They live off us, but without causing us any harm in the process.

Project to Map Our Bacterial Life

According to the latest estimates, every human being is host to around 500 trillion bacteria. This being a hundred times the number of cells in the body, or around a hundred and forty times the US government budget in dollars. At the same time, however, most bacteria are a hundred times smaller than human cells, and impossible to grow in a laboratory – which is precisely why we know so little about them. It was only as recently as 2007 that the Human Microbiome Project was launched, which – similar to the Human Genome Project – is seeking to map and decipher the entire bacterial life of the human organism. To achieve this aim, the project is relying on a new method. Scientists formerly had to first apply a sample of a part of the body to a nutritional culture to see what would grow as a result. Now, however, the genome of all bacteria contained in the sample can be directly investigated by machine. This is a quicker and more comprehensive approach, even if at the end there is sometimes confusion as to which gene belongs to which bacterium.

Accordingly, the initial results are still rather vague and provisional. It is estimated that the human body is colonized by several hundred or perhaps even several thousand different types of bacteria. A continual process of interaction takes place between these different types, as well as between the bacteria and the human body they inhabit. Many researchers believe that man should not be viewed as an individual organism but as a genuine ecosystem – indeed, this theory further posits that there is actually an entire network of ecosystems blooming inside and upon us, each of which we are inextricably linked with. Why? Because the composition of "microflora" differs in every part of the human body. They also vary over time, and above all from person to person. Even today, no one knows whether there is a basic strain of bacterium types common to all mankind. "Our microbe communities," opines American biologist Robert L. Dorit, "are substantially more multifaceted, more complex, more structured and more fascinating than was ever believed possible."

As a rule, only five areas of the human body are sterile: the brain, the lungs, the abdominal cavity, the bladder and the blood. Everywhere else we are teeming with bacteria:

- Some 99 percent of human bacteria live in the **intestines**, which cover an impressive area of 400 square meters thanks to their invaginations and meandering courses. The greatest density of bacteria population is found in the colon, with up to a billion bacteria per gram of intestinal content. Around a third of the feces excreted from the body comprise bacteria. The whole system is one of give and take: The microbes receive free food, and in return produce valuable vitamins, help with sugar absorption and break down fibers that we would not otherwise be able to digest. In this respect, even the human appendix has a purpose: Many researchers believe it to be a kind of shelter from which the bacteria can recolonize the intestines after an attack of diarrhea, for example. At least 500 types of bacteria can settle in the intestines, though in all likelihood the number is much higher. Overweight people often have a significantly increased proportion of bacteria of the "firmicute" strain that helps to break down carbohydrates; this could be one explanation of obesity. That said, it is not clear which is the chicken and which the egg here: Are these people fat because they have more food-processing bacteria, or do they have more food-processing bacteria because they eat more?
- Around 600 types of bacteria make up the human **oral flora**. This moist area with guaranteed food supply is popular with protozoa such as mastigophorans and the amoeba Entamoeba gingivalis, a con-

sumer of bacteria that moves through the saliva at a maximum speed of 2.5 centimeters per hour. When oral hygiene is poor, the bacteria cluster themselves in deposits on the teeth and tongue, leading to dental cavities and halitosis. An investigation involving participants of the Pfahlbauer project organized in 2007 by the Swiss broadcaster Schweizer Fernsehen showed that the proportion of enamel-damaging bacteria decreases significantly if the individual takes no refined sugar for a period of four weeks.

■ As our **skin** covers an area of just 2 square meters, it naturally has less bacteria than the intestines – but instead has a greater variety of bacteria types. Key areas of biodiversity include the forearms, the hands, the index fingers and the backs of the knee. When it comes to sheer numbers, the moist parts of the body such as the armpits, the area between fingers and the rectal tags have the densest populations. Local and individual differences are enormous, however. A study into the forearms of six people, for example, found a total of 182 different types of bacteria, but only four of these types were common to all six individuals. "The moist and hairy armpits are not far from the smooth, dry forearms," wrote American researcher Elizabeth A. Grice in the specialist journal Science, "but in environmental terms these areas differ as radically as the rainforest and the desert." The bacteria on our skin feed on dandruff, hard fats and sweat – and their decomposition by-products are what give our bodies their individual smells. These bacteria also live in the pores of our skin, and it is from here that they recolonize the surface of the skin after we wash our hands, for example. Moreover, yeast fungi can be found on most people's skin, while one area of our skin – our faces, no less – hosts around a thousand mites of two particular genera that reach at least a quarter millimeter in size.

