

Humans as holobionts

Our relationship with nature



**Piotr Skubała, University of Silesia,
Department of Ecology, Katowice, Poland**

A photograph of a dense forest. The foreground is filled with vibrant green ferns and other undergrowth. Several tall, slender tree trunks are visible, some with moss growing on them. The background is a thick canopy of green leaves and branches, creating a sense of depth and a lush environment.

Our relationship with nature

Do we understand nature?

Do we understand nature?

What do plants need to live?



1. sunlight
2. CO₂
3. water
4. mineral salts



thousands of species of bacteria, fungi, plants and animals with which they form an ecosystem

Do we understand nature?

What do I need to live?

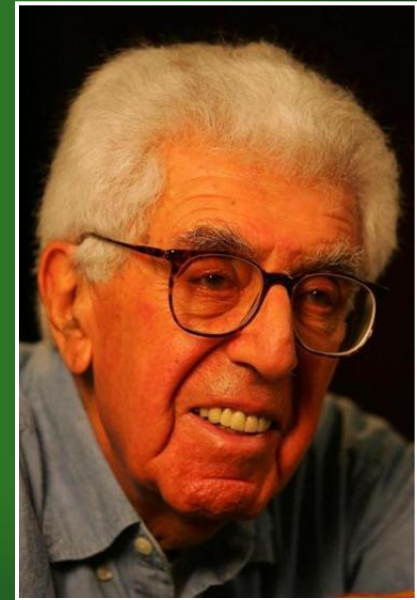


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What is the fundamental law of nature?

What is the fundamental law of nature?

Barry Commoner (1917-2012)
American biologist



Commoner B. 1971. *The Closing Circle: Nature, Man, and Technology*. New York: Random House.

What is the fundamental law of nature?

I. Everything is Connected to Everything Else

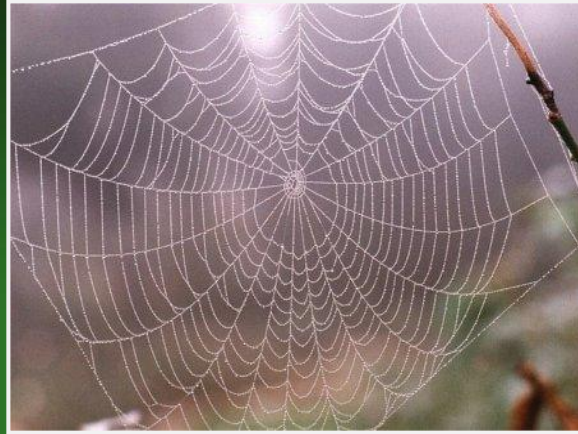


Commoner B. 1971. *The Closing Circle: Nature, Man, and Technology*. New York: Random House.

What is the fundamental law of nature?



What is the fundamental law of nature?



„ We do not have solitary beings. Every creature is, in some sense, connected to and dependent on the rest”

Lewis Thomas (1913-1993)
physician, poet

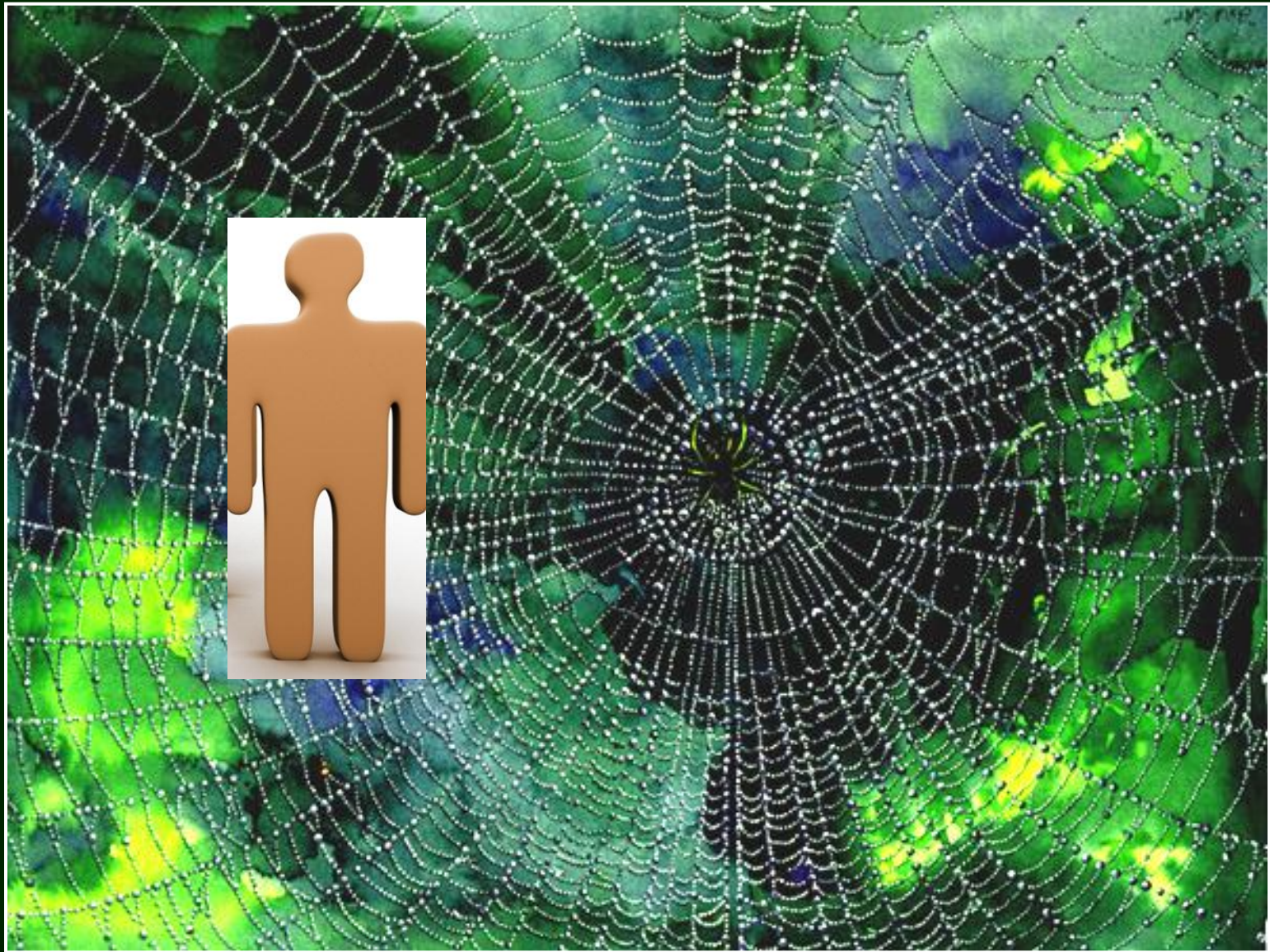


Lewis Thomas. *The Lives of a Cell: Notes of a Biology Watcher*, 1974, Viking Press, p. 7.

A photograph of a dense forest. The foreground is filled with vibrant green ferns and other undergrowth. Several tall, slender tree trunks are visible, some with moss growing on them. The background is a thick canopy of green leaves and branches, creating a sense of depth and a rich, natural environment.

Our place in the web of life

Our place in the web of life



Nature Is Speaking – Julia Roberts is Mother Nature



<https://www.youtube.com/watch?v=WmVLcj-XKnM>

<https://www.youtube.com/watch?v=hCSQH3zl6ig>

P

A photograph of a dense forest. The scene is filled with tall, slender trees, some with moss on their trunks. The ground is covered in a thick layer of green ferns and other undergrowth. The lighting is soft, suggesting a shaded forest environment. A white rectangular box is superimposed over the center of the image, containing the text 'The origin of human cells'.

The origin of human cells

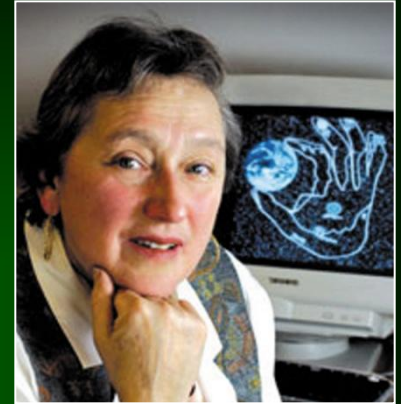
The origin of human cells

The origin of human, animal and plant cells?



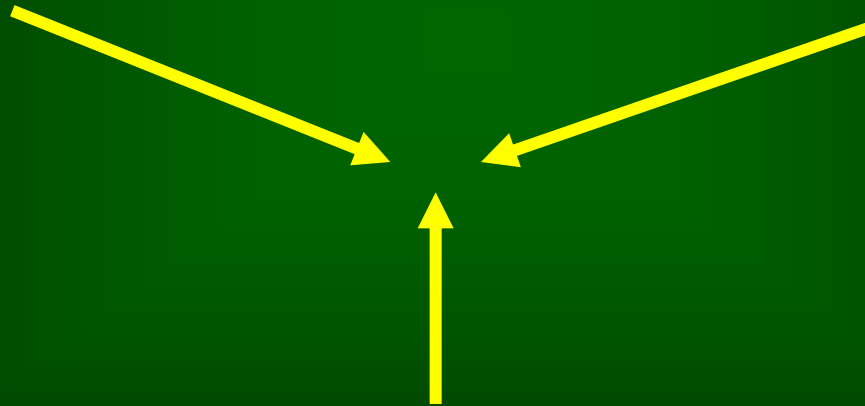
The origin of human cells

Serial Endosymbiotic Theory (SET)



Eucaryot's ancestor

Proteobacteria



Cyanobacteria

Margulis L. 1981. Symbiosis in Cell Evolution, 1st Edition. Freeman, New York.

The origin of human cells

Serial Endosymbiotic Theory (SET) and our body



Our physical bodies are chimeras, composites of innumerable life-forms and mergers which still retain traces of long-gone beings.

The origin of human cells

Serial Endosymbiotic Theory (SET) and our body

*„It is a mystery. There they are, moving about in my cytoplasm, breathing for my own flesh, but strangers. They are much less closely related to me than to each other and to the free-living bacteria out under the hill. They feel like strangers, but the thought comes that the same creatures, precisely the same, are out there in the cells of sea gulls and whales, and dune grass, and seaweed, and hermit crabs, and further inland in the leaves of the beech in my backyard and in the family of skunks beneath the back fence, and even in that fly on the window. **Through them, I am connected; I have close relatives ...**”.*

Lewis Thomas. The Lives of a Cell: Notes of a Biology Watcher, 1974, Viking Press.
p. 73.

A photograph of a dense forest. The scene is filled with tall, slender trees, some with moss on their trunks. The ground is covered in a thick layer of green ferns and other undergrowth. The lighting is soft, suggesting a shaded forest environment. A white rectangular box is superimposed over the center of the image, containing the text 'Our body as a superorganism'.

Our body as a superorganism

Our body as a superorganism

Humans, animals and plants are no longer viewed as autonomous entities, but rather as “holobionts”, composed of the host plus its symbiotic microbes.



Bordenstein S.R., Theis K.R. 2015. Host Biology in Light of the Microbiome: Ten Principles of Holobionts and Hologenomes. PLoS Biol 13(8): e1002226. doi:10.1371/journal.pbio.1002226

Our body as a superorganism

Man is not biont (living creature) but **holobiont**.



Bordenstein S.R., Theis K.R. 2015. Host Biology in Light of the Microbiome: Ten Principles of Holobionts and Hologenomes. PLoS Biol 13(8): e1002226.
doi:10.1371/journal.pbio.1002226

Our body as a superorganism

*“Highly complex animals such as humans can be considered “**superorganism**” with an internal ecosystem of diverse symbiotic microbiota and parasites that have interactive metabolic processes”*



Humans are more than human (?)

Jeremy Nicholson (biochemik z Londynu)

Nicholson J. K., Holmes E., Lindon J. C., Wilson I. D. 2004. The challenges of modeling mammalian biocomplexity. *Nature Biotechnology* 22(10): 1268-1274.

Our body as a superorganism

How many cells made up my body?



Our body as a superorganism



Several trillions "own" cells

> 100 trillion cells of microorganisms

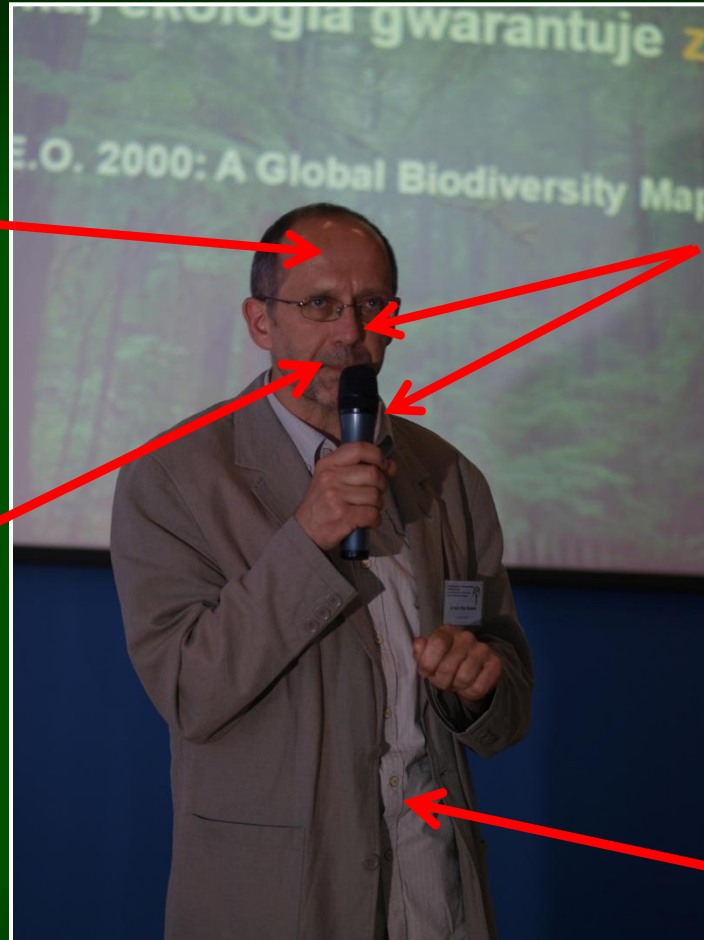
90% of our cells are microorganisms

Nicholson J. K., Holmes E., Lindon J. C., Wilson I. D. 2004. The challenges of modeling mammalian biocomplexity. *Nature Biotechnology* 22(10): 1268-1274.

Our body as a superorganism

Several trillions

1 billion



100 millions

100 trillions

Our body as a superorganism

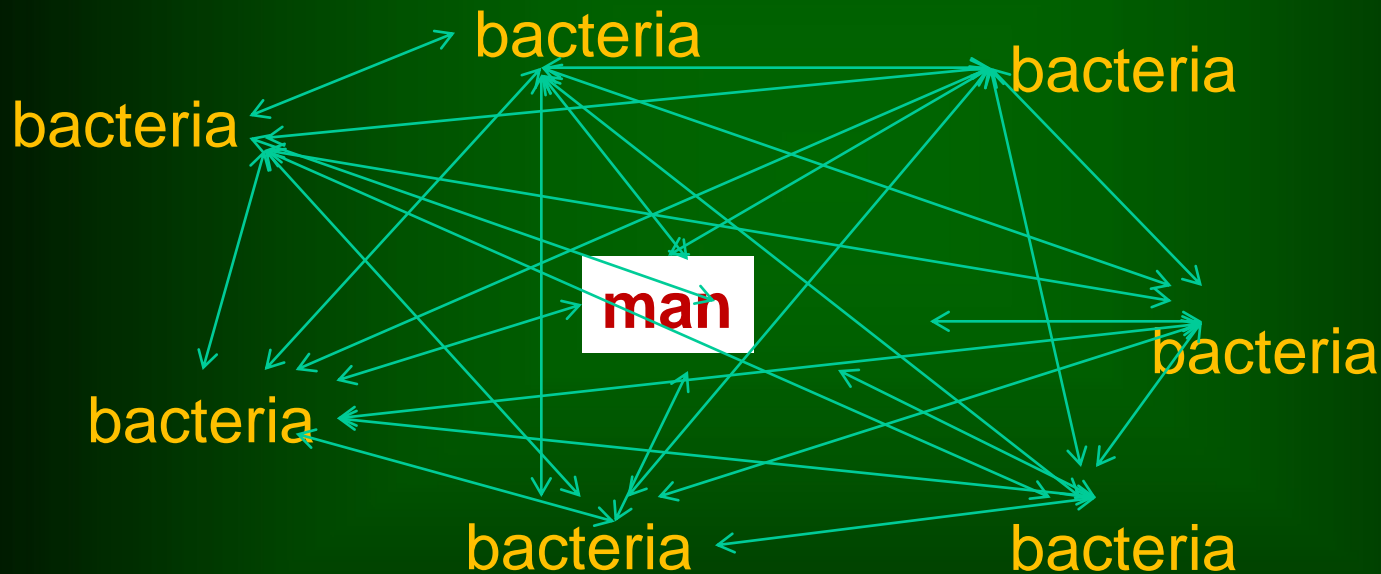


How many kg of my body is intestinal microbiota?

