Microbial Ecology

Microorganisms in human & animal

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Human as microbial habitat
Oral cavity, skin, gastrointestinal tract

Anaerobic processes in rumen
Degradation of cellulose

Microbes in termites
Degradation of wood

Habitate 'Human'

We are always in contact with microorganisms

Human body represents a convinient environmen

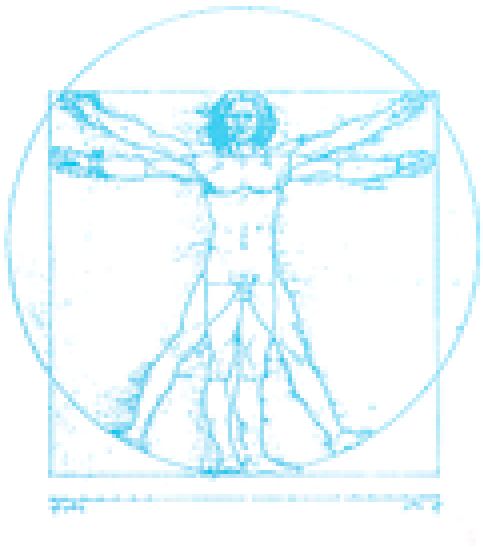
Certain regions of the body provide constant chemical and physical conditions

Different environemnts between distinc organs

Rich in organic substrates

There are many pathogenic microbes out which want to get access to potential substrates

Most of our microbial flora is harmless



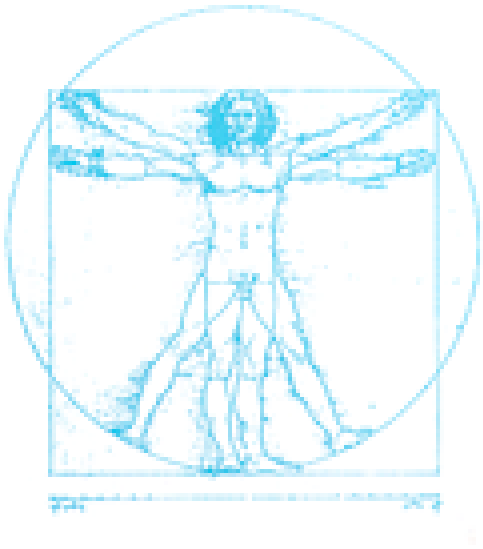
Habitat Human

Skin

Oral cavity

Intestinal tract

Urogenital tract



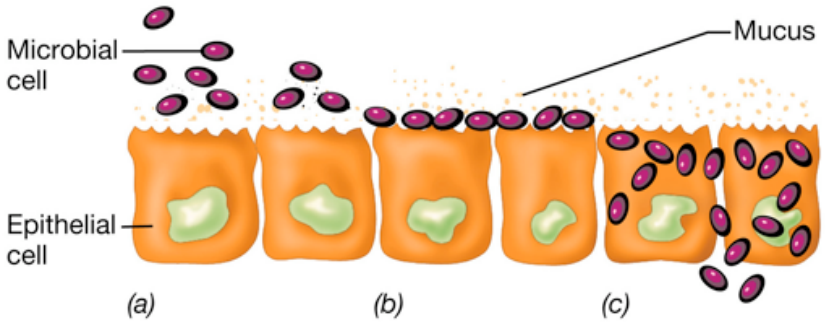
Body surfaces with direct contact to the environment.
(Usually no microbes in blood, lymph or neural system)

Infection occurs often via mucosa

Consist of layers of epithiall cells

Represent barrier to environment

Slime creates viscous protection layer and consists of soluble glycoproteins



Definitions

Parasites: Organisms, that live in or on a host and damage the host

Pathogens: Microbial parasites, that cause a disease

Opportunistic pathogens: Microbes that do not infect healthy individuals, but that can cause a disease if host defense mechanisms are reduced

Infection and **disease** are not the same!

Normal microbial flora of the skin

Largest human organ; average surface of $2m^2$

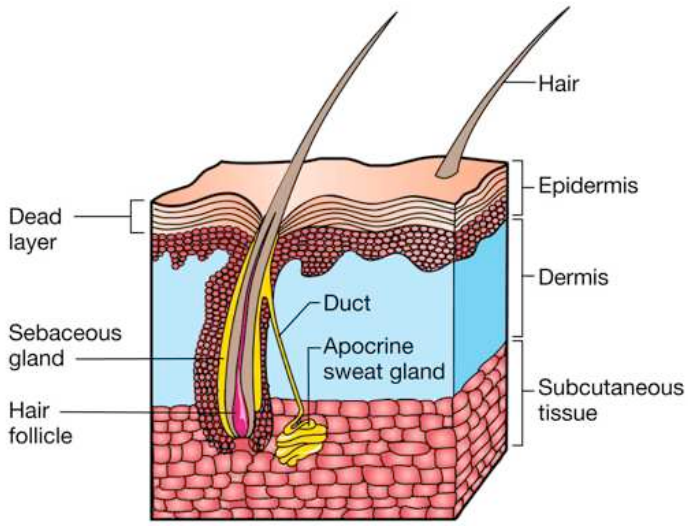
Local variation in chemical composition and moisture