■ The acidity of the **stomach** kills off almost all microorganisms, which is why it was long regarded as a sterile environment. Not until 1979 was the bacterium Helicobacter pylori discovered, which not only lives in the human stomach (and those of other animals) but is also widespread. This microbe is typically passed on within families, and has played its part in the whole of modern human history since the evolutionary exodus out of Africa. It is therefore helpful in reconstructing historical migration flows. Given their different origins, for example, the Buddhist and Muslim peoples of the Indian region of Ladakh have greatly differing variants of Helicobacter pylori in their stomachs, despite the fact that it is impossible to separate these two peoples genetically. It is only in recent years that scientists have become aware of the potential existence of many more microorganisms in the human stomach – for example, a member of the Deinococcus strain that was previously only believed to live in hot springs, nuclear power plant coolant and waste contaminated with arsenic was found in the stomach of a test patient.

For a long time, it was an open question as to why the body did not defend itself more vigorously against microbe colonization. When oral flora were first discovered toward the end of the 19th century, these bacilli colonies were considered a form of disease and given the name "intestinal blood poisoning." Some doctors even recommended removing the large intestine as the best solution. It was only much later that the digestion-enhancing properties of bacteria were realized. However, it nonetheless remains true that bacteria can be dangerous. Many types of microorganism that live a benign existence in our intestines can turn into potentially lethal pathogens if they manage to break through the intestinal wall. Today, for example, it is believed that many more ailments could be caused by bacteria and viruses than was previously believed – such as many types of cancer, multiple sclerosis, asthma, depression and even heart attacks.

But this is only half of the truth. The bacterial borderline between good and bad is continually in flux. If this is to be understood, we have to see man and all his resident microorganisms as a complex ecosystem that is in equilibrium when he is healthy. The immune system keeps our bacteria in check, the bacteria keep the immune system going, while the bacteria control one another – neither can dominate at the cost of the other to the point where the ecosystem tips over. This is why, for example, a healthy person can harbor tuberculosis bacteria within their bodies for decades without the disease ever manifesting itself.

Tolerating Dangerous Territorial Defenders

Many of our apparently useless or even potentially dangerous residents are tolerated because their presence prevents an even more dangerous counterpart from taking their place. The trick, according to biologist Richard Roberts, winner of the Nobel Prize in medicine, is for every environmental niche both in and on the body to be populated by the most innocuous germs. Because once germs are established, they defend their territory. For example, our skin flora take on the role of hygiene police and are permanently on the lookout for marauding newcomers. If we are too zealous in scrubbing away this security service, we can open ourselves up to the spread of fungi and harmful microbes, which in turn can lead to ringworm, dandruff and eczema. The use of broad-spectrum antibiotics can have a similar effect. If many niches are suddenly freed of bacteria, a previously unproblematic germ may become excessively widespread and thus dangerous. Experts warn us as a general rule not to interfere in our body's own ecosystems other than in an emergency, until we have understood at least the rudiments of how they work. >