2.0 – 2.5 kg

Our body as a superorganism

„Multidirectional network of relations, through which it is possible to transfer the signal and communication bacteria with bacteria, bacteria with the host, and the host with the bacteria makes the microorganisms together with the host cells form a **comprehensive interactive ecosystem** deciding on a variety of biological processes, including the health or illness”



Hörmannspenger G., Haller D. 2010. Molecular crosstalk of probiotic bacteria with the intestinal immune system: clinical relevance in the context of inflammatory bowel disease. *Int.J.Med. Microbiol* 300, 63–73.

Our body as a superorganism

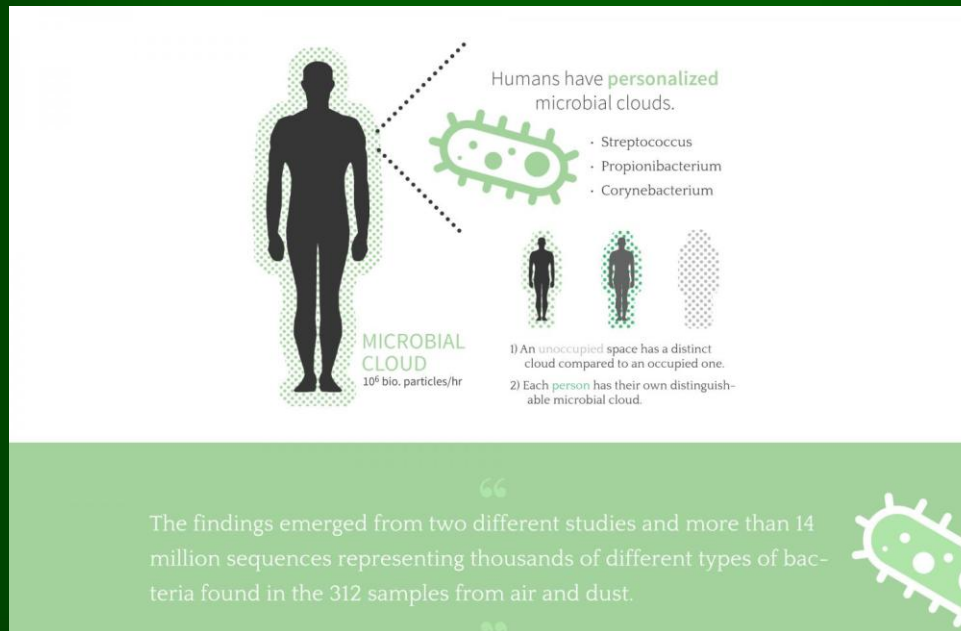
„The universe of microbes that lives in your intestine may be nearly as unique as your fingerprint,,



Stanford Gut Check Shows Diversity Of Intestinal Ecosystem. 2005. ScienceDaily,
<http://www.sciencedaily.com/releases/2005/05/050513101848.htm>

Our body as a superorganism

Humans emit a detectable microbial cloud into surrounding indoor air and we exchange with these symbiotic bacteria.



Meadow J. F., Altrichter A. E., Bateman A. C., Stenson J., Brown G., Green J. L., Bohannan B. J. M. 2015. Humans differ in their personal microbial cloud. PeerJ 3:e1258 <https://dx.doi.org/10.7717/peerj.1258>

Our body as a superorganism

Kiss = microbiome exchange



Meadow J. F., Altrichter A. E., Bateman A. C., Stenson J., Brown G., Green J. L., Bohannan B. J. M. 2015. Humans differ in their personal microbial cloud. PeerJ 3:e1258 <https://dx.doi.org/10.7717/peerj.1258>

Our body as a superorganism

10 seconds kiss = exchange **80 mln** bacteria



Dutch scholars, creators of the Micropia exhibition in Amsterdam

Our body as a superorganism

The Human Microbiome Project

HMP
NIH HUMAN
MICROBIOME
PROJECT

Current News

- January 2015
Metagenome Analysis Workshop
March 3-6
- September 2014
IHMC 2015 from Mar. 31 to Apr. 2
- May 2014
Poster and Booth at ASM 2014

[More News Items](#)

Publications

- Comparative metabolomics in vegans and omnivores reveal constraints on...
- High Frequency of Detection by PCR of Viral Nucleic Acid in The Blood ...
- Inflammation, Antibiotics, and Diet as Environmental Stressors of the ...

[More Publications](#)

OVERVIEW REFERENCE GENOMES MICROBIOME ANALYSIS HEALTH & ETHICS RESOURCES OUTREACH DATA BROWSER

Welcome to the Data Analysis and Coordination Center (DACC) for the National Institutes of Health (NIH) Common Fund supported Human Microbiome Project (HMP). This site is the central repository for all HMP data. The aim of the HMP is to characterize microbial communities found at multiple human body sites and to look for correlations between changes in the microbiome and human health. More information can be found in the menus above and on the NIH Common Fund site.

[GET DATA](#)

[GET TOOLS](#)

Areas of Interest

Outreach
We welcome feedback on all aspects of the HMP, and are soliciting recommendations for microbial reference genomes. Contact us for more information...

A photograph of a dense forest with tall, thin trees and a thick carpet of green ferns and other plants on the forest floor. The scene is captured in a natural, slightly overcast light.

Our body as a superorganism

Hologenome

Our body as a superorganism. Hologenome

„We are an amalgamation of the human and microbial genomes”



Julia Segre, National Human Genome Research Institute

Pennisi E. 2008. Bacteria are picky about their homes on human skin. Science 320 (5879): 1001.

Our body as a superorganism. Hologenome



Gut microbiota – 3.3 mln genes

150 more than „human” genes

Bordenstein S.R., Theis K.R. 2015. Host Biology in Light of the Microbiome: Ten Principles of Holobionts and Hologenomes. PLoS Biol 13(8): e1002226.
doi:10.1371/journal.pbio.1002226

Our body as a superorganism. Hologenome



„The genes of bacteria living in our intestines may be as important to health as our own genome“

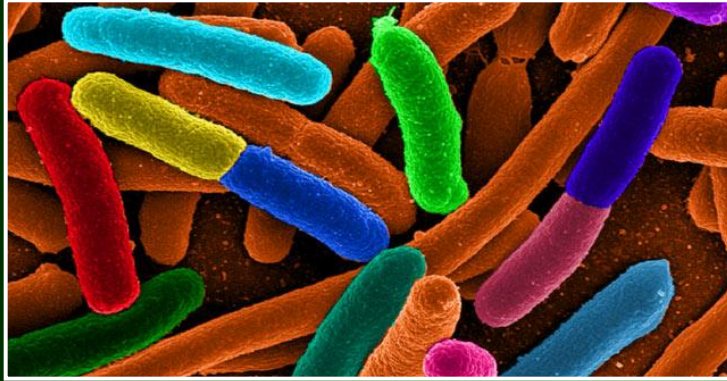
Nicholson J. K., Holmes E., Lindon J. C., Wilson I. D. 2004. The challenges of modeling mammalian biocomplexity. *Nature Biotechnology* 22(10): 1268-1274.

A photograph of a dense forest with tall, thin trees and a thick carpet of green ferns and other plants on the forest floor. The scene is brightly lit, suggesting a sunny day. Two white text boxes are overlaid on the image.

Our body as a superorganism

Mikroorganismy and human health

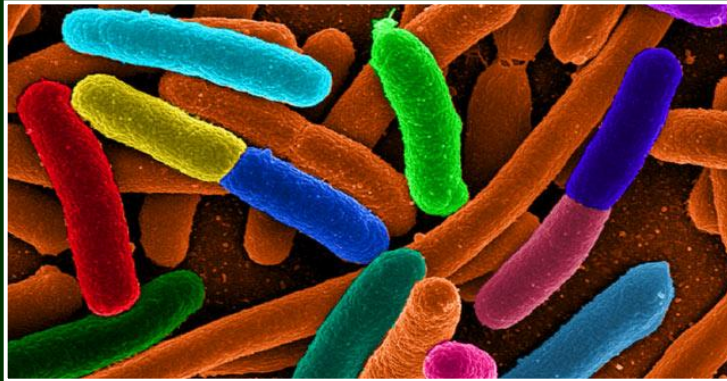
Our body as a superorganism. Mikroorganisms and human health



They are fundamental to nearly all aspect of host form, function, and fitness, including behaviour, sociality.

Bäckhed F., Ley R. E., Sonnenburg J. L., Peterson D. A., Gordon J. I. 2005. Host-bacterial mutualism in the human intestine. *Science* 307:1915-1920.

Our body as a superorganism. Mikroorganisms and human health



We rely on them to aid in nutrition (help body extract energy from food, store is as fat), resist pathogens, and educate our immune system.

Bäckhed F., Ley R. E., Sonnenburg J. L., Peterson D. A., Gordon J. I. 2005. Host-bacterial mutualism in the human intestine. *Science* 307:1915-1920.

Our body as a superorganism. Mikroorganisms and human health

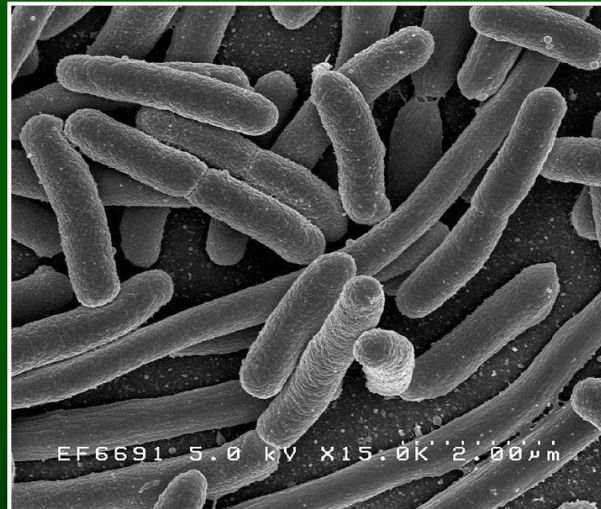
- **Protect against pathogens**
- **Produce vitamins**
- **Stimulate the maturation of the immune system**
- **Regulate metabolism**
- **They help digest and absorb compounds that the human body can not decompose**
- **Regulate bowel motility**
- **Control the level of happiness hormone (serotonin)**
- **They mediate the sending of signals of hunger, thirst and fatigue**
- **They can also break down harmful toxins**
- **Limiting the absorption of harmful cholesterol**

Bäckhed F., Ley R. E., Sonnenburg J. L., Peterson D. A., Gordon J. I. 2005.
Host-bacterial mutualism in the human intestine. *Science* 307:1915-1920.

Our body as a superorganism. Mikroorganisms and human health

Human cells can produce less than **100** carbohydrate-degrading enzymes

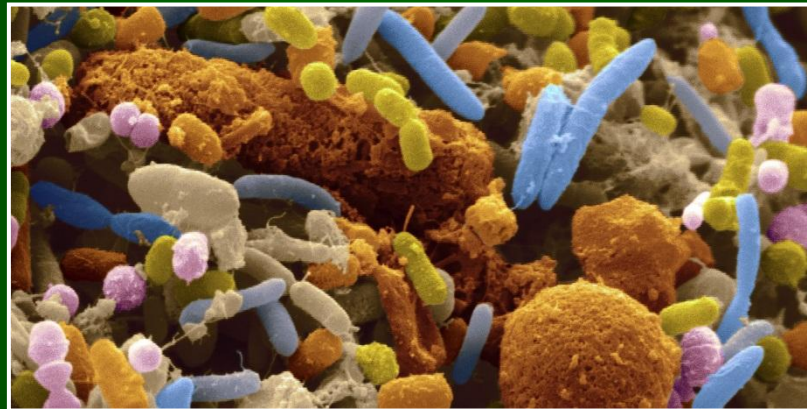
Bacteroides thetaiotaomicron (6% gut microbiota) produces **240** enzymes



Snyder Sachs J. 2008. Good Germs, Bad Germs. Health and Survival in a Bacterial World. Hill & Wang, New York.

Our body as a superorganism. Mikroorganisms and human health

„Symbiotic microbes are fundamental to nearly every aspect of host form, function, and fitness, including in traits that once seemed intangible to microbiology: behavior, sociality, and the origin of species.”



Bordenstein S.R., Theis K.R. 2015. Host Biology in Light of the Microbiome: Ten Principles of Holobionts and Hologenomes. PLoS Biol 13(8): e1002226.
doi:10.1371/journal.pbio.1002226

Our body as a superorganism. Mikroorganisms and human health

HOW GUT BACTERIA AFFECTS THE BRAIN AND BODY

We are more bacteria than we are human. Mounting research has suggested that the bacteria living in our digestive tract play a significant role in our overall health. Here are some of the physical and mental health conditions that have been linked to imbalances in gut flora.

DEPRESSION

More than a third of depression sufferers have "leaky gut," or permeability of the gut lining that allows bacterium to seep out into the bloodstream.

ANXIETY

Prebiotics can have anti-anxiety and antidepressant effects. Consuming beneficial bacteria can also positively change the way the brain responds to the environment.

SCHIZOPHRENIA

Studies in mice have linked a lack of normal gut bacteria with changes in brain development, but the genetics of the disorder are complex and not fully understood.

AUTISM

Autism often co-occurs with gastrointestinal issues like leaky gut or irritable bowel syndrome.

PARKINSON'S DISEASE

People suffering from this disease have different gut bacteria than healthy people.

OBESITY & DIABETES

A number of studies have linked instability in the gut microbiome to obesity and obesity-related health problems.

CROHN'S DISEASE

Abnormally high levels of certain bacteria strains may be present when Crohn's Disease develops, possibly triggering an atypical immune response.

COLON CANCER

Sugar-loving microbes in the gut — along with the carbs that feed them — can fuel colon cancer. High carb-diets may even be contributing to the rise of colon cancer.

ULCERATIVE COLITIS

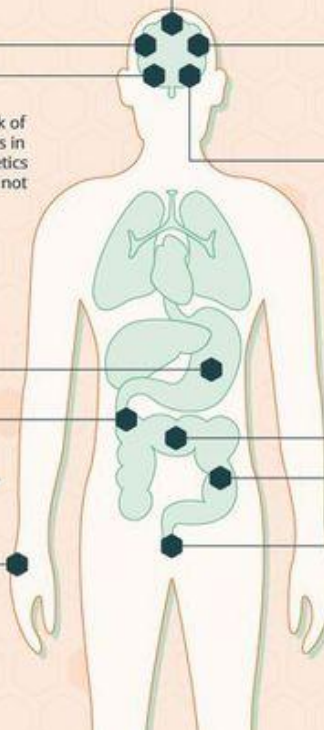
Imbalances in gut flora may be a main factor in both the onset and continuing symptoms of ulcerative colitis.

RHEUMATOID ARTHRITIS

Studies have found a link between low levels of certain good gut bacteria, high levels of unhealthy *Prevotella copri* bacteria, and autoimmune joint disease.

IRRITABLE BOWEL SYNDROME

There is a definitive link between IBS and an overgrowth of bacteria in the small intestines.



A photograph of a dense forest. The foreground is filled with vibrant green ferns and other plants. The middle ground shows a path covered in brown leaves and moss. The background is a thick stand of tall, thin trees with green foliage. The lighting is soft and natural, suggesting a shaded forest environment.

Our body as a superorganism

Gut microbiota – brain and sanity

Our body as a superorganism. Gut microbiota – brain and sanity

Gut microbiota may have a major impact on our state of mind.

Our body as a superorganism. Gut microbiota – brain and sanity

There is a direct link between **anxiety** and **depression** and intestinal bacteria.



The image shows a screenshot of a web page from Nature Communications. At the top, there is a logo for "nature COMMUNICATIONS" with a stylized orange and yellow wave graphic. Below the logo is a navigation bar with buttons for "Home", "About the journal", "Authors and referees", "Browse archive", and "Search". A breadcrumb trail reads "nature.com > journal home > archive by date > july > abstract". The main content area is titled "ARTICLE PREVIEW" and includes a link to "view full access options". Below this, the text "NATURE COMMUNICATIONS | ARTICLE" is displayed. The article title is "Microbiota and host determinants of behavioural phenotype in maternally separated mice". The authors listed are G. De Palma, P. Blennerhassett, J. Lu, Y. Deng, A. J. Park, W. Green, E. Denou, M. A. Silva, A. Santacruz, Y. Sanz, M. G. Surette, E. F. Verdu, S. M. Collins & P. Bercik. There are also icons for sharing and printing.

De Palma G., Blennerhassett P., Deng J. Lu, Y., Park A. J., Green W., Denou E., Silva M. A., Santacruz A., Sanz Y., Surette M. G., Verdu E. F., Collins S. M., Bercik P. 2015. Microbiota and host determinants of behavioural phenotype in maternally separated mice. Nature Communications 6: 7735 DOI: [10.1038/ncomms8735](https://doi.org/10.1038/ncomms8735)

Our body as a superorganism. Gut microbiota – brain and sanity

People who are infected with *Escherichia coli* and *Campylobacter jejuni* (causing severe gastroenteritis) are characterized by depression and anxiety disorders.