Most of skin not a favorable environment because of periodic drying

Growth of bacteria often associated with apocrine glands (apokrine Drüsen) in:
Underarm, genital regions, nipples and umbilicus

Human skin

Microbes are primarily associated with sweat ducts and hair follicles



Substrates: Urea, amino acids, lactate, lipids

The bacterial community of the skin

Distinction between transient and residential communities

Genera of residential communities:
Acinetobacter, Corynebacterium, Enterobacter, Klebsiella, Propionibacterium, Micrococcus, Proteus, Pseudomonas, Staphylococcus

Influenced by:
Weather,age , hygiene

Limiting factors: low pH, drying

The human oral cavity

Oral cavity represents complex and heterogenic habitat

Saliva is most pervasive source for nutrients but is not a medium (nutrient poor and contains antibacterial substances like lysozyme and lactoperoxydase)

Connection to outer environment

Uptake of microbes by breathing and eating

Connected with upper and lower respiratory tracts

Microorganisms of the oral cavity

By date about 600 species identified

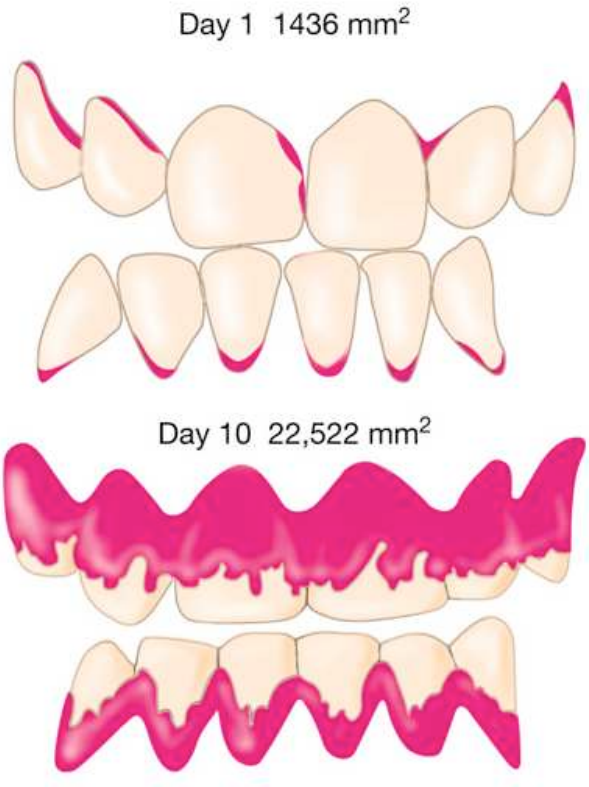
Consist of Bacteria, Archaea and fungi

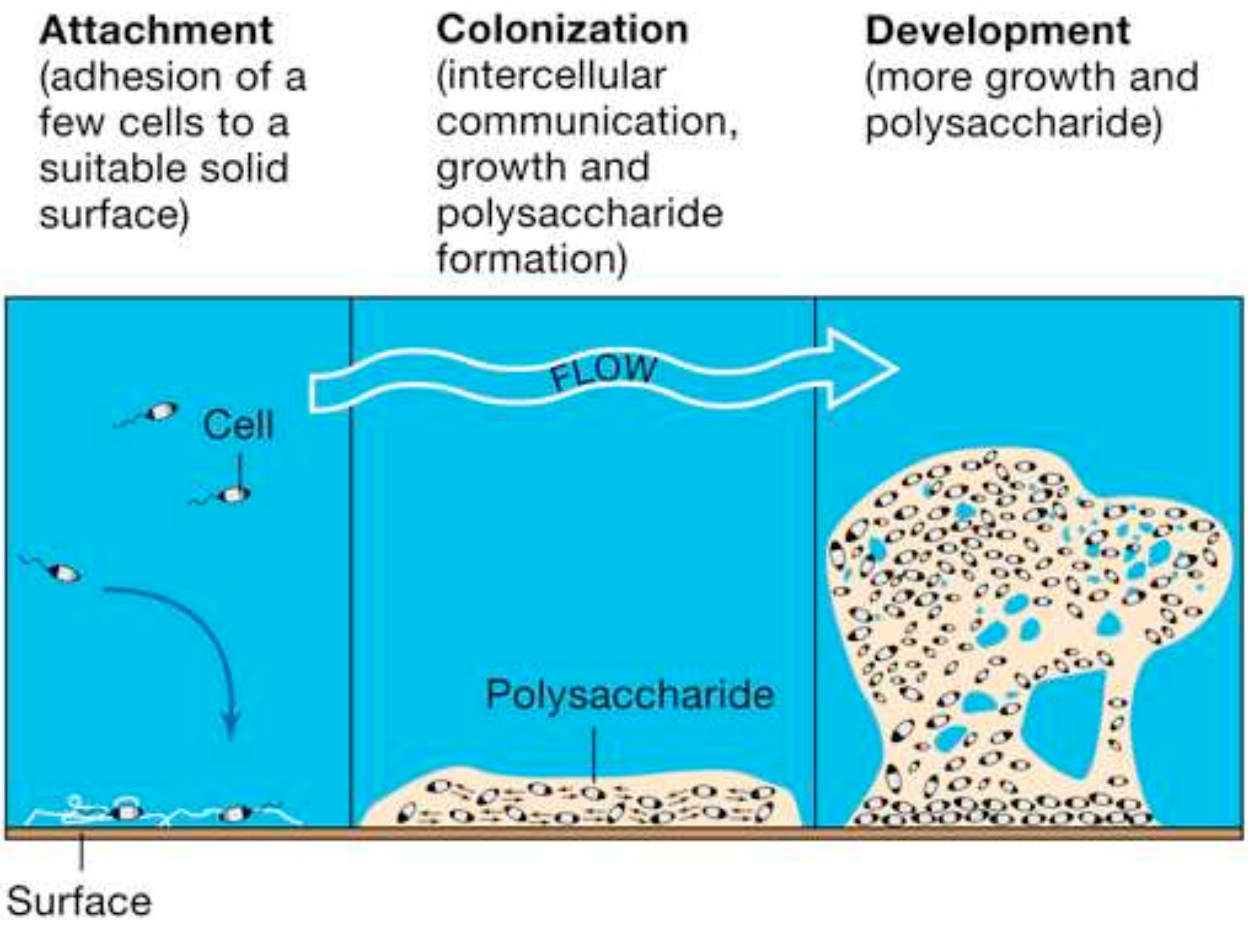
Colonization occurs with well organized biofilm formation