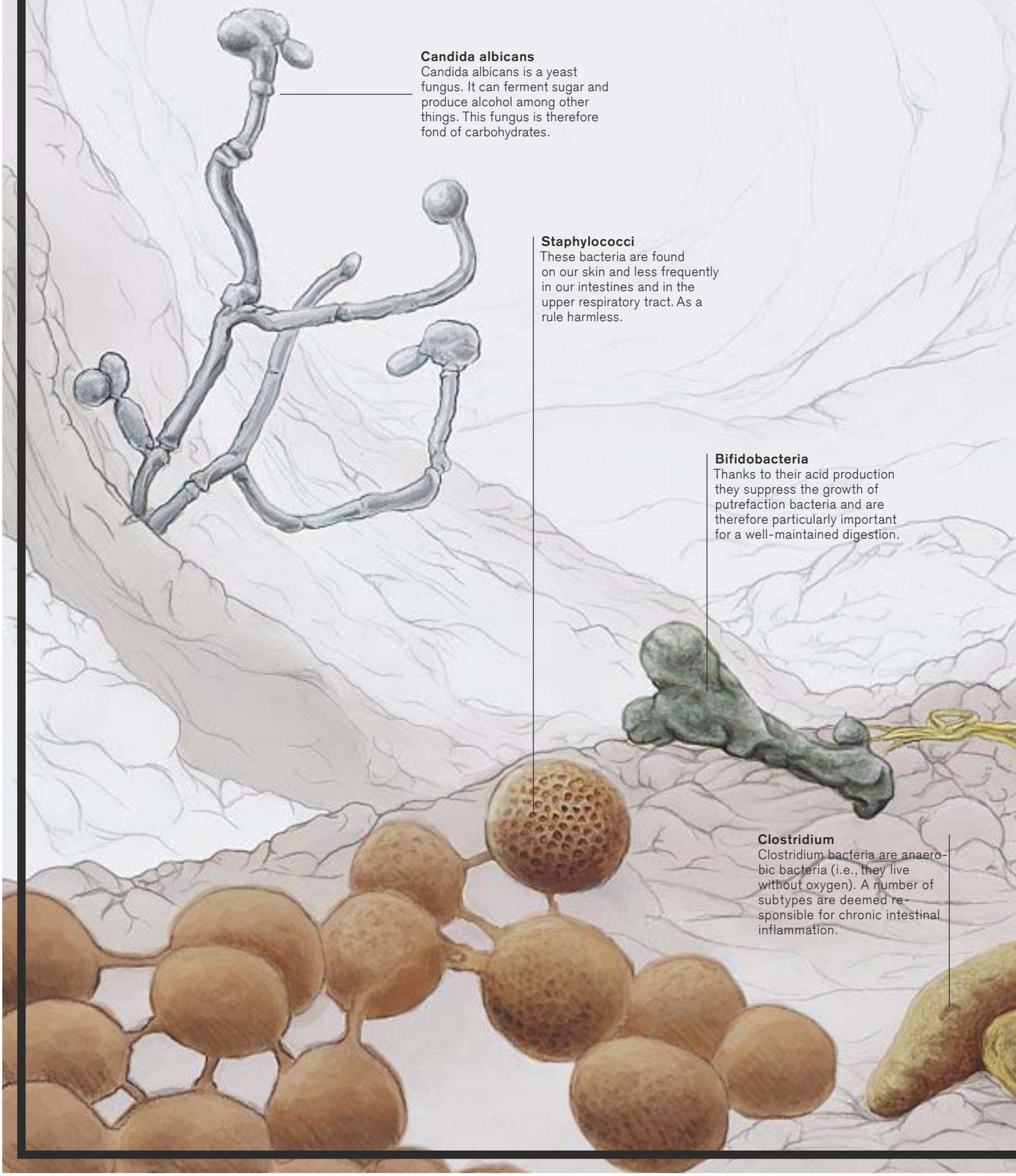
A scanning electron microscopic image of Helicobacter pylori. This helical-shaped gram-negative bacterium causes peptic ulcers, gastritis and duodenitis.

Photo: Medical RF.com, Science Photo Library

Figure 1

The Seething Mass of Life in Our Intestines

The microorganisms in our gastrointestinal tract produce vitamins, strengthen the immune system and prevent pathogens from establishing themselves. Detailed descriptions of our most important residents and their functions can be found at **www.credit-suisse.ch/bulletin.**