Ford A. C., Thabane M., Collins S. M. et al. 2010. Prevalence of uninvestigated dyspepsia 8 years after a large waterborne outbreak of bacterial dysentery: a cohort study. *Gastroenterology* 138:1727–1736.

Our body as a superorganism. Gut microbiota – brain and sanity

Naturally timid and shy mice became daring and exploratory after transplantation of intestinal bacteria from probiotically disposed mice.

Diaz Heijtz R., Wang S., Anuar F., Qian Y., Björkholm B., Samuelsson A., et al. 2011. Normal gut microbiota modulates brain development and behaviour. Proc. Natl. Acad. Sci. U.S.A. 108(7): 3047-3052.

Our body as a superorganism. Gut microbiota – brain and sanity

Mice born of caesarean section - symptoms of depression

Reason



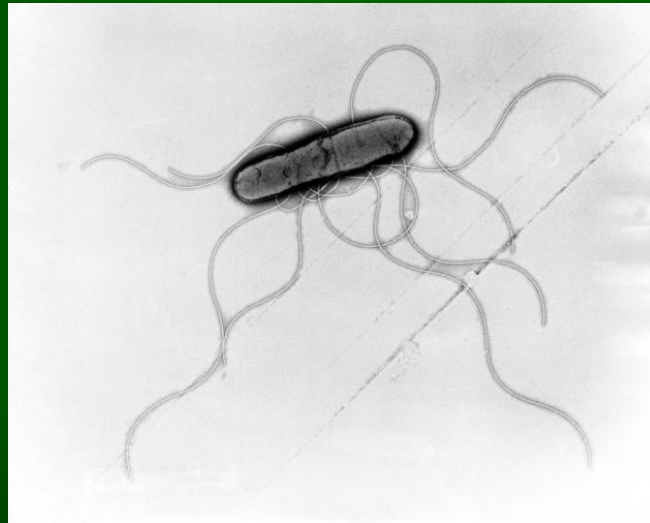
Deprivation of the possibility of taking the bacteria from the mother during childbirth

Reardon S. 2014. Gut–brain link grabs neuroscientists. *Nature* 515: 175-177.
doi:10.1038/515175a

Our body as a superorganism. Gut microbiota – brain and sanity

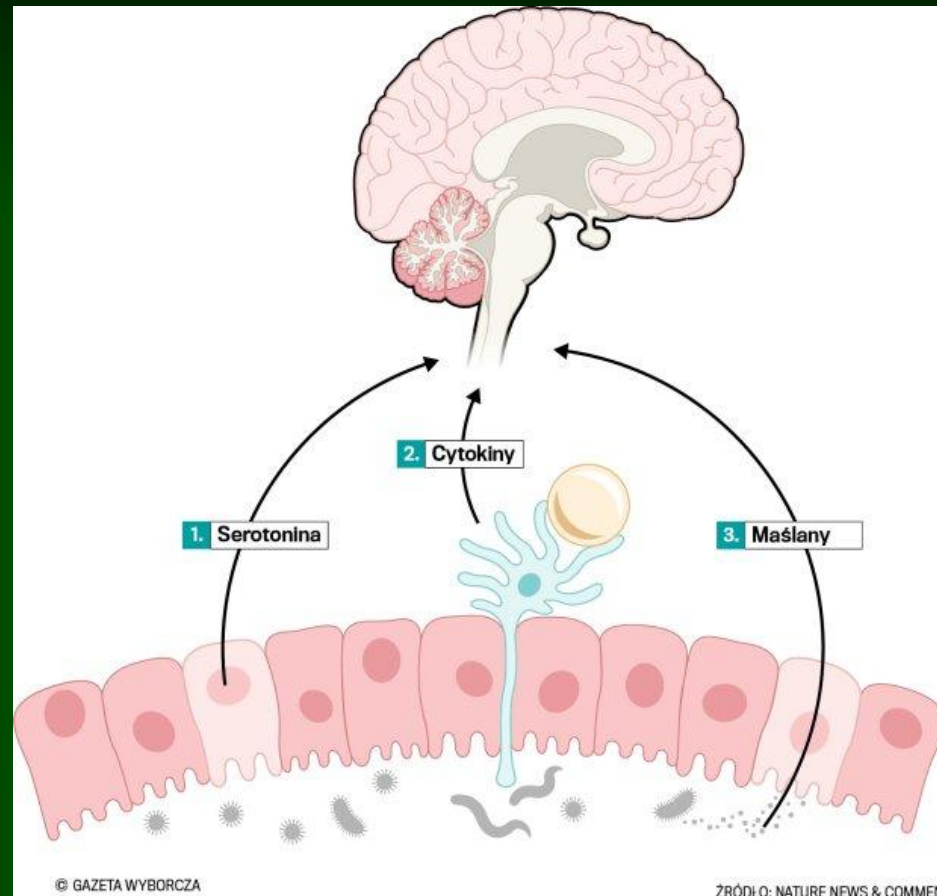
Mice suffering with autism-like symptoms – lower number of gut bacteria *Bacteroides fragilis*.

Feeding with *Bacteroides fragilis* – reverses the symptoms.



Hsiao E. Y., McBride S. W., Hsien S., Sharon G., Hyde E. R., McCue T., Codelli J. A., Chow J., Reisman S. E., Petrisino J. F., Patterson P. H., Mazmanian S. K. 2013. Microbiota Modulate Behavioral and Physiological Abnormalities Associated with Neurodevelopmental Disorders. *Cell* 155(7):1451-63. doi: 10.1016/j.cell.2013.11.024.

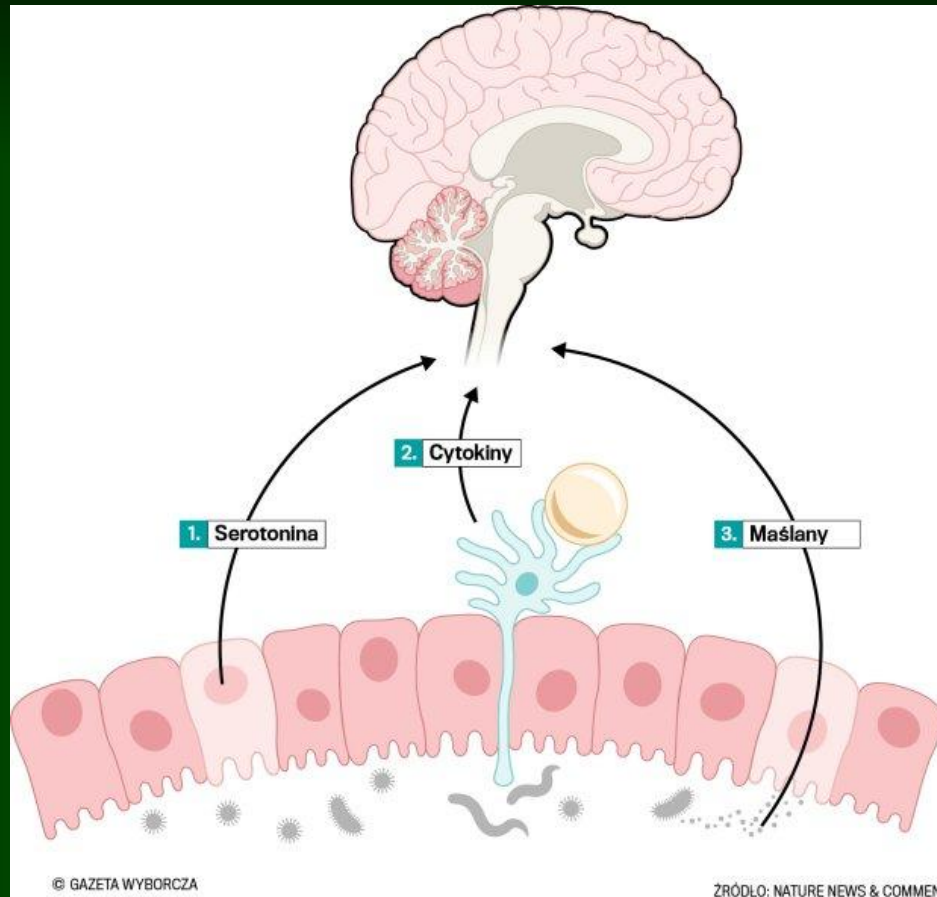
Our body as a superorganism. Gut microbiota – brain and sanity



1. Bacteria in the intestines produce **serotonin (the hormone of happiness) that affects the communication of cells in the brain.**

Diaz Heijtz R., Wang S., Anuar F., Qian Y., Björkholm B., Samuelsson A., et al. 2011. Normal gut microbiota modulates brain development and behaviour. Proc. Natl. Acad. Sci. U.S.A. 108(7): 3047-3052.

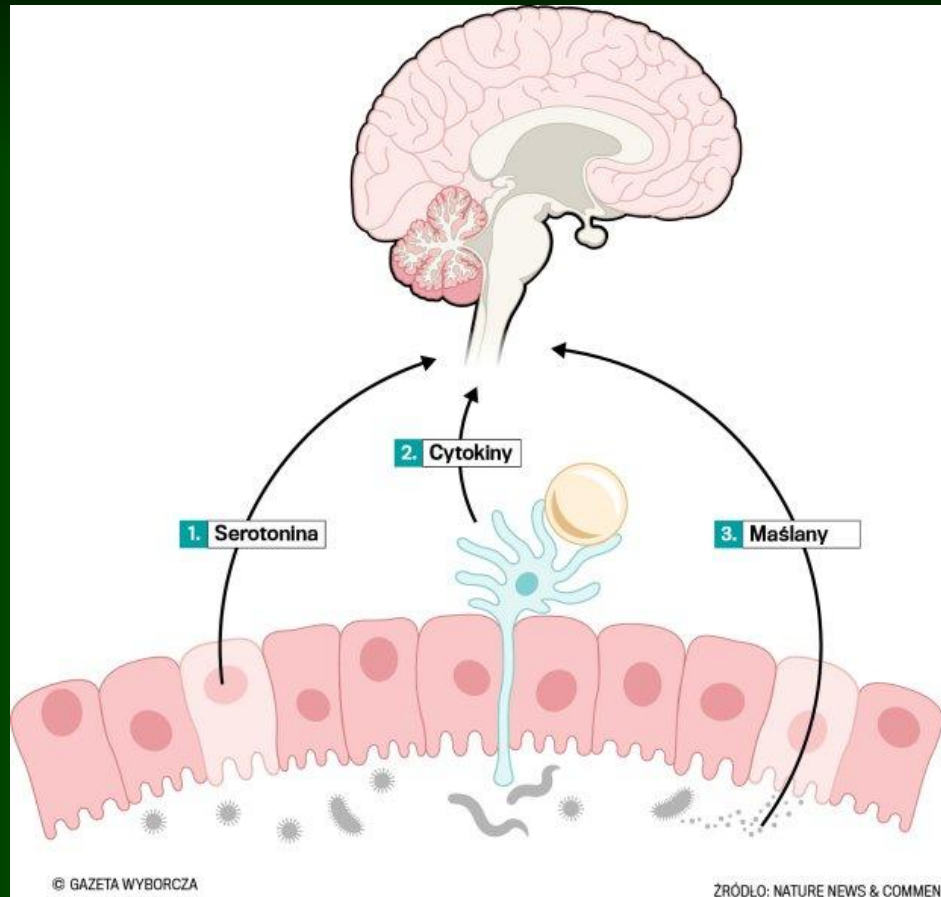
Our body as a superorganism. Gut microbiota – brain and sanity



2. Microbes stimulate the immune system to produce **cytokines (inflammatory proteins). This affects the physiology of the brain.**

Diaz Heijtz R., Wang S., Anuar F., Qian Y., Björkholm B., Samuelsson A., et al. 2011. Normal gut microbiota modulates brain development and behaviour. Proc. Natl. Acad. Sci. U.S.A. 108(7): 3047-3052.

Our body as a superorganism. Gut microbiota – brain and sanity



3. The products of metabolism produced by bacteria (e.g. **butyrate) affect the activity of cells in the blood-brain barrier.**

Diaz Heijtz R., Wang S., Anuar F., Qian Y., Björkholm B., Samuelsson A., et al. 2011. Normal gut microbiota modulates brain development and behaviour. Proc. Natl. Acad. Sci. U.S.A. 108(7): 3047-3052.

Our body as a superorganism. Gut microbiota – brain and sanity

Probiotics and the human brain

Women (healthy) – for one month yogurt was given twice a day



Weak reaction of areas of the brain responsible for emotional reactions

Better mood, better memory, more cognitive ability

Tillisch K., Labus J., Kilpatrick L., Jiang Z., Stains J., Ebrat B., Guyonnet D., Legrain–Raspaud S., Trotin S., Naliboff B., Mayer E. A. Consumption of Fermented Milk Product With Probiotic Modulates Brain Activity. *Gastroenterology* 144 (7): 1394–1401.e4;

DOI: <http://dx.doi.org/10.1053/j.gastro.2013.02.043>

Our body as a superorganism. Gut microbiota – brain and sanity

"Studies show that bacteria in our intestines actually affect how we interpret the world."

Emeran A. Mayer

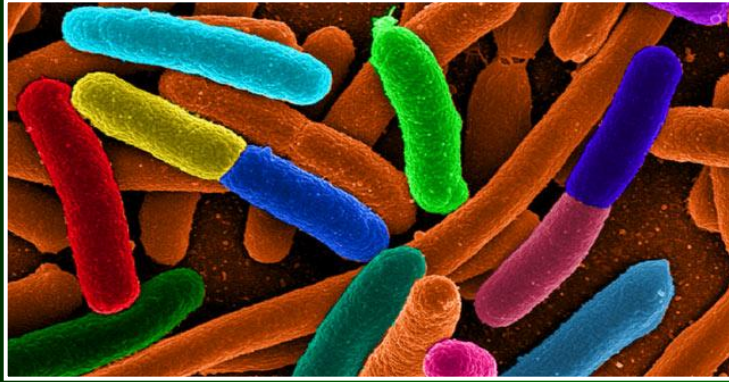
Tillisch K., Labus J., Kilpatrick L., Jiang Z., Stains J., Ebrat B., Guyonnet D., Legrain–Raspaud S., Trotin S., Naliboff B., Mayer E. A. Consumption of Fermented Milk Product With Probiotic Modulates Brain Activity. *Gastroenterology* 144 (7): 1394–1401.e4;
DOI: <http://dx.doi.org/10.1053/j.gastro.2013.02.043>

A photograph of a dense forest with tall, thin trees and a thick carpet of green ferns and other plants on the forest floor. The lighting is soft, suggesting a shaded woodland environment.

Our body as a superorganism

Intestinal microbiota as our partner

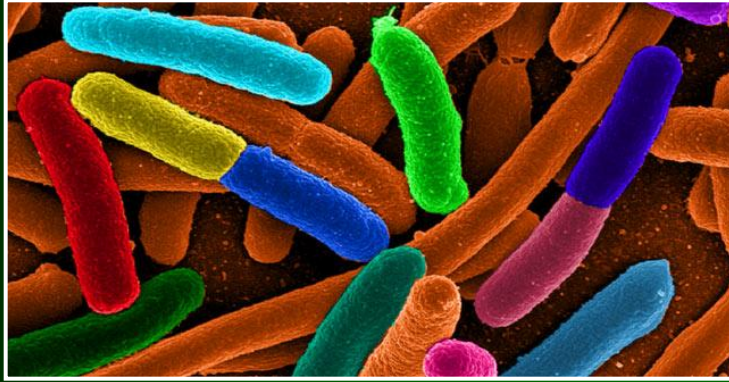
Our body as a superorganism. Intestinal microbiota as our partner



"Intestinal microbiota is not our enemy, but a partner that is useful and of which we are totally dependent"

Olivier Goulet, Gut Microbiota for Health 1st World Summit, marzec 2012

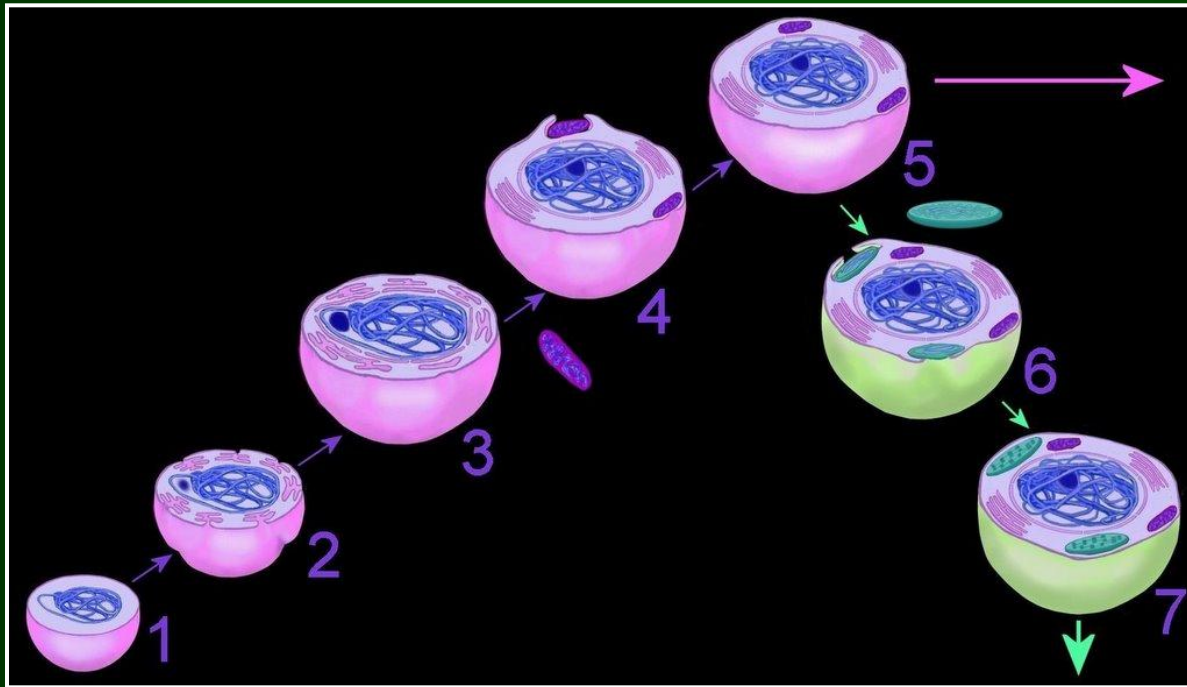
Our body as a superorganism. Intestinal microbiota as our partner



This "strategic alliance", a unique symbiosis of mammals and bacteria, has been going on for millions of years and is a guarantee of continued existence.