Thicker bacterial layers are named dental plaque

Heavy colonization may cause dental carries, gingivitis or parodontitis

Formation of dental plaque





Biofilm formation in dental plaques

Specific attachment of *Streptococcus*-species (formation of adhesive dextranpolysaccharides)

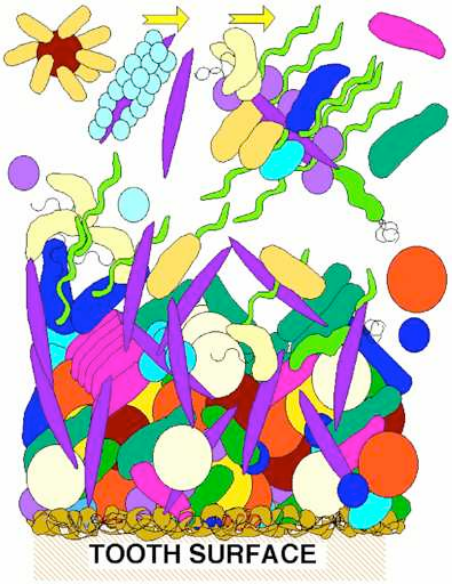
Formation of microcolonies and matrix

Colonization of filamentous Fusiobacteria

Increase of complexity and thickness of biofilm

Formation of anoxic condition (decreasing O_2-diffusion and respiration activity)

Growth of different anaerobic microorganisms



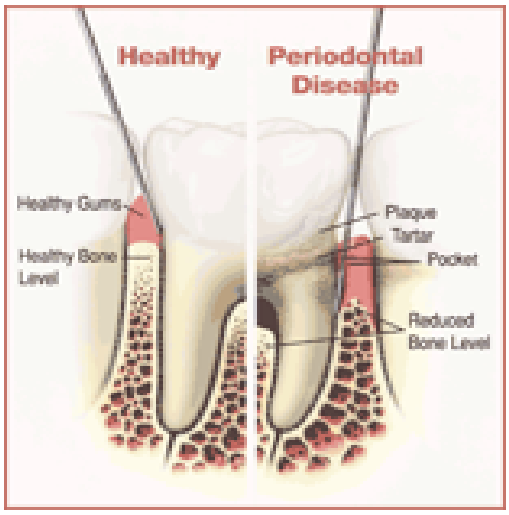
Consequences of dental infection

Production of organic acids results in destruction of protecting dental enamel (Decalcification)