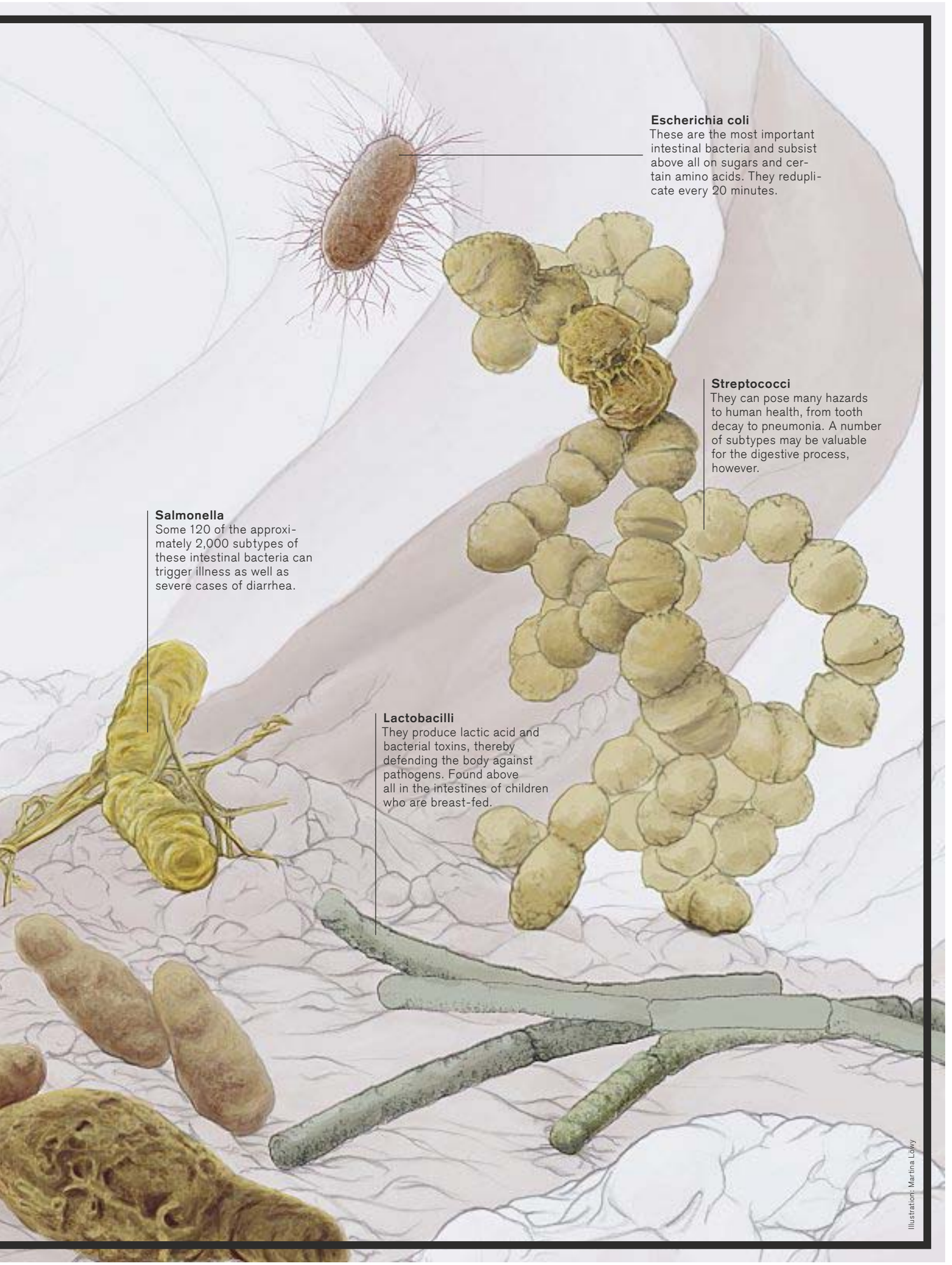
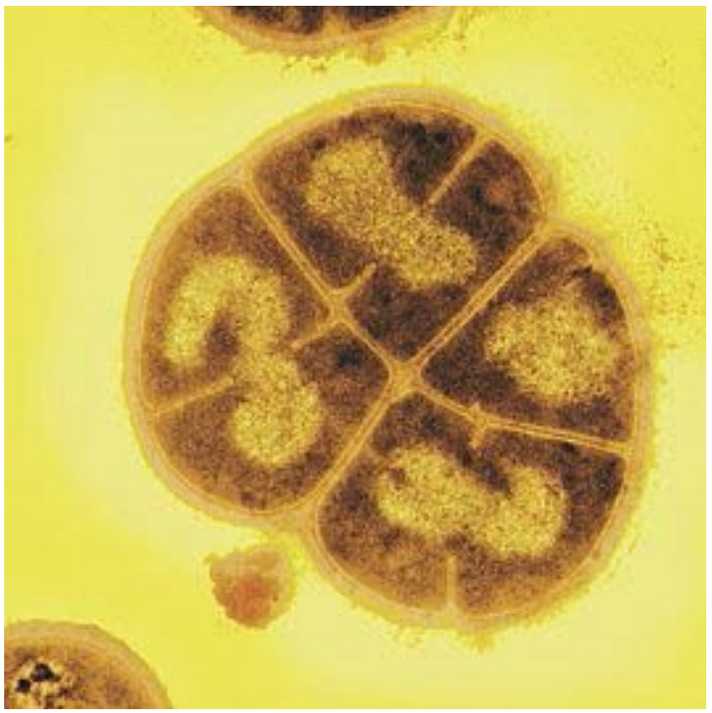