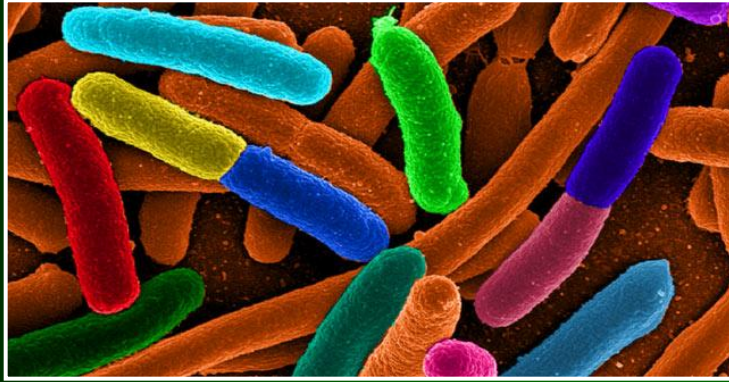
Our body as a superorganism. Intestinal microbiota as our partner

Serial Endosymbiotic Theory (SET)



Margulis L. 1981. Symbiosis in Cell Evolution, 1st Edition. Freeman, New York.

Our body as a superorganism. Intestinal microbiota as our partner



"This makes us more microbe than man,,

Homo bacterius ?

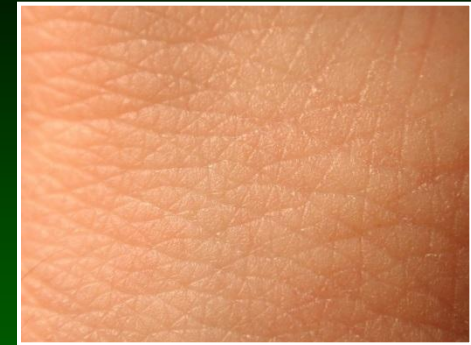
Jeffrey Gordon, director of the Center for Genome Sciences at Washington University School of Medicine in St. Louis.

A photograph of a dense forest with tall, thin trees and a thick carpet of green ferns and other plants on the forest floor. The lighting is soft and natural, suggesting a shaded woodland environment.

Our body as a superorganism

Skin

Our body as a superorganism. Skin



NIH National Human Genome Research Institute
Advancing human health through genomics research

SEARCH GEN


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- Sood Group


Julie Segre, Ph.D.



Chief & Senior Investigator
[Translational and Functional Genomics Branch](#)

Head
Microbial Genomics Section

B.A. Amherst College, 1987
Ph.D. Massachusetts Institute of Technology, 1996

 **NIH Public Access**
Author Manuscript
Nat Rev Microbiol. Author manuscript; available in PMC 2013 January 03.

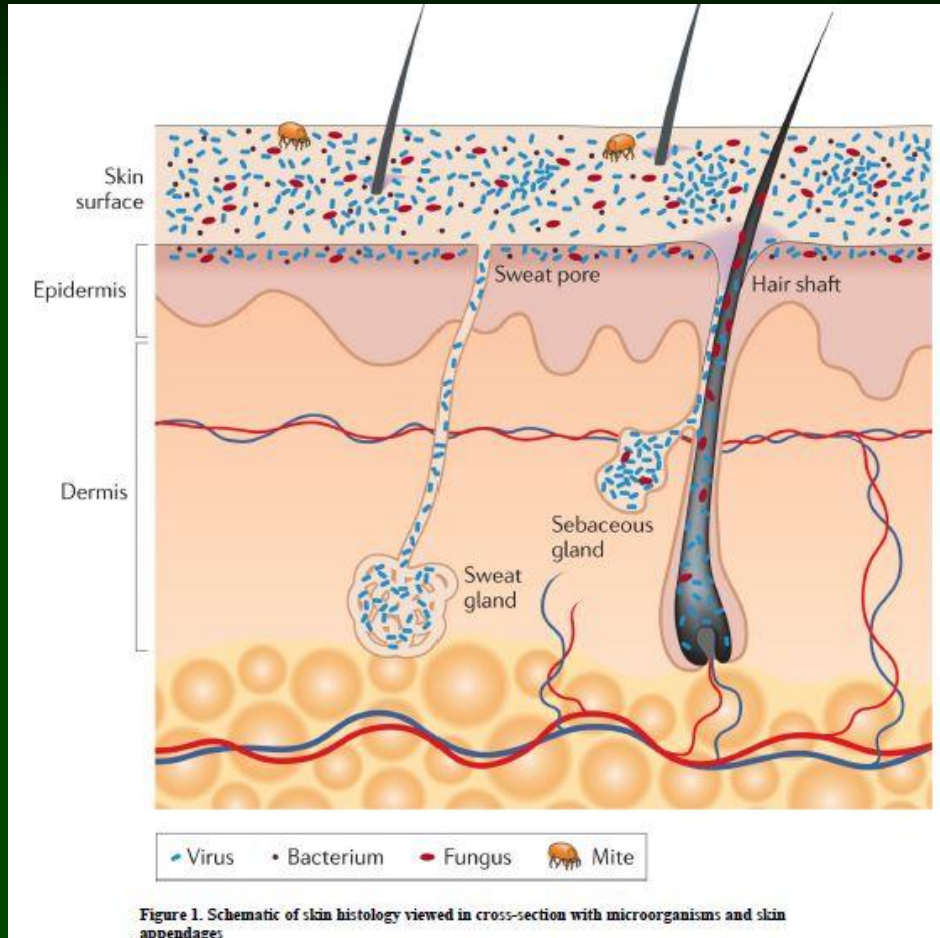
Published in final edited form as:
Nat Rev Microbiol. 2011 April ; 9(4): 244-253. doi:10.1038/nrmicro2537.

The skin microbiome

Elizabeth A. Grice and Julia A. Segre
Genetics and Molecular Biology Branch, National Human Genome Research Institute, National Institutes of Health, Bethesda, Maryland, 20892-4442, USA.

NIH

Our body as a superorganism. Skin



Skin is composed of diverse habitats: bacteria, fungi, viruses and mites.

Our body as a superorganism. Skin



Skin – the human body's largest organ (1.8 m²)

Grice E. A., Segre J. A. 2011. The skin microbiome. *Nature Reviews Microbiology* 9: 244-253.

Our body as a superorganism. Skin



Skin of a man : 500 – 1000 species

Pennisi E. 2008. Bacteria are picky about their homes on human skin. *Science* 320 (5879): 1001.

Our body as a superorganism. Skin



Skin of a man – several billions of bacteria

1 cm² of skin – 1 milion bacteria

Srinivas G., Möller S., Wang J., Künzel S., Zillikens D., Baines J. F., Ibrahim S. M. 2013. Genome-wide mapping of gene–microbiota interactions in susceptibility to autoimmune skin blistering. *Nature Communications*; 4.

Our body as a superorganism. Skin



Most of these microorganisms are symbiotic and protect against invasion by more pathogenic or harmful organisms.

Pennisi E. 2008. Bacteria are picky about their homes on human skin. *Science* 320 (5879): 1001.

Our body as a superorganism. Skin



Small variation of microbiota on the skin surface - increased susceptibility to atopic dermatitis (AD).

Srinivas G., Möller S., Wang J., Künzel S., Zillikens D., Baines J. F., Ibrahim S. M. 2013. Genome-wide mapping of gene–microbiota interactions in susceptibility to autoimmune skin blistering. *Nature Communications*; 4.

Our body as a superorganism. Skin



Dandruff - the effect of disturbed balance of skin microbiota

Skin without dandruff

Propionibacterium (71%)
Staphylococci (26%)

Skin with dandruff

Propionibacterium (50%)
Staphylococci (44%)

Xu et al. 2016. Dandruff is associated with the conjoined interactions between host and microorganisms. Scientific Reports 9, Article number: 24877, doi:10.1038/srep24877

Our body as a superorganism. Skin



How improper composition of microbes is conducive to disease?

Bacteria and fungi – modulate the response of the immune system

Frank D. N., Feazel L. M., Bessesen M. T., Price C. S., Janoff E. N., Pace N. R.
2010. The Human Nasal Microbiota and *Staphylococcus aureus* Carriage. PLoS
ONE 5(5): e10598. doi:10.1371/journal.pone.0010598

Our body as a superorganism. Skin

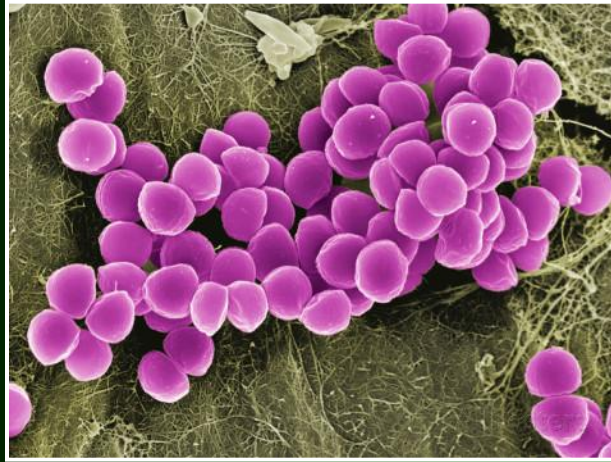


Skin bacteria – known mostly from soils

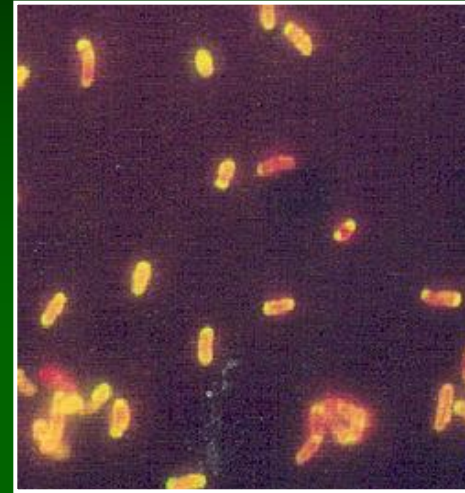
Skin bacteria – mostly beneficial to us

Pennisi E. 2008. Bacteria are picky about their homes on human skin. *Science* 320 (5879): 1001.

Our body as a superorganism. Skin



Staphylococcus sp.

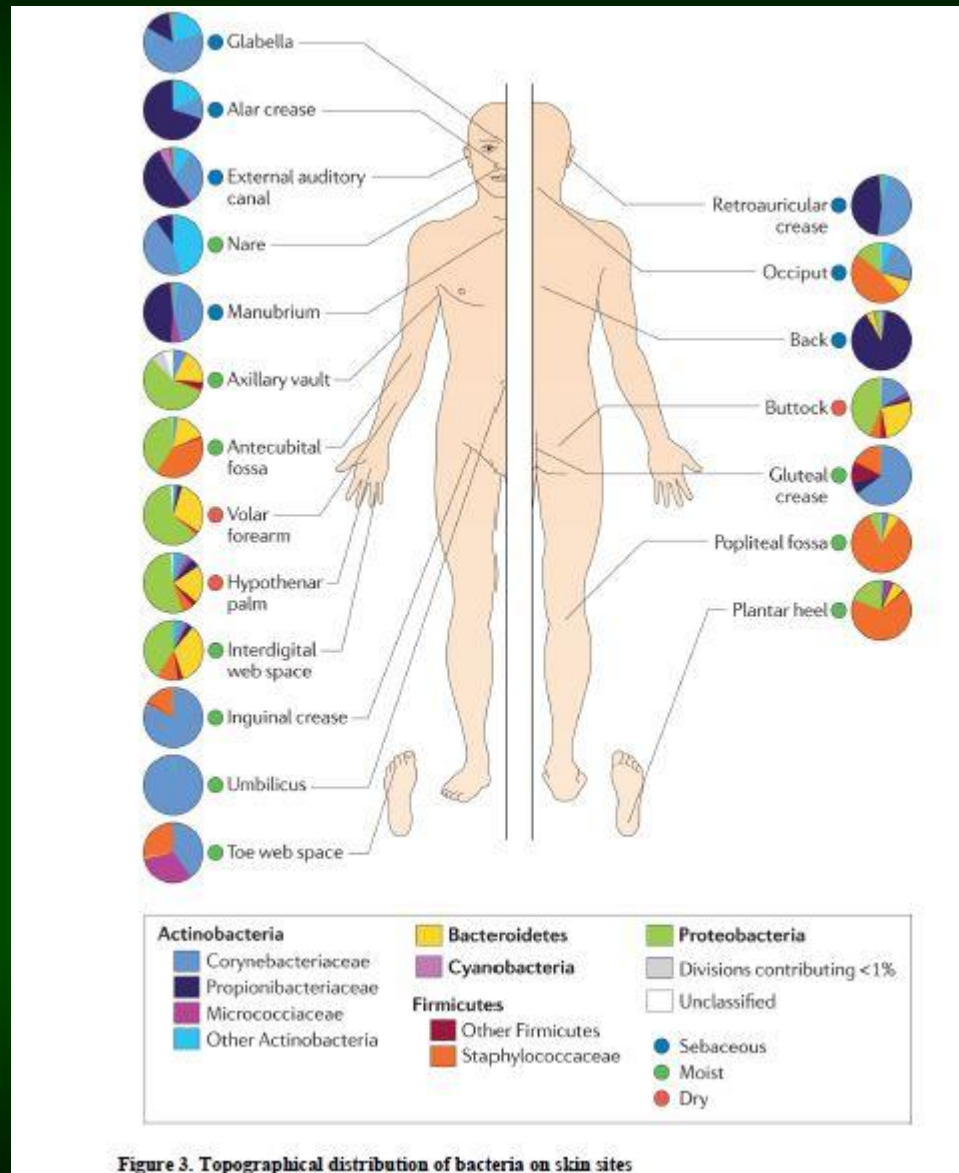


Propionicacterium sp.

Dominant bacteria in skin microbiota

Grice E. A., Segre J. A. 2011. The skin microbiome. Nature Reviews Microbiology 9: 244-253

Our body as a superorganism. Skin



Our body as a superorganism. Skin

The most rich region of our skin?



Our body as a superorganism. Skin

Forearm



~ **44** species

Pennisi E. 2008. Bacteria are picky about their homes on human skin. *Science* 320 (5879): 1001.

Our body as a superorganism. Skin

The most barren region of our skin?