Formation of deep pockets

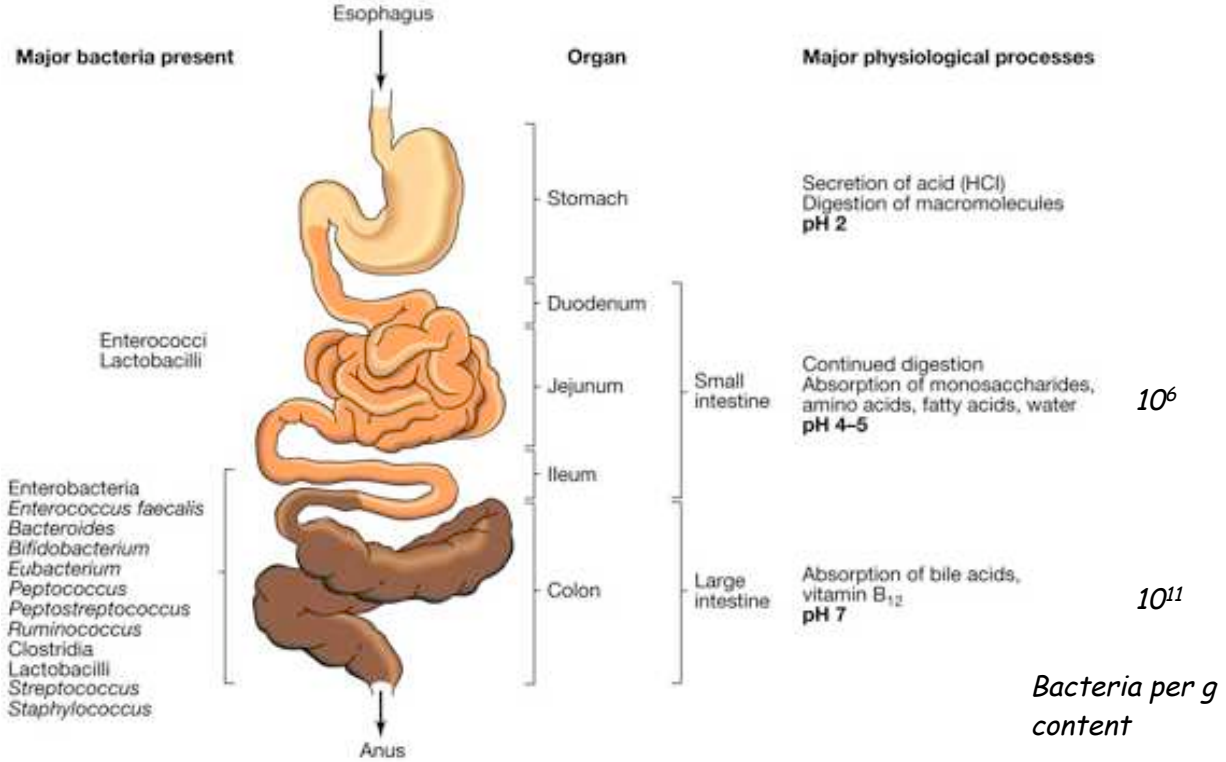
Accumulation of substrates and colonization of transient pathogens

Infection may result to Gingivitis und bone- and tissue destruction (parodontitis)



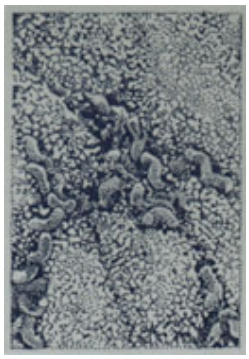
Dental infections are dependent on age , hygiene, diet and health condition