Illustration: Martina Lőwy



Radiation-resistant bacteria. Colored scanning electron micrograph (SEM) of four Deinococcus radiodurans bacteria forming a tetrad. This extremophile bacteria can withstand extremes in radiation, low temperature, dehydration, vacuum and acidity. It can survive up to 3,000 times the radiation dose that would normally kill a human. It is thought that high levels of manganese help protect DNA repair proteins within the bacteria.

The earlier mentioned stomach bacterium Helicobacter pylori also represents a vivid example of the Janus-like nature of many microbes. Its discovery was a milestone, because scientists realized that this was the main trigger of stomach cancer (and not "stress," which was always formerly cited as the cause). Since this knowledge entered the medical canon, antibiotics have been a potential method for counteracting this bacterium. Indeed, while stomach cancer was still the most lethal form of cancer in the US a hundred years ago, its prevalence has since declined by 80 percent. Less than 5 percent of children in the Western world are still carriers of Helicobacter pylori nowadays. By contrast, for thousands of years the standard rate for humanity was an occurrence of almost 100 percent, a situation that nowadays is only found in one or two developing countries.

So far, so good. However, microbiologist Martin Blaser of New York University has now established that the decline of stomach cancer has its flipside: Since the 1970s, a particularly aggressive form of esophageal cancer has begun to spread in developed countries. In the US, this type of cancer is displaying the highest rate of increase. Blaser attributes this to the disappearance of Helicobacter pylori, which among other traits has the effect of regulating the stomach's acidity levels. In its absence, man is increasingly prone to acid reflux and as a consequence esophageal cancer. And not only that: This natural stomach inhabitant would also be a valuable asset in the fight against asthma, hay fever and even obesity. Children with Helicobacter pylori have a 40 percent lower risk of suffering from asthma than those without it. Indeed, Blaser believes that this bacterium would in all probability have more positive than negative repercussions for most people. So much so that in his view it could even be administered in a targeted way to children so as to protect them from asthma. After all, it could always be eliminated at a later stage with antibiotics to ward off the danger of stomach cancer.

The immune system of children quite clearly relies on a certain quantity of bacteria to get it up and running. If the immune system is underemployed, it starts hunting down the wrong types of bacteria – hence the risk of asthma and allergies. And indeed, we have probably done it a disservice with modern-day standards of hygiene. "Good parents should let their children eat dirt," says Blaser provocatively. Bacteria are simply part and parcel of human life. Babies are preserved in a sterile environment in the uterus, but are then first colonized by the mother's vaginal and fecal bacteria in the birth canal and later receive important bacteria from the mother's milk. Life is not possible without bacteria – or at any rate no healthy life: In experiments involving rats brought up in sterile conditions, neither the rodents' gastric nor immune systems developed properly; when the creatures were then exposed to germs at a later stage they suffered dangerous infections.

Exaggerated standards of hygiene and the far too widespread use of antibiotics are threatening to destroy a natural equilibrium built up over thousands of years. "Man and his bacteria are unquestionably a single unit," says Richard Roberts. We should make sure that it remains that way. <

Further reading:

Jörg Blech. "Leben auf dem Menschen: Die Geschichte unserer Besiedler". rororo, 2006. ("Life on Man: The History of Our Colonizers" [not available in English])