Our body as a superorganism. Skin

behind the ear



~ **15** species

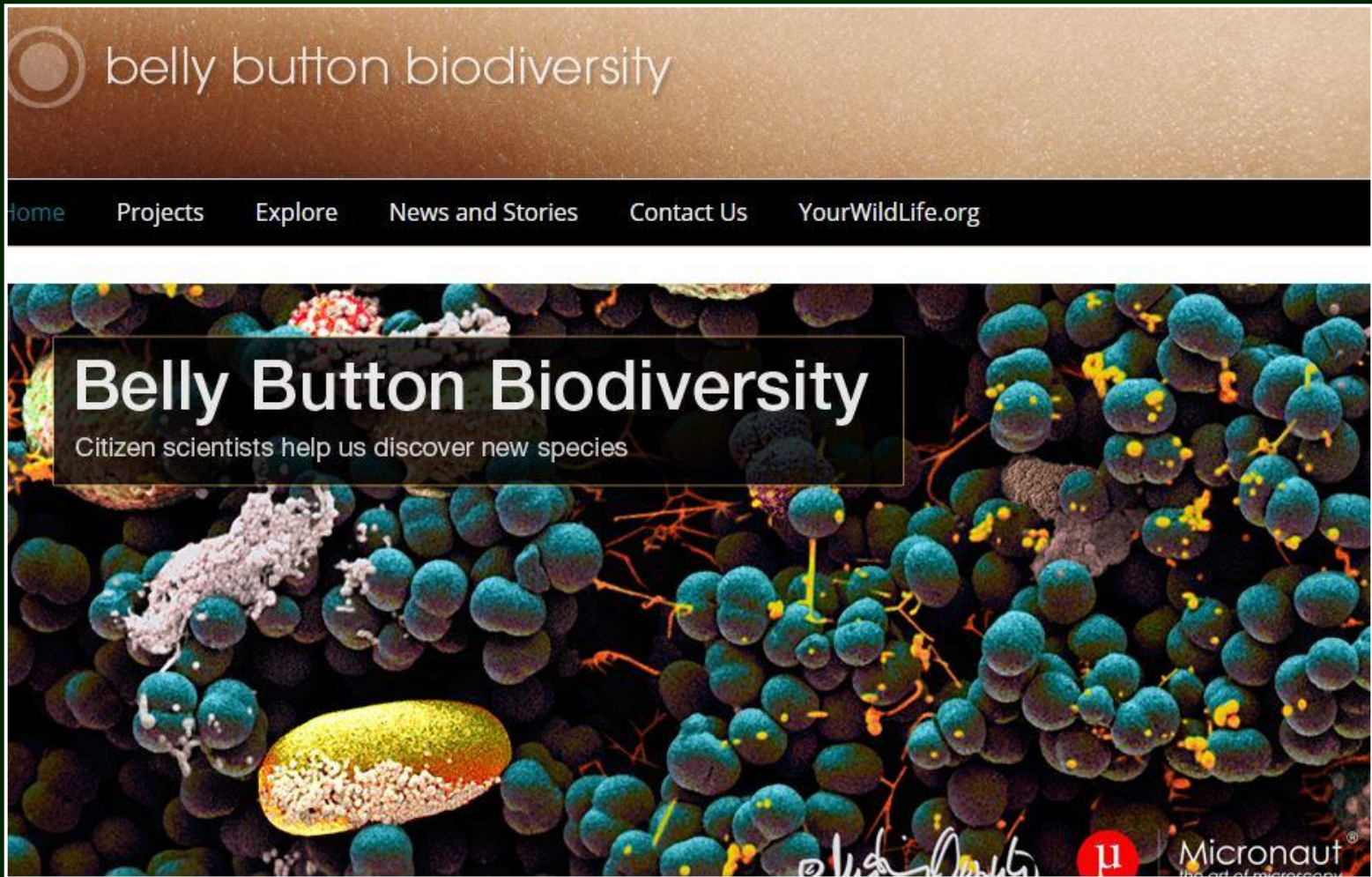
Pennisi E. 2008. Bacteria are picky about their homes on human skin. *Science* 320 (5879): 1001.

A photograph of a dense forest with tall, thin trees and a thick carpet of green ferns and other plants on the forest floor. The scene is brightly lit, suggesting a sunny day.

Our body as a superorganism

Belly button

Our body as a superorganism. Belly button



<http://navels.yourwildlife.org/>

<http://navels.yourwildlife.org/>

Our body as a superorganism. Belly button



Hulcr, J., Latimer, A. M., Henley, J. B., Rountree, N. R.** , Fierer, N., Lucky, A., Lowman, M. D., Dunn RR 2012. **A jungle** in there: bacteria in belly buttons are highly diverse, but predictable. *PLoS ONE* 7(11): e47712. doi:10.1371/journal.pone.0047712

Our body as a superorganism. Belly button



2 years of study – 500 volunteers – 2368 species of bacteria

1458 species new for science



Hulcr, J., Latimer, A. M., Henley, J. B., Rountree, N. R.** , Fierer, N., Lucky, A., Lowman, M. D.,
Dunn RR 2012. **A jungle** in there: bacteria in belly buttons are highly diverse, but predictable. *PLoS ONE* 7(11): e47712. doi:10.1371/journal.pone.0047712

Our body as a superorganism. Belly button



67 (29-107) species / belly button

6 species were present in > 80% belly buttons

Hulcr, J., Latimer, A. M., Henley, J. B., Rountree, N. R.** , Fierer, N., Lucky, A., Lowman, M. D., Dunn RR 2012. **A jungle** in there: bacteria in belly buttons are highly diverse, but predictable. *PLoS ONE* 7(11): e47712. doi:10.1371/journal.pone.0047712

Our body as a superorganism. Belly button



Each navel - a unique composition of bacteria (fingerprint)

- bacteria previously been found only in soil from Japan
- Archaea (typically thrive in ice caps and thermal vents)

Hulcr, J., Latimer, A. M., Henley, J. B., Rountree, N. R.** , Fierer, N., Lucky, A., Lowman, M. D., Dunn RR 2012. **A jungle** in there: bacteria in belly buttons are highly diverse, but predictable. *PLoS ONE* 7(11): e47712. doi:10.1371/journal.pone.0047712

A photograph of a dense forest with tall, thin trees and a thick carpet of green ferns and other plants on the forest floor. The scene is captured from a low angle, looking slightly up at the trees.

Our body as a superorganism

Nose

Our body as a superorganism. Nose

Nose



„Most of our skin is like an arid desert. But as you walk through this desert you encounter an oasis, which is the inside of your nose. You encounter a stream, which is a moist crease. [These] areas are like habitats rich in diversity”

Julia Segre, National Human Genome
Research Institute in Bethesda, Maryland

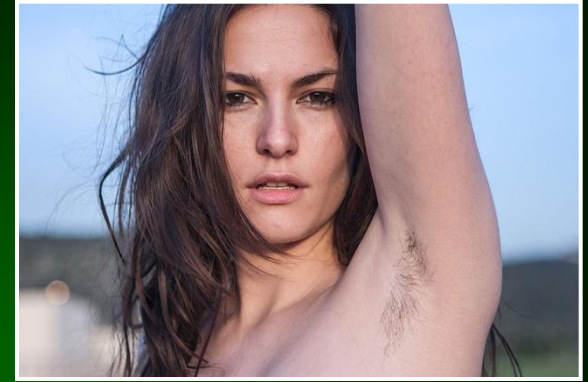
Brian Handwerk for National Geographic News. Armpits Are "Rain Forests" for Bacteria, Skin Map Shows. May 28, 2009, <http://news.nationalgeographic.com/news/2009/05/090528-armpits-bacteria-rainforests.html>

A photograph of a dense forest with tall, thin trees and a thick carpet of green ferns and other plants on the forest floor. The scene is brightly lit, suggesting a sunny day. The text is overlaid on the image in white boxes.

Our body as a superorganism

Armpit

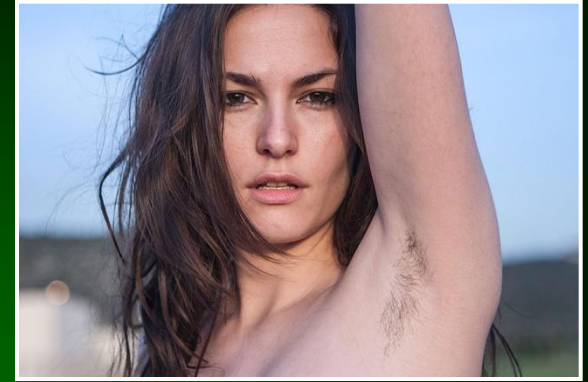
Our body as a superorganism. Armpit



„Armpits are „rain forests” for bacteria”

Brian Handwerk for National Geographic News. Armpits Are "**Rain Forests**" for Bacteria, Skin Map Shows. May 28, 2009, <http://news.nationalgeographic.com/news/2009/05/090528-armpits-bacteria-rainforests.html>

Our body as a superorganism. Armpit



„The bacteria in my underarm are more similar to those in your underarm than they are to those on my forearm”

Julia Segre, National Human Genome
Research Institute in Bethesda, Maryland

Brian Handwerk for National Geographic News. Armpits Are "**Rain Forests**" for Bacteria, Skin Map Shows. May 28, 2009, <http://news.nationalgeographic.com/news/2009/05/090528-armpits-bacteria-rainforests.html>

A photograph of a dense forest with tall, thin trees and a thick carpet of green ferns and other plants on the forest floor. The scene is brightly lit, suggesting a sunny day.

Our body as a superorganism

Microbiophobia

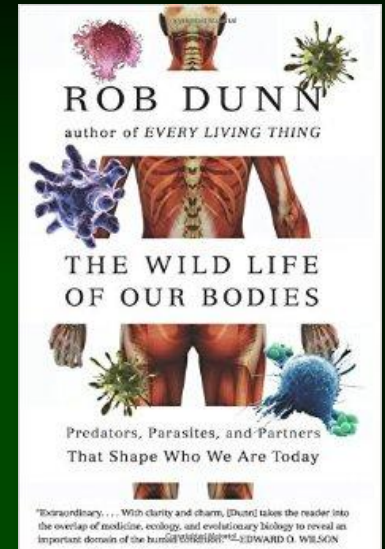
Our body as a superorganism. Microbiophobia

„People are eating probiotic yougurts to promote (beneficial) bacteria growth, but we want to sterilize the skin”



Grice E. A., Segre J. A. 2011. The skin microbiome. Nature Reviews Microbiology 9: 244-253

Our body as a superorganism. Microbiophobia



„75 percent of us use at least some *antimicrobial* substance in our house”

„... when they used the *antibiotic soaps*, they were actually more likely to get sick than if they didn't use any soap at all”

Rob Dunn. 2011. The Wildlife of Our Bodies: Predators, Parasities and Partners That Shape Who We are Today. *HarperCollins Publishers.*

Our body as a superorganism. Microbiophobia

Instead of suffering from microbiophobia, we should accept that we live in the ocean of microorganisms.



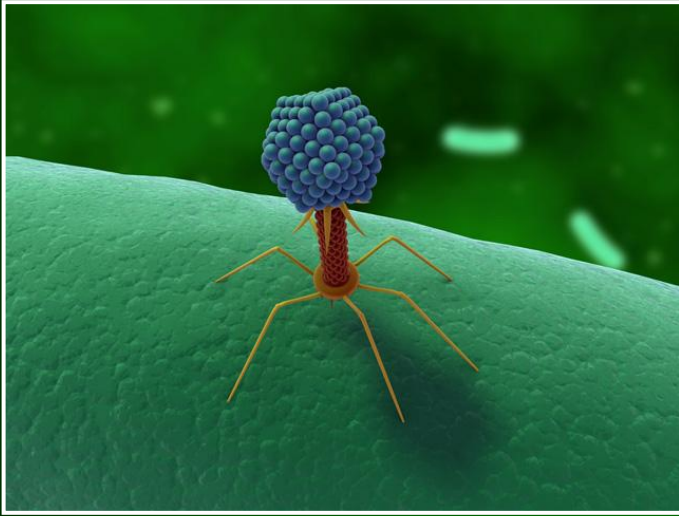
Seth Bordenstein, University
Vanderbilt, Nashville

Bordenstein S.R., Theis K.R. 2015. Host Biology in Light of the Microbiome: Ten Principles of Holobionts and Hologenomes. PLoS Biol 13(8): e1002226.
doi:10.1371/journal.pbio.1002226

A photograph of a dense forest. The scene is filled with tall, slender trees, likely spruce or fir, with green needles. The forest floor is covered in a thick layer of green ferns and other undergrowth. The lighting is soft and diffused, suggesting a canopy overhead. A white rectangular box is superimposed over the middle of the image, containing the text 'Bacteriophages and human body'.

Bacteriophages and human body

Bacteriophages and human body



1 000 000 000 000 000 000 000 = 10^{18}

1000 tryllions

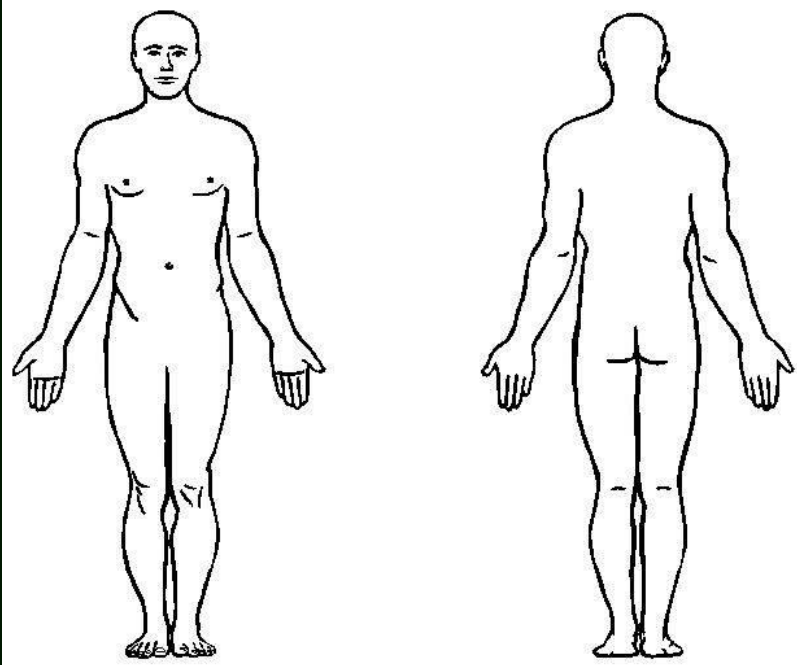
Aziz R.K. 2009. A hundred-year-old insight into the gut microbiome. Gut. Pathog 1: 21.

A lush forest scene with tall trees and dense undergrowth. The forest is filled with various types of trees, including tall, thin trunks and some with moss. The ground is covered in green ferns and other plants. The overall atmosphere is vibrant and natural.