The intestinal tract



Bacteria may account for up to 1/3 of the mass of faeces

Helicobacter pylori
Chemolithoautotrophic Knallgasbacteria

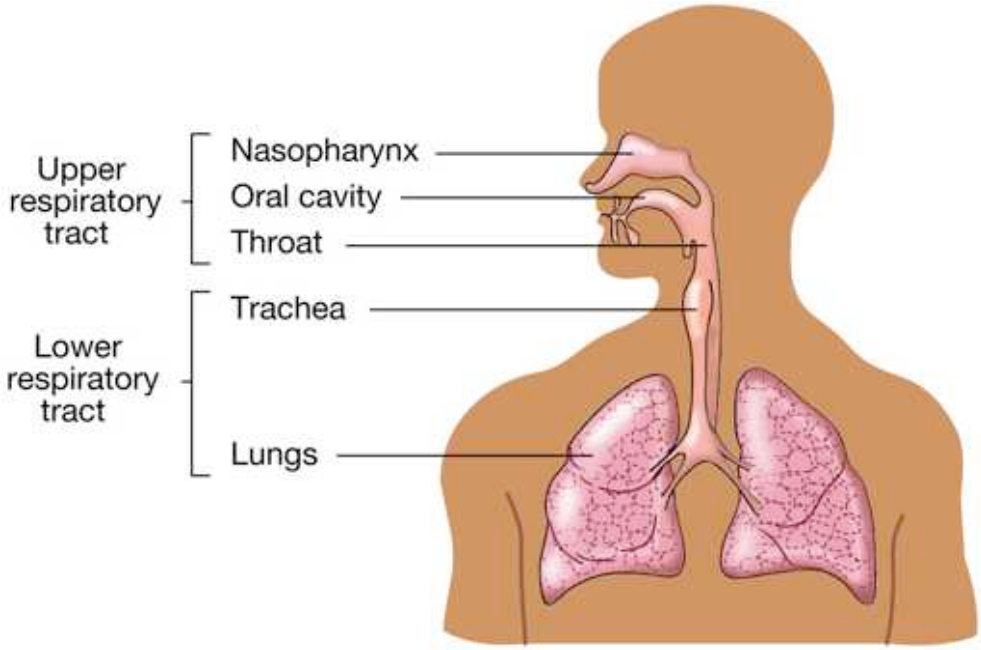


Helicobacter pylori

Infection may cause to chronic gastritis

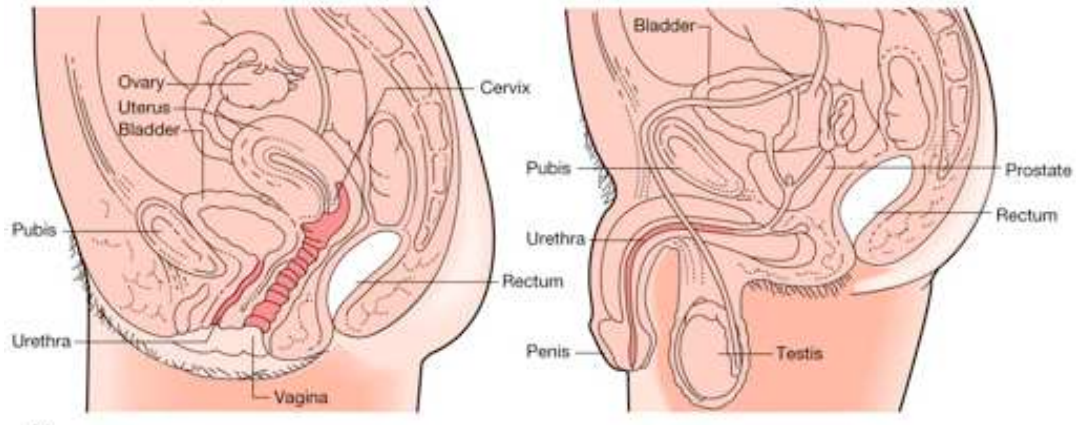
Isolated by Robin Warren and Barry Marschall
(Nobelprize 2005)

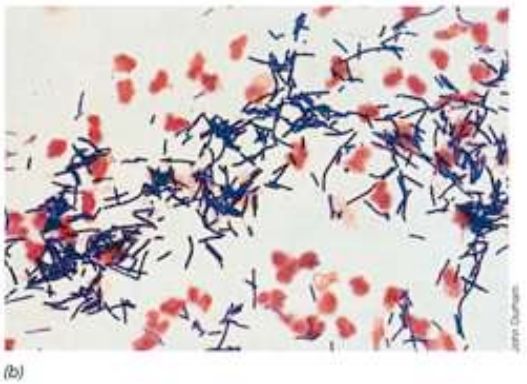
The respiratory tract



Staphylococcus aureus and *Streptococcus pneumoniae* are opportunistic pathogens of the respiratory tract

The human urogenital tract





Healthy bladder are sterile
Epithelial cells lining the urethra are colonized *(eg. E. coli* und *Proteus)*

The vagina exhibits varying conditions (residential bacterium *Lactobacillus acidophilus*, gram+)

The normal microbial community on skin, the respiratory tract and the urogenital tract protect the body from colonization of pathogens!

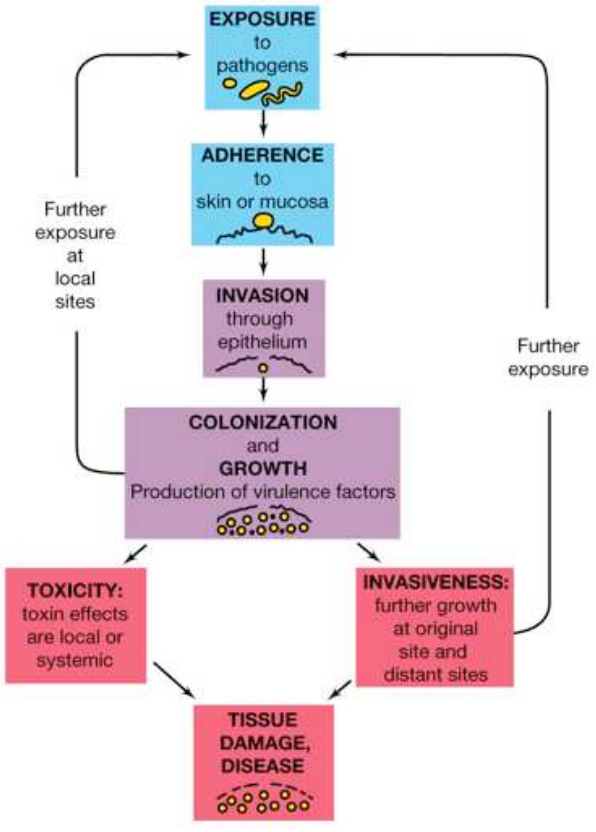
Pathogenity of microorganisms

Access via wounds, respiratory tract, intestinal- or urogenital tract

Adherence highly selective for certain body regions

Penetration through epithelium often necessary

Colonization and growth enhance toxicity (*Clostridium tetani*) and further invasion (*Streptococcus pneumoniae*)

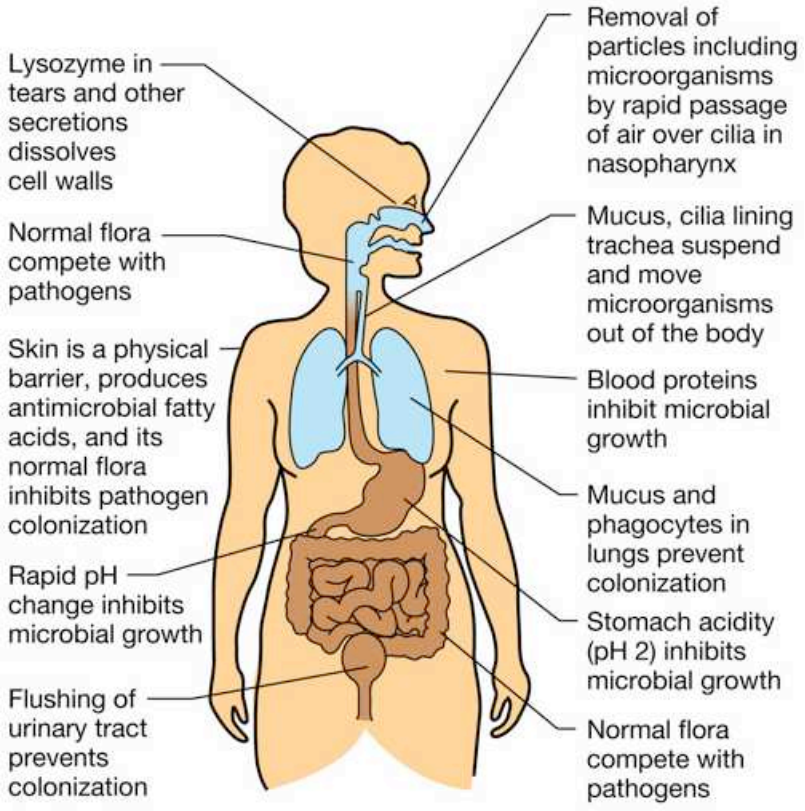


Why do pathogens harm the body?

Production of enzymes which destruct or change the structure of cells/tissues
Access to nutrients produced by the host

Further production of virulence factors enhance protection from the human defence system and devoid colonization of other pathogens

Infection barriers in the human body

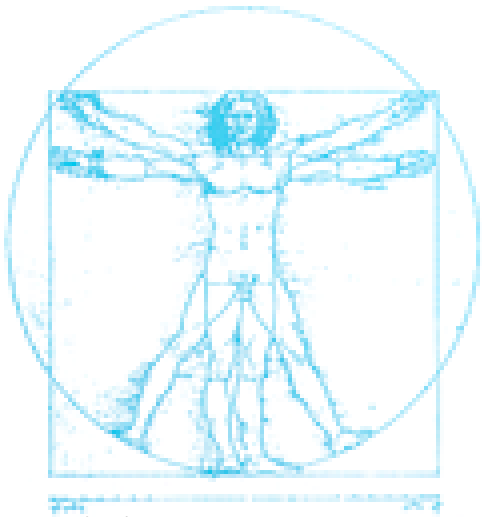


Habitat Human

A metagenomic approach

Human intestinal microbiota is com
of 10^{13} to 10^{14} microorganisms

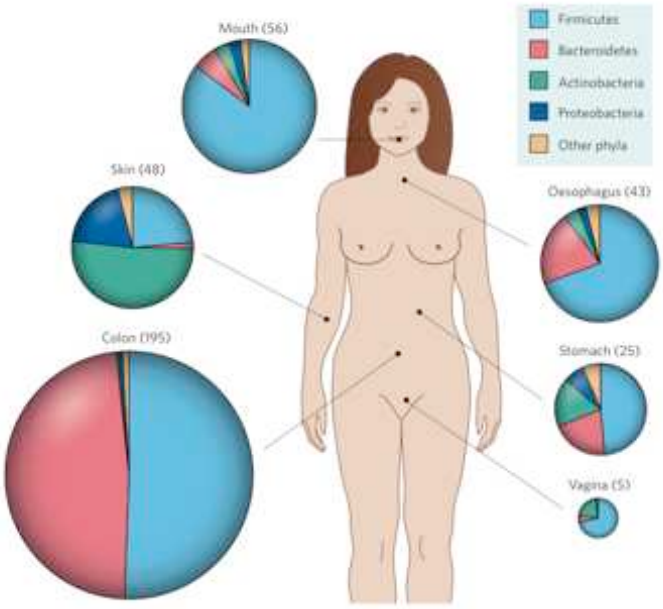
Whose collective genome contains
100 times as many genes as our ow



"Humans are superorganisms whose metabolism represents an amalgamation of microbial and human attributes."

S. Gill et al. 2006

Phylogenetic groups of human microbes



Dethlefsen et al. 2007

How do microorganisms help cows with their digestion?

Mammals lack enzymes to degrade cellulose!

Cows are ruminants, herbivorous mammals that posses a special digestive vessel, the rumen.

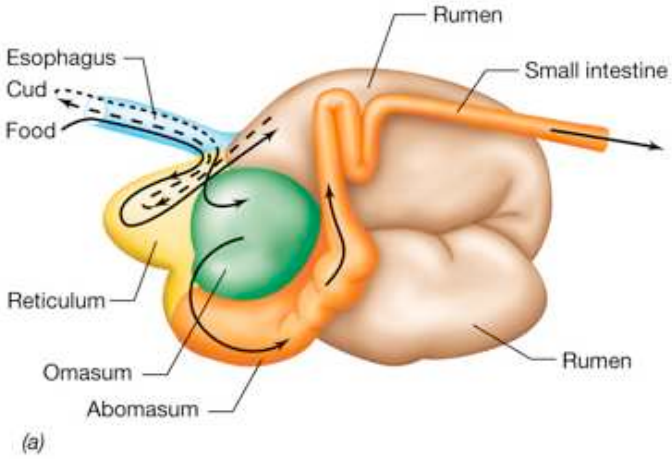
Rumen contain microorganisms that degrade cellulose and other hardly degradable plant polysaccharides

The rumen (ca 100-150 l for cows) provide constant temperature (39°C), almost constant pH (6.5), and anoxic atmosphere

The rumen represents a natural chemostat

Bacterial cell concentration is 10^{10}-10^{11} cells per g rumen fluid

Schematic diagram of the rumen



(a)