Fungi and human body

Fungi and human body

Atlas of human fungi



Fungi and human body

Atlas of human fungi

130 species of fungi

Malessezia

Rhodotorula

Debaromyces

Cryptococcus

Candida

Penicillium

Aspergillus

Alternaria

Chaetomium

Chrysosporium

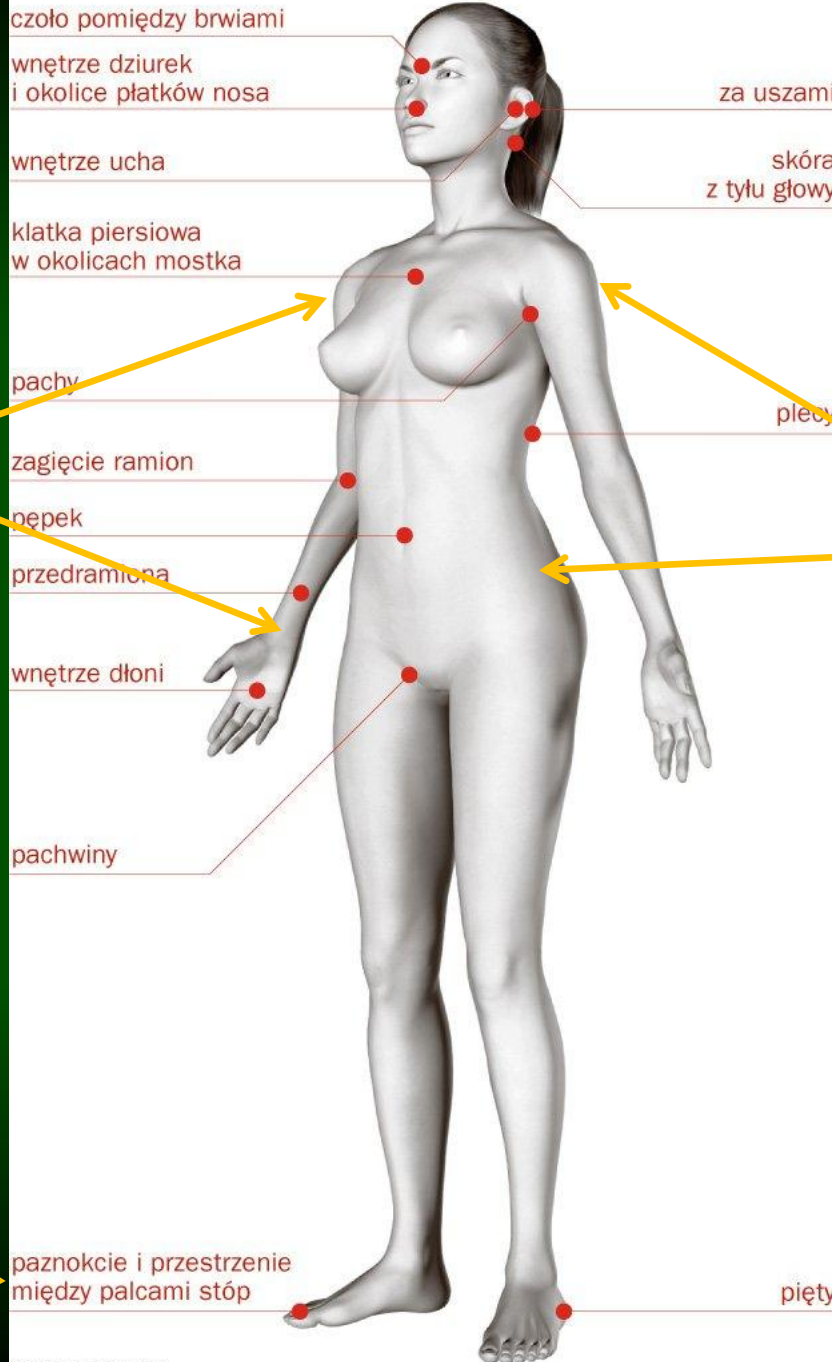
Cladosporium

Mucor

Trichophyton

Atlas of human fungi

130 species of fungi



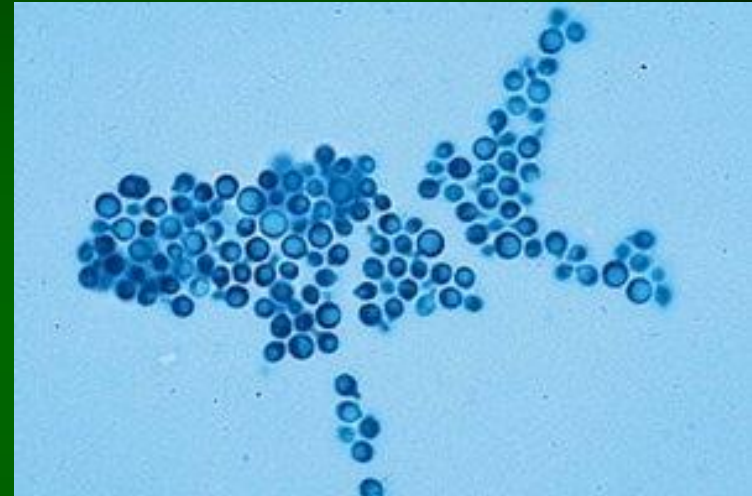
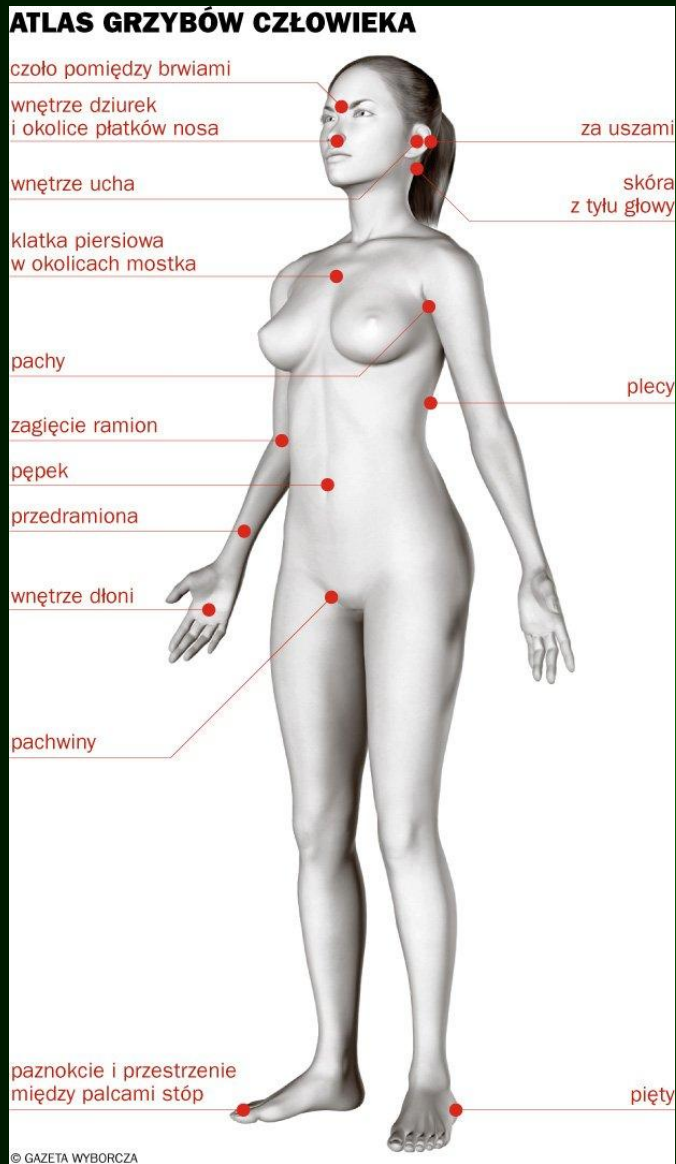
18-32 species (arms)

2-10 species (torso)

40-60 species (nails and the spaces between the toes)

80 species (heel)

Fungi and human body

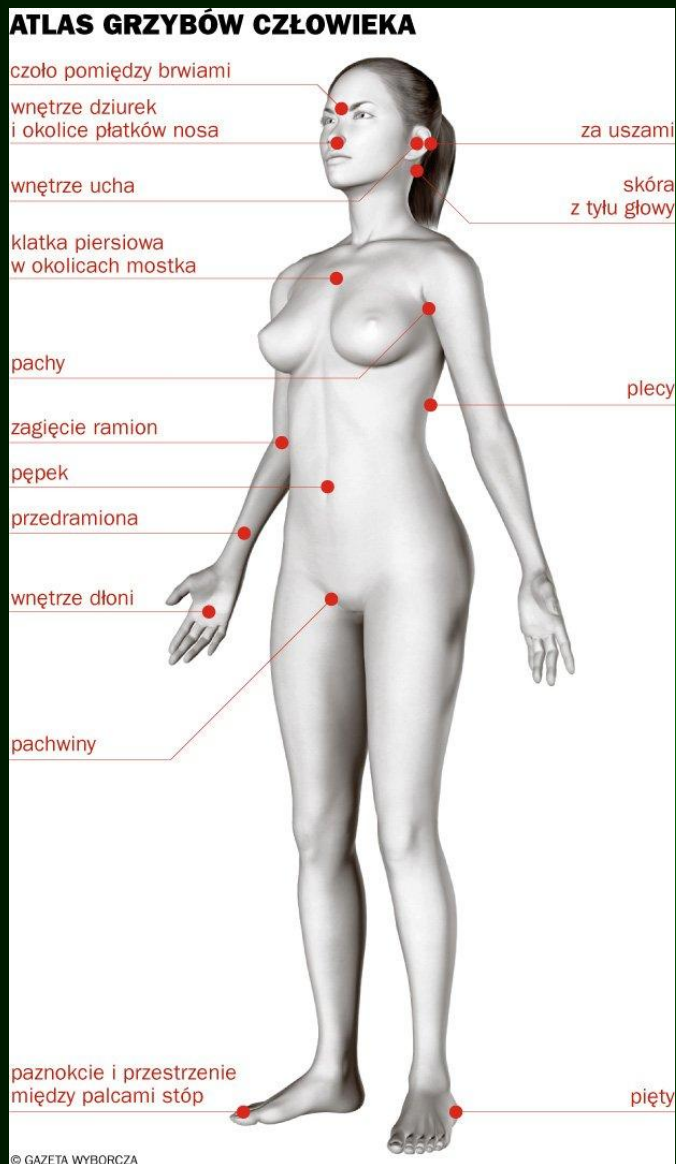


Malassezia globosa

Findley K. et al. 2013. Topographic diversity of fungal and bacterial communities in human skin. Nature (22 May 2013) doi:10.1038/nature12171

http://www.reviberoammicol.com/photo_gallery/Malassezia/globosa/

Fungi and human body



Fungi play major roles in human health and disease.

- protect humans from invasion by pathogenic microorganisms

- provide a home for diverse commensal microbiota.

Findley K. et al. 2013. Topographic diversity of fungal and bacterial communities in human skin. *Nature* (22 May 2013) doi:10.1038/nature12171

http://upload.wikimedia.org/wikipedia/commons/a/a2/Trichophyton_rubrum_var_rodhaini.jpg

A photograph of a dense forest with tall, thin trees and a thick carpet of green ferns and other plants on the forest floor. The scene is brightly lit, suggesting a sunny day. A white rectangular box is overlaid on the center of the image, containing the text 'Parasites and human body'.

Parasites and human body

Parasites and human body

In the last 50 years we have started to rid ourselves of worms and autoimmune diseases have started to become more common.



In the absence of worms, our immune system can be kind of over-reactive.

Dunn R. 2011. *The Wildlife of Our Bodies: Predators, Parasities and Partners That Shape Who We are Today*. HarperCollins Publishers.

Parasites and human body

Allergies, asthma, intestinal inflammation (Crohn's disease), psoriasis, rheumatoid arthritis, multiple sclerosis



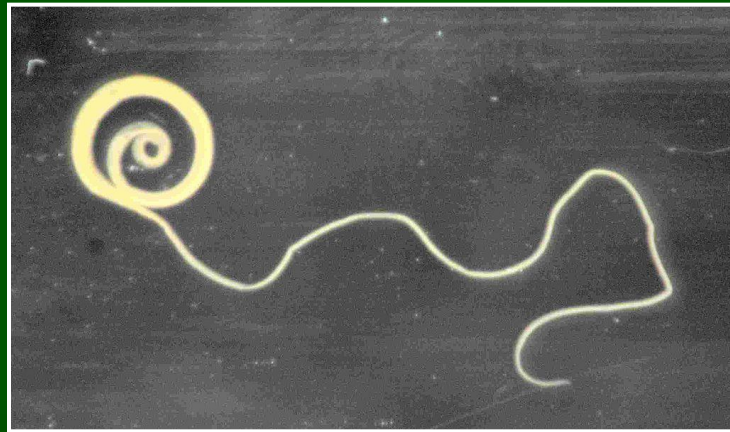
David Pritchard
(parasitologist, University of Nottingham)

„Parasites can cure people who suffer from these diseases”

Pritchard D. 2012. Worm therapy: How would you like your medicine?
International Journal for Parasitology: Drugs and Drug Resistance 2: 106-108.

Parasites and human body

Introduction to the body of eggs *Trichuris suis* is an effective "drug" in combating Crohn's disease.



Summers R. W., Elliot D. E., Urban J. F., Thompson Jr. R., Weinstock J. V. 2005. *Trichuris suis* therapy in Crohn's disease. Gut 54(1): 87–90.

Parasites and human body

***Necator americanus* has a positive effect on Crohn's disease, inflammation of the intestines and asthma.**



McKay D. M. 2009. The therapeutic helminth? Trends in Parasitology 25(3): 109-114.

Parasites and human body

Bloodstream (*Schistosoma haematobium*) and human worm (*Ascaris lumbricoides*) reduce the signs of skin allergies



McKay D. M. 2009. The therapeutic helminth? Trends in Parasitology 25(3): 109-114.

Parasites and human body

How do parasites manipulate our immune system?

Parasites can block the effects of the immune system



Removal: over-activation of defense mechanisms and damage to healthy tissues

Wills-Karp M., Santeliz J., Karp C. L. 2001. The germless theory of allergic disease: revisiting the hygiene hypothesis. *Nature Reviews Immunology* 1: 69-75.

Parasites and human body

*"Our organism has lived in symbiosis with its beneficial parasites for more than three million years, and they have become some sort of **transplanted organ** in it."*



Weinstock J. V. 2012. Autoimmunity: The worm returns. Nature 491: 183-185.

Parasites and human body

„You could almost argue that the worms are us”



Rick Maizel (Edinburgh University)

Schubert Ch. 2004. News Feature: The worm has turned. *Nature Medicine*, 25 November 2004; | doi:10.1038/nm1204-1271

A photograph of a dense forest with tall, thin trees and a thick carpet of green ferns and other plants on the forest floor. The scene is brightly lit, suggesting a sunny day. A white rectangular box is superimposed over the center of the image, containing the text "Mites and human body".

Mites and human body

Mites and human body

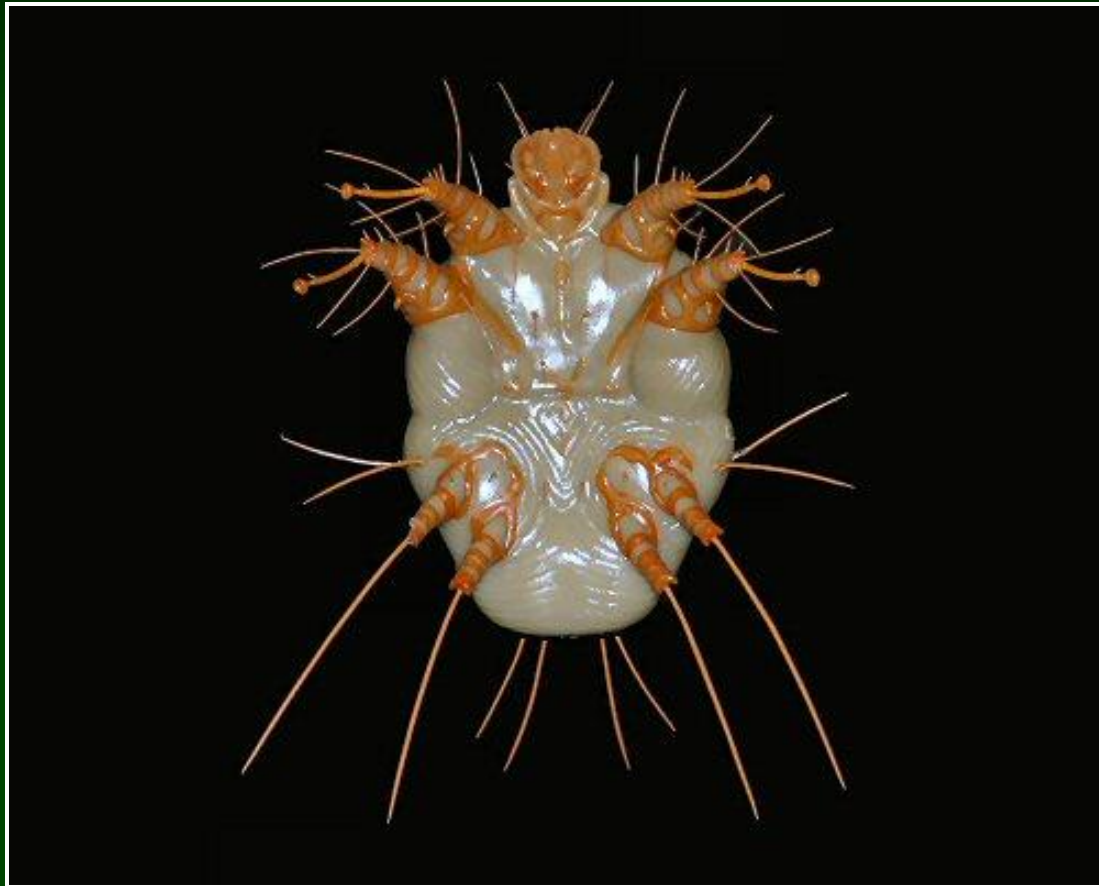


Mites and human body



The Castor bean *tick* - *Ixodes ricinus* (Linnaeus, 1758)

Mites and human body



The itch mite - *Sarcoptes scabiei* (Linnaeus, 1758)

Mites and human body



The trombiculid mite - *Neotrombicula autumnalis* (Shaw, 1790)

Mites and human body



The skin mite - *Demodex folliculorum* Simon, 1842

Mites and human body



1 cm² of face: 2 skin mites

Healthy person – 2 000 skin mites

eyelids, nose, cheeks, forehead, chin, Italian auditory canal, groin, nipple area, chest, buttocks

Mites and human body

Role – clean our body from

- harmful bacteria

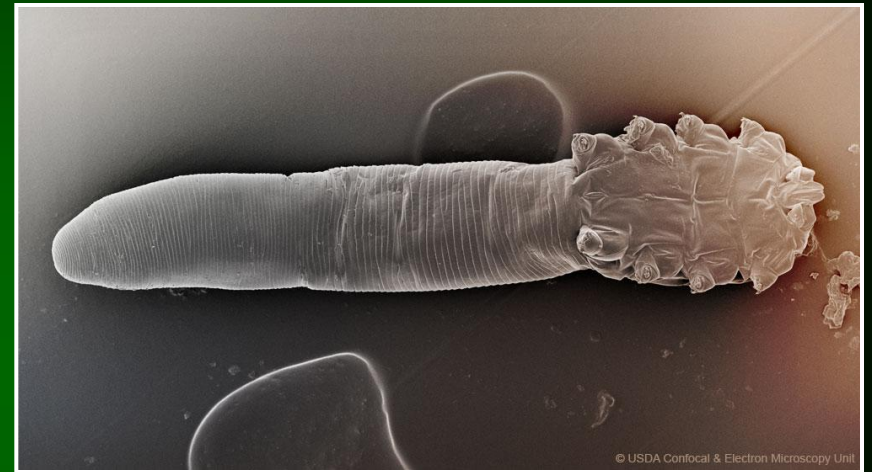
- dead epidermis

- excess secretion of sebaceous glands

sanitation workers



Mites and human body



The skin mite *Demodex brevis* Akbulatova

Mites and human body



Dust mites – *Pyroglyphidae*

Mites and human body



Dermatophagoides pteronyssinus (Trouessart, 1968)

Mites and human body

What happens to your skin?