Fistulated cow


(b)

Digestive processes in the rumen

Plant material is taken up and physical hackled, mixed with saliva and transferred to the rumen

Food mass migrates into the reticulum where it is formed into small clumps (cud), which are regurgitated and chewed again

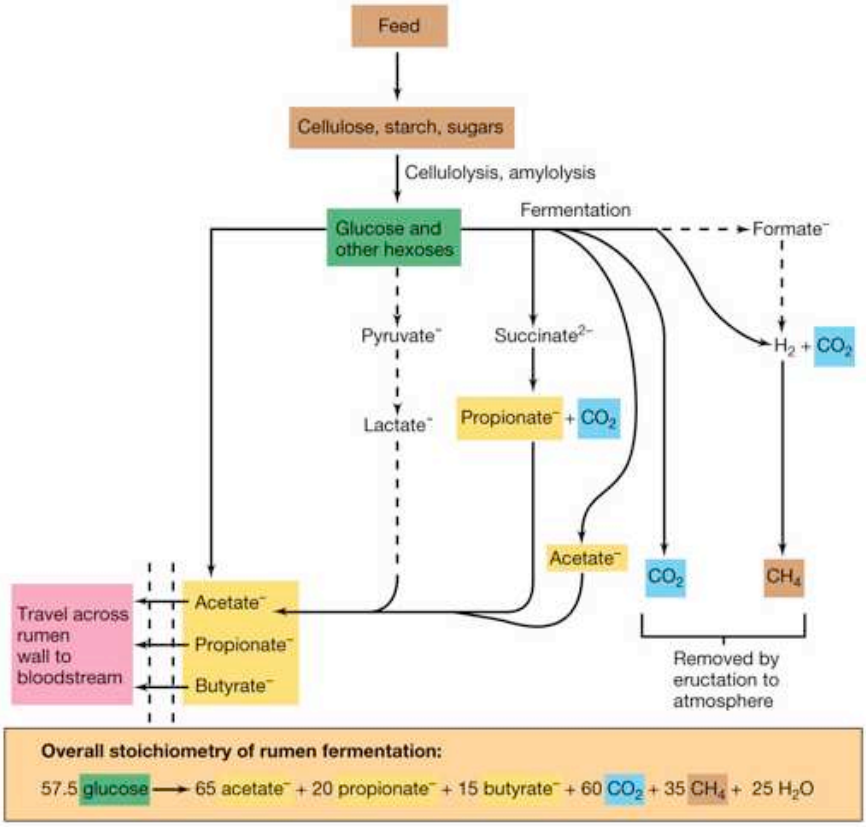
The omasum posses the reduction of the water content

The food mass is than transported to abomasum, where the pH is dropped down and the cow digestion starts enzymatical

Rumen microorganisms are also digested and represent an important source for proteins and vitamins

Volatile fatty acids, produced by fermentative bacteria, pass the rumen wall into the blood stream and are further oxidized by the cow as major source of energy

Microbial degradation within the rumen



Merkmale einiger Pansenprokaryoten

Organismus	Gramfärbung	Phylogenetische Domäne[a]	Morphologie	Motilität	Gärungsprodukte
Cellulosezersetzer					
Fibrobacter succinogenes[b]	negativ	B	Stäbchen	–	Succinat, Acetat, Formiat
Butyrivibrio fibrisolvens[c]	negativ	B	gekrümmtes Stäbchen	+	Acetat, Formiat, Lactat, Butyrat, Wasserstoff, Kohlendioxid
Ruminococcus albus[b]	positiv	B	Kokkus	–	Acetat, Formiat, Wasserstoff, Kohlendioxid
Clostridium lochheadii	positiv	B	Stäbchen (Endosporen)	+	Acetat, Formiat, Butyrat, Wasserstoff, Kohlendioxid
Stärkezersetzer					
Prevotella ruminicola	negativ	B	Stäbchen	–	Formiat, Acetat, Succinat
Ruminobacter amylophilus	negativ	B	Stäbchen	–	Formiat, Acetat, Succinat
Selenomonas ruminantium	negativ	B	gekrümmte Stäbchen	+	Acetat, Propionat, Lactat
Succinomonas amylolytica	negativ	B	oval	+	Acetat, Propionat, Succinat
Streptococcus bovis	positiv	B	Kokken	–	Lactat
Lactatzersetzer					
Selenomonas lactilytica	negativ	B	gekrümmtes Stäbchen	+	Acetat, Succinat
Megasphaera elsdenii	positiv	B	Kokken	–	Acetat, Propionat, Butyrat, Valerat, Capronat, Wasserstoff, Kohlendioxid
Succinatzersetzer					
Schwartzia succinovorans	negativ	B	Stäbchen	+	Propionat, Kohlendioxid
Pektinzersetzer					
Lachnospira multiparus	positiv	B	gekrümmtes Stäbchen	+	Acetat, Formiat, Lactat, Wasserstoff, Kohlendioxid
Methanogene					
Methanobrevibacter ruminantium	positiv	A	Stäbchen	–	Methan (aus Wasserstoff + Kohlendioxid oder Formiat)
Methanomicrobium mobile	negativ	A	Stäbchen	+	Methan (aus Wasserstoff + Kohlendioxid oder Formiat)