Our skin loses **50,000**
dead cells / minute

Nasza skóra

złuszczy się



Podczas całego
życia złuszcza się
z nas średnio

18 kg
naskórka

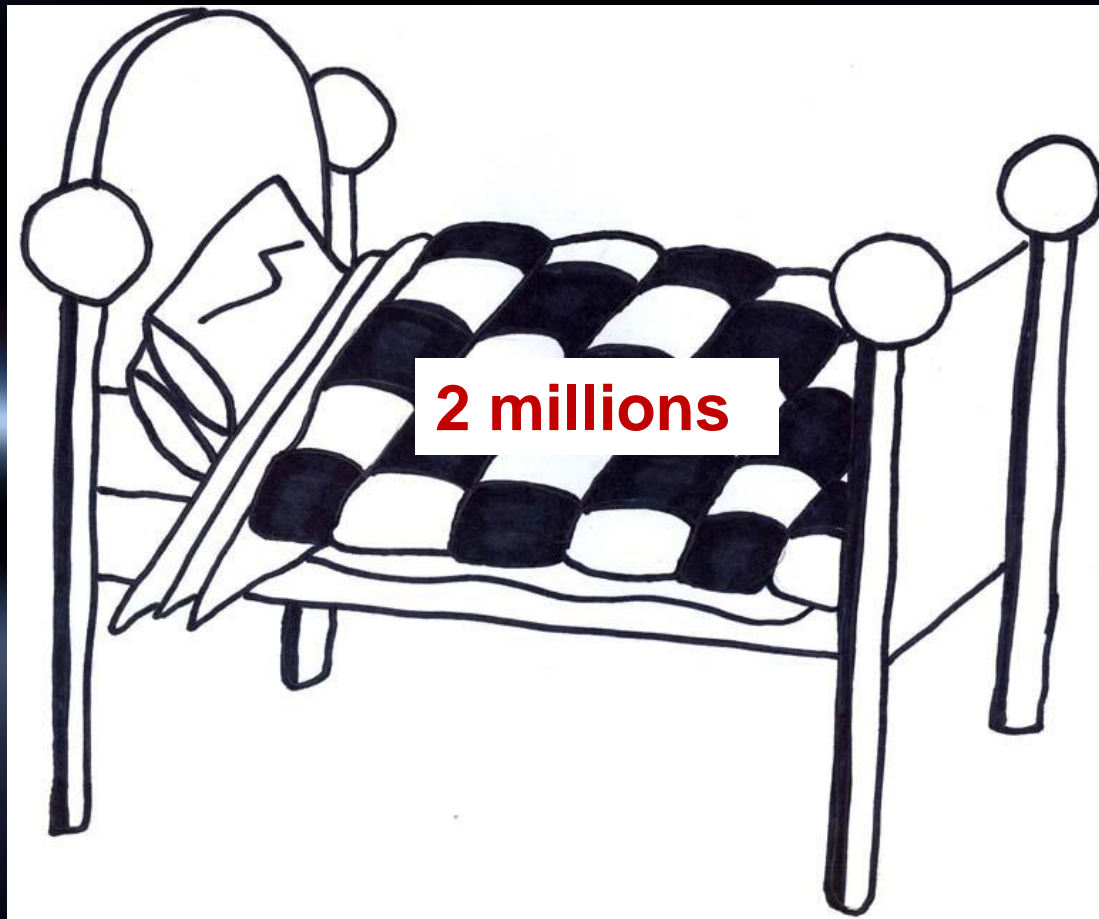
Kurz w
70-90 proc.
składa się z martwych
komórek skóry



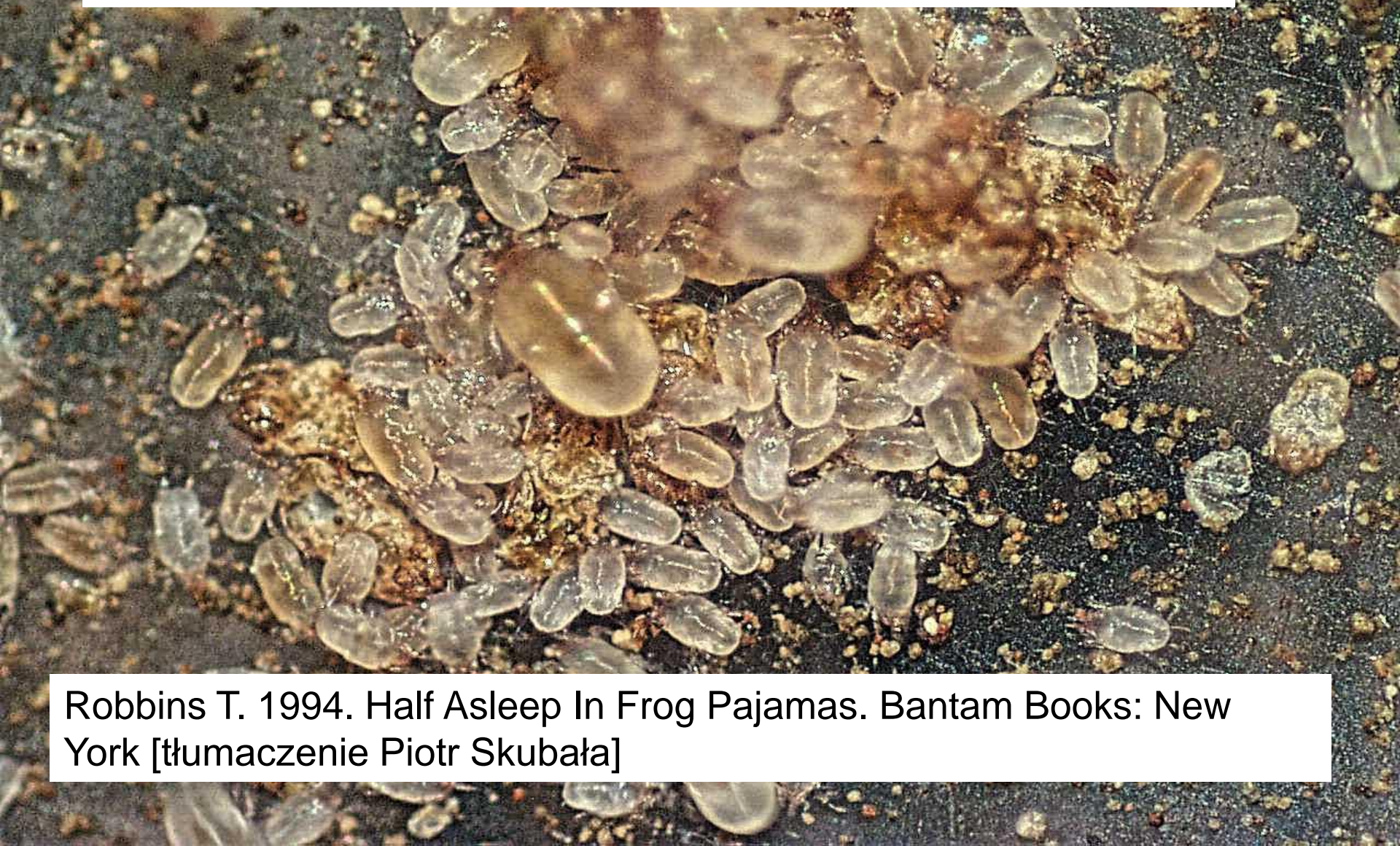
Złuszczone komórki
składają się na blisko

1 mld ton
kurzu w atmosferze
Ziemi

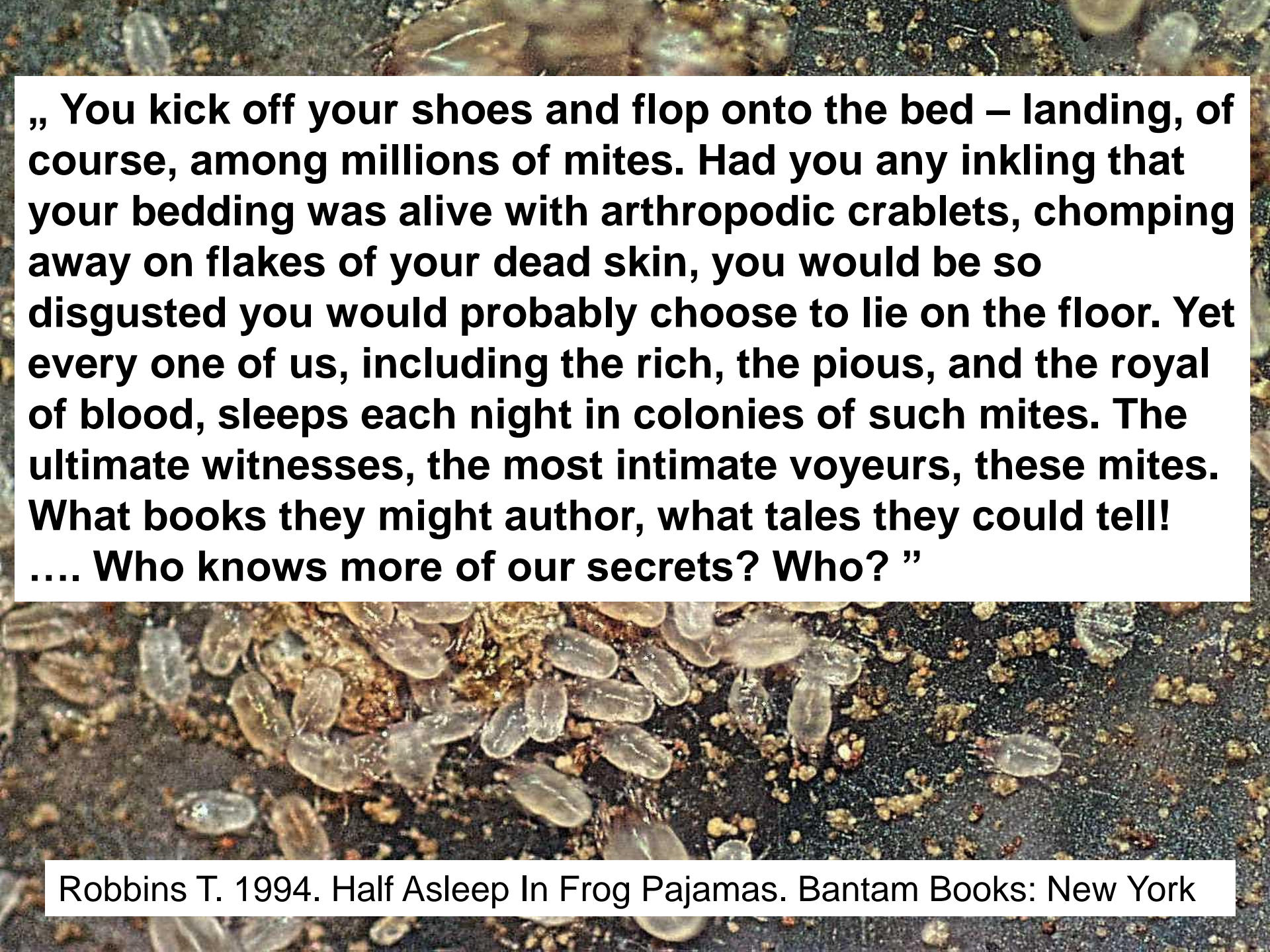
How many mites sleeping with me in bed?



„You kick off your shoes and flop onto the bed – landing, of course, among millions of mites”

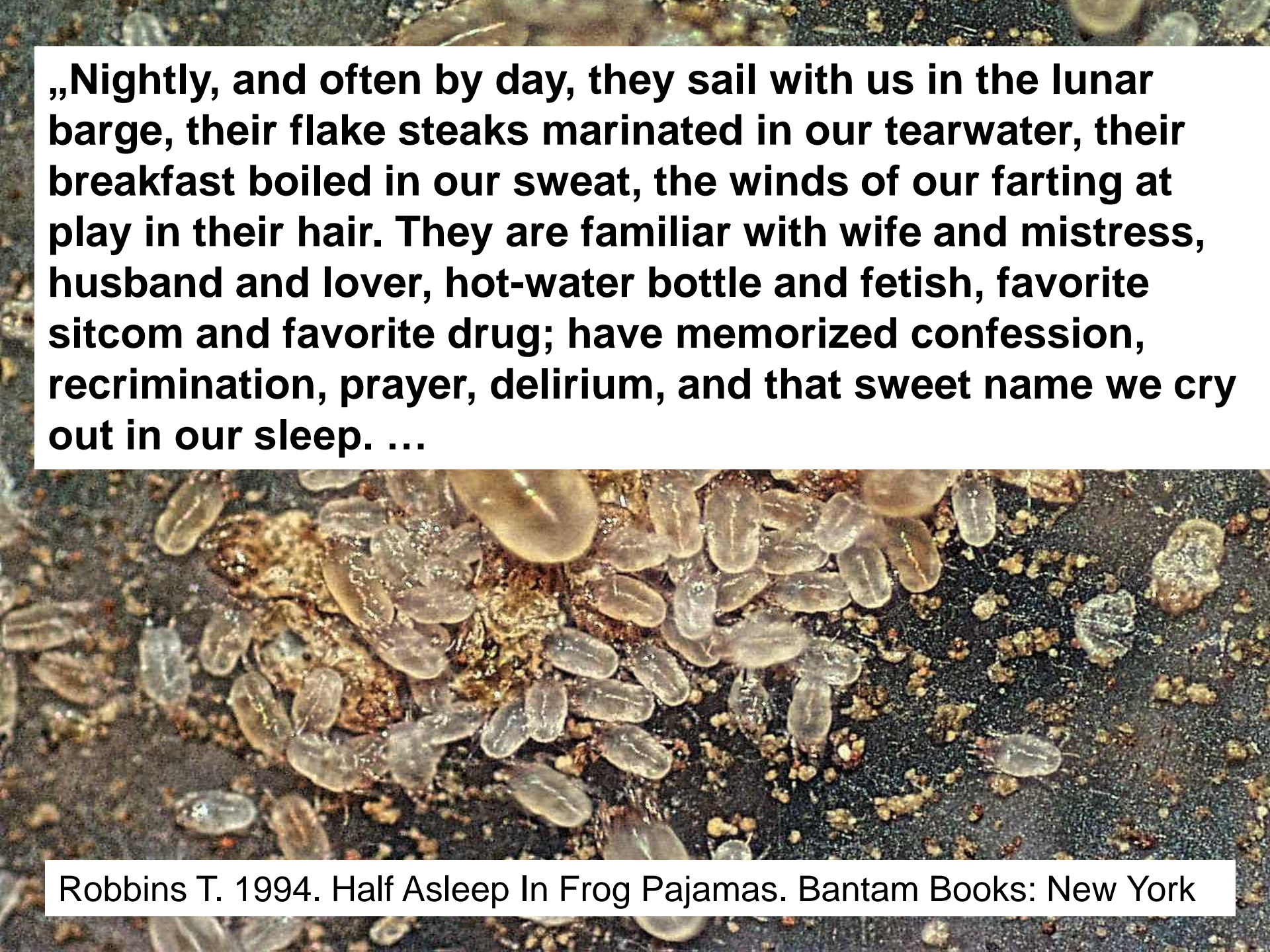


Robbins T. 1994. Half Asleep In Frog Pajamas. Bantam Books: New York [tłumaczenie Piotr Skubała]

A microscopic view of a dark, textured surface, likely a bed, covered with numerous small, translucent, oval-shaped mites. The mites are densely packed in some areas and more sparse in others. The background is a dark, granular material, possibly dust or fabric fibers.