Eukaryotic microorganisms in the rumen

Obligate anaerobic Ciliates:
Degradation of cellulose
Regulation of the bacteria concentration

Obligate anaerobic fungi (*Neocallimastix*):
Degradation of cellulose, lignin und pectin
Have no mitochondria, but hydrogenosoms

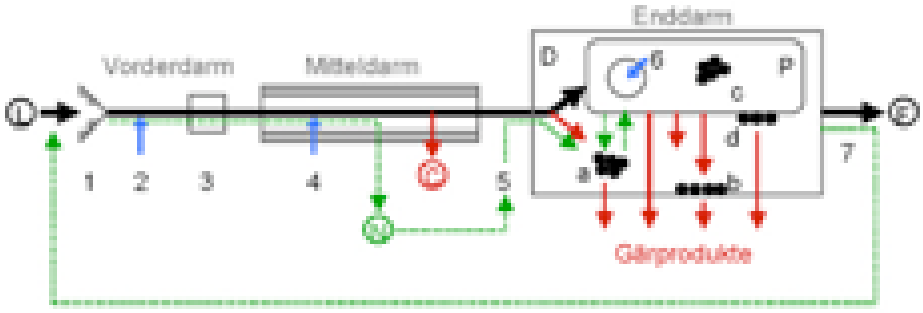
Wood degradation by microbes in the termite gut

2600 described termite species

Wood is the major substrate

Posses a special gut for symbiosis with wood degrading protists and bacteria

Symbiotic degradation of wood in termites



1	Mandibeln	6	Nahrungsvakuolen	L	Lignocellulose
2	Speicheldrüsen	7	Proctodeale Trophallaxis	C	Kohlenhydrate
3	Proventriculus			N	Stickstoffhaltige Verbindungen
4	Mitteldarmepithel	D	Darmlumen		
5	Malpighische Gefäße	P	Protozoen	F	Faeces

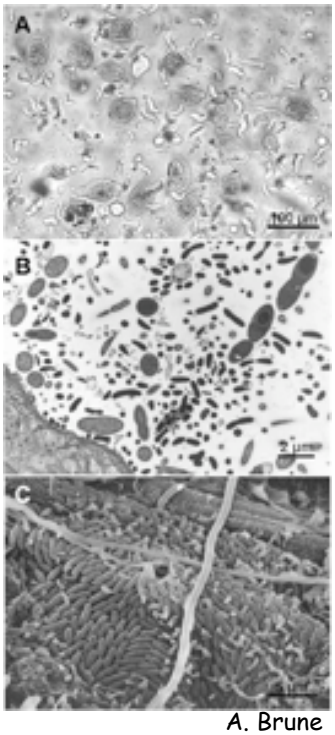
A. Brune

Microbial symbionts in wood degrading termites

Anaerobic Flagellates

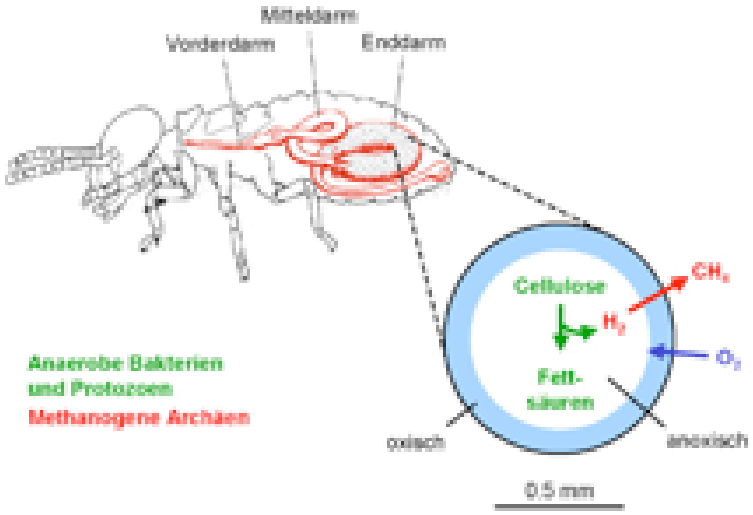
Prokaryotes in the periphery of the gut

Colonization on the gut wall (inside)



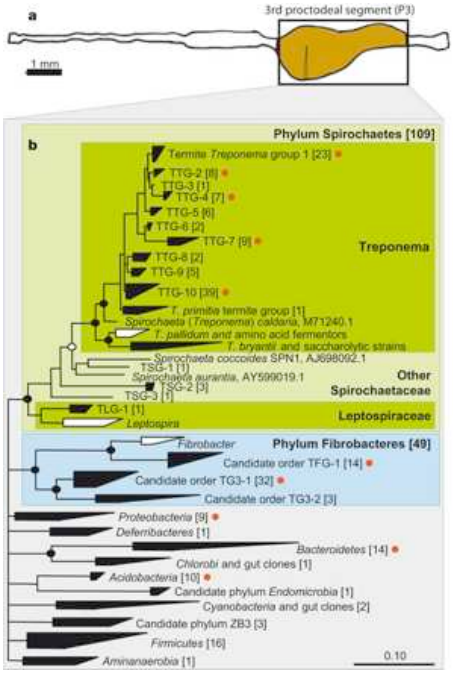
A. Brune