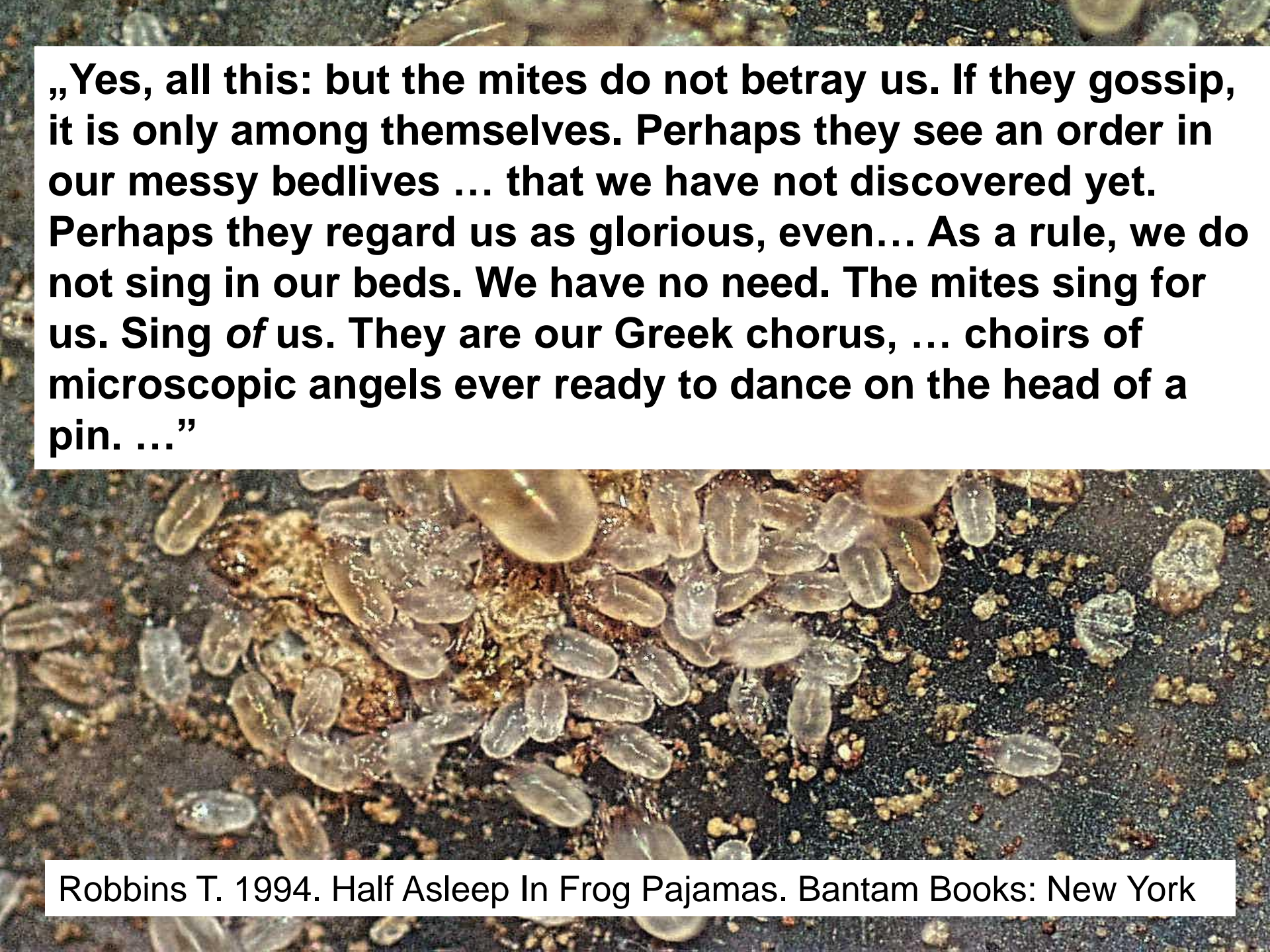
„ You kick off your shoes and flop onto the bed – landing, of course, among millions of mites. Had you any inkling that your bedding was alive with arthropodic crablets, chomping away on flakes of your dead skin, you would be so disgusted you would probably choose to lie on the floor. Yet every one of us, including the rich, the pious, and the royal of blood, sleeps each night in colonies of such mites. The ultimate witnesses, the most intimate voyeurs, these mites. What books they might author, what tales they could tell! Who knows more of our secrets? Who? ”

Robbins T. 1994. Half Asleep In Frog Pajamas. Bantam Books: New York



„Nightly, and often by day, they sail with us in the lunar barge, their flake steaks marinated in our tearwater, their breakfast boiled in our sweat, the winds of our farting at play in their hair. They are familiar with wife and mistress, husband and lover, hot-water bottle and fetish, favorite sitcom and favorite drug; have memorized confession, recrimination, prayer, delirium, and that sweet name we cry out in our sleep. ...

Robbins T. 1994. Half Asleep In Frog Pajamas. Bantam Books: New York

A high-magnification photograph showing a dense population of mites on a dark, textured surface. The mites are small, translucent, and oval-shaped, with some showing internal structures. They are scattered across the frame, with a higher concentration in the center and left side. The background is dark and granular, possibly representing a bed or fabric.

„Yes, all this: but the mites do not betray us. If they gossip, it is only among themselves. Perhaps they see an order in our messy bedlives ... that we have not discovered yet. Perhaps they regard us as glorious, even... As a rule, we do not sing in our beds. We have no need. The mites sing for us. Sing *of* us. They are our Greek chorus, ... choirs of microscopic angels ever ready to dance on the head of a pin. ...”

Robbins T. 1994. *Half Asleep In Frog Pajamas*. Bantam Books: New York

A photograph of a dense forest. The scene is filled with tall, slender trees, some with moss on their trunks. The ground is covered in a thick layer of green ferns and other undergrowth. The lighting is soft, suggesting a shaded forest environment. A white rectangular box is superimposed over the middle of the image, containing the text "What actually means 'human'?".

What actually means "human"?

What actually means "human"?



particles of water

genes

bacteria

fungi

viruses

parasites

What actually means "human"?



Human body - complex ecosystem (biosphere)

What actually means "human"?



„Humans are like coral, an assemblage of life-forms living together”

Dr David Relman, microbiologist, Stanford University

Kolata G. 2012. In Good Health? Thank Your Trillion Bacteria. New York Times, June 13.
<http://www.nytimes.com/2012/06/14/health/human-microbiome-project-decodes-our-100-trillion-good-bacteria.html>

What actually means "human"?



„Humans in some sense are made mostly of microbes. From the standpoint of our microbiome, we may just serve as **packing**”

Dr Barnett Kramer, National Cancer Institute

Kolata G. 2012. In Good Health? Thank Your Trillion Bacteria. New York Times, June 13.
<http://www.nytimes.com/2012/06/14/health/human-microbiome-project-decodes-our-100-trillion-good-bacteria.html>

What actually means "human"?



*"Each part of the body is a separate **ecosystem**. Two teeth in the same mouth can be populated by different bacteria."*

Martin Blaser (New York University), Newsweek 11.11.207: 61-64.

What actually means "human"?



*“because of the variety and often disjunct distribution of habitats on one mammal, we can look on the mammal as a wandering **Galapagos archipelago** with each Island (e.g., and eyelid) having several differing habitats”*

Nutting W.B. 1985. Prostigmata-Mammalia: validation of coevolutionary significance. In: Kim K.C. (ed.). Coevolution of parasitic arthropods and mammals. Wiley-Interscience: New York, pp. 569-640.

What actually means "human"?

Galapagos Archipelago

ecosystem



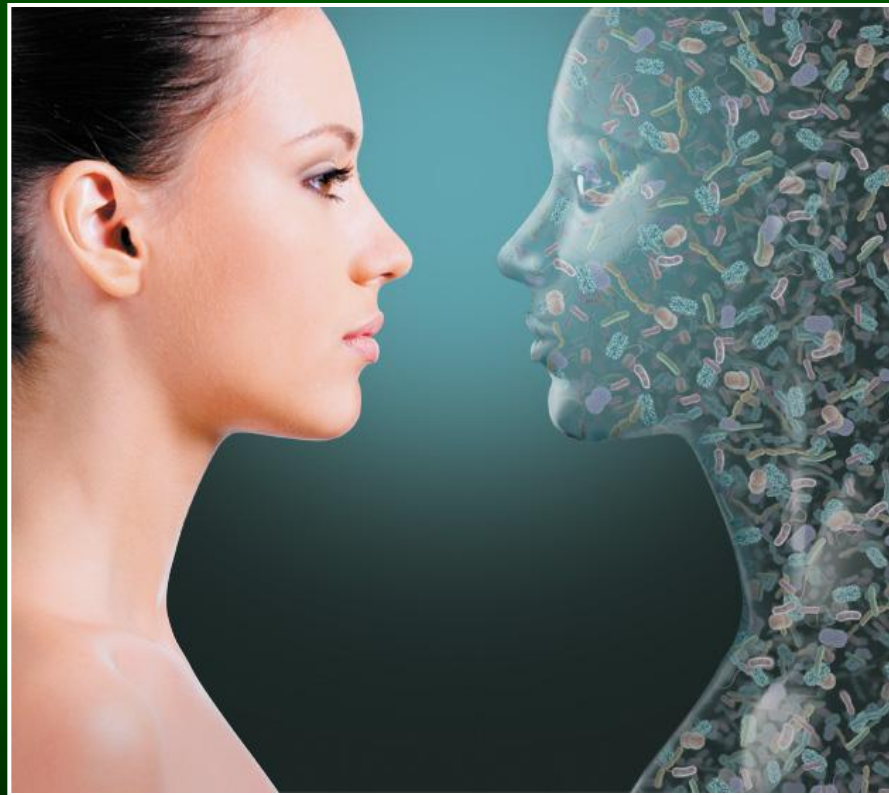
coral

packing

A photograph of a dense forest. The scene is filled with tall, slender trees, some with moss on their trunks. The ground is covered in a thick layer of green ferns and other undergrowth. The lighting is soft, suggesting a shaded forest environment. A white rectangular box is overlaid in the center of the image, containing the text "Coexistence - the key to survival".

Coexistence - the key to survival

"Get along" with the microorganisms living our body is a guarantee of our survival

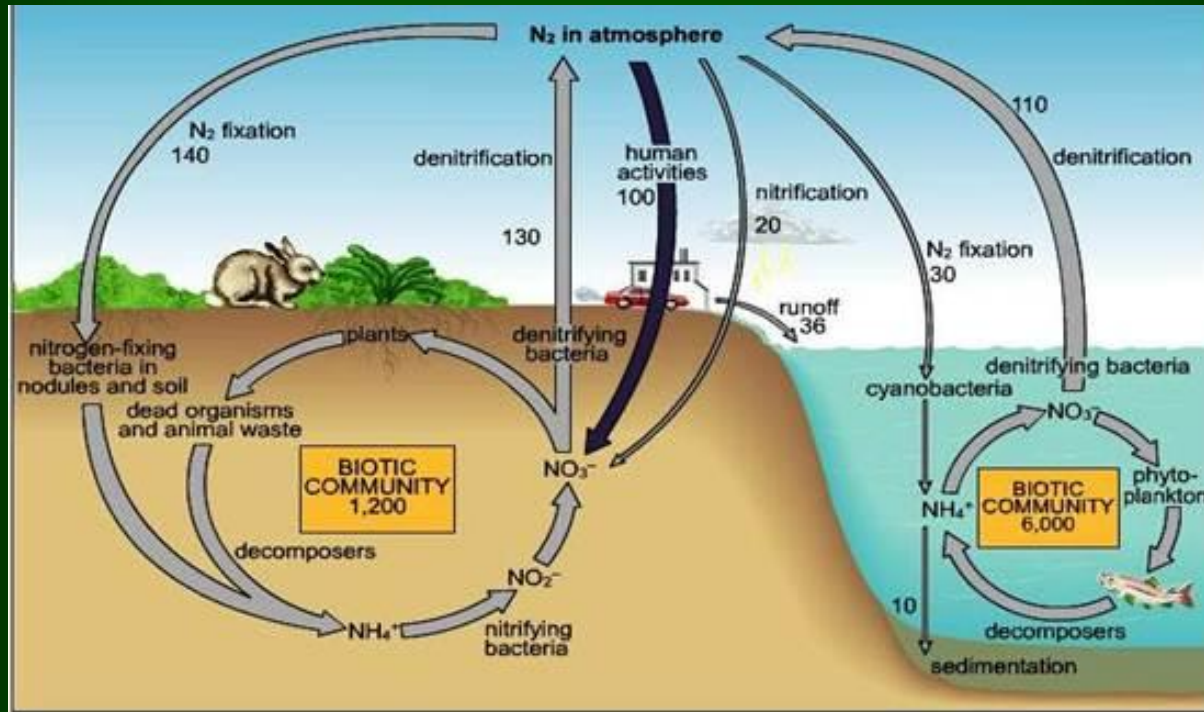


A lush green forest scene with tall trees and dense undergrowth. The foreground is filled with various green plants, including ferns and grasses. The background shows a dense stand of trees, with some trunks showing signs of decay or insect damage. The overall atmosphere is vibrant and natural.

My body and nature

My body and nature

Circulation of matter in nature



My body and nature

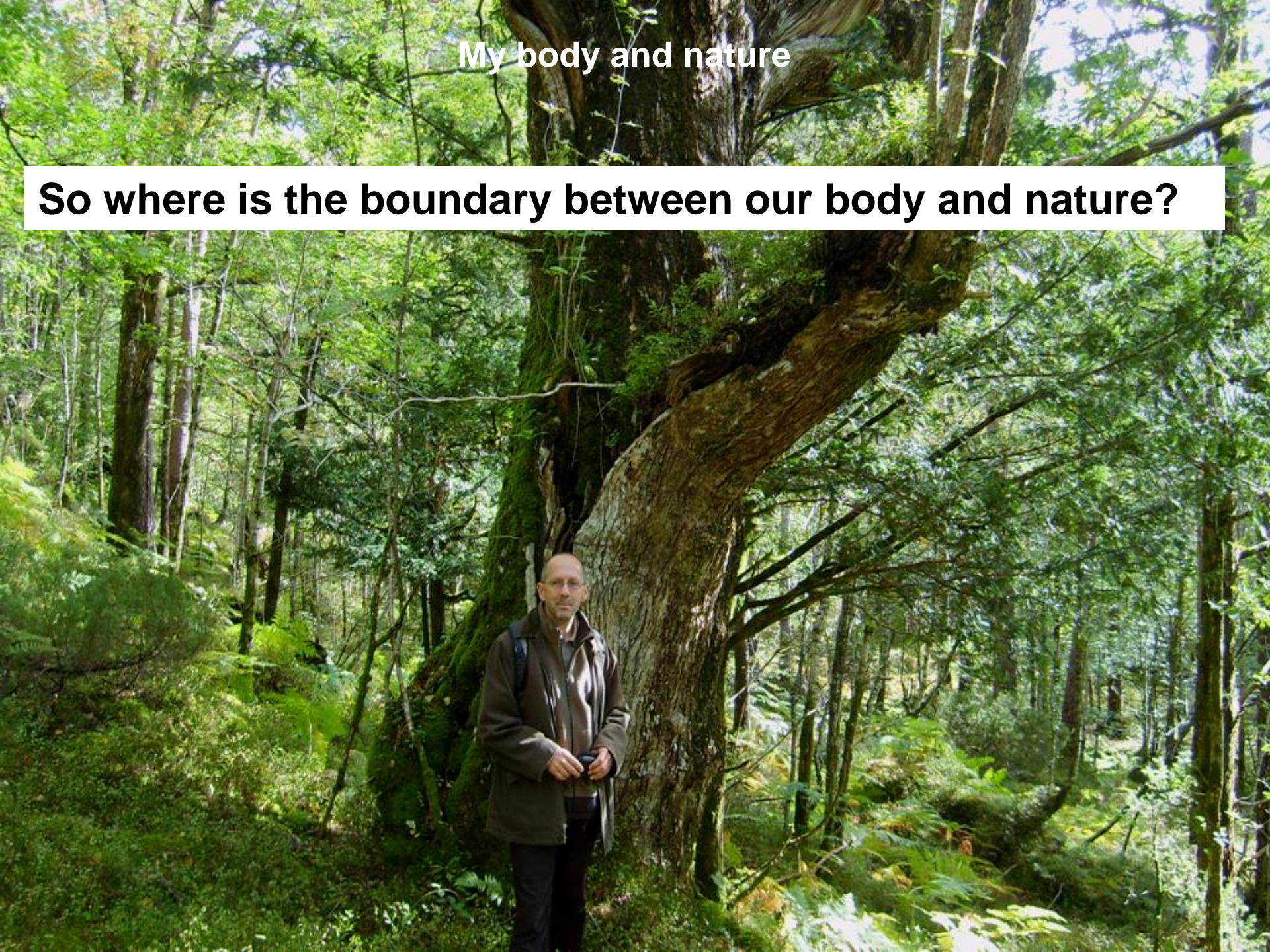
How many years does it take ~100% of our matter is to be replaced?

A photograph of a man standing in a lush green forest. He is wearing a dark jacket and glasses. A large, thick tree trunk is prominent in the foreground, and a yellow circle is drawn around it. Two yellow arrows point from the circle towards the man, suggesting a connection between the tree and the human body. The background is filled with dense green foliage and other trees.

7-8 years

My body and nature

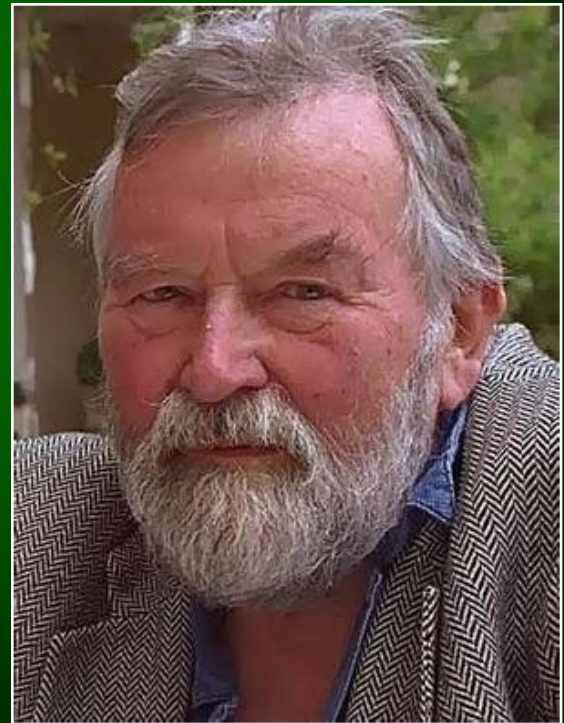
So where is the boundary between our body and nature?



My body and nature

„ As long as nature is seen as in some way outside us, frontieraed and foreign, separate, it is lost both to us and in us”

John Fowles (1926-)



FOWLES J. 2000. The Tree. Vintage, London.

Tall trees

tall trees - warm fire,
strong winds - deep water,
I feel it in my body,
I feel it in my soul...

(Indian song, North America)

<https://www.youtube.com/watch?v=qkzfsnSJgtg#t=83>

Humans as holobionts

Our relationship with nature



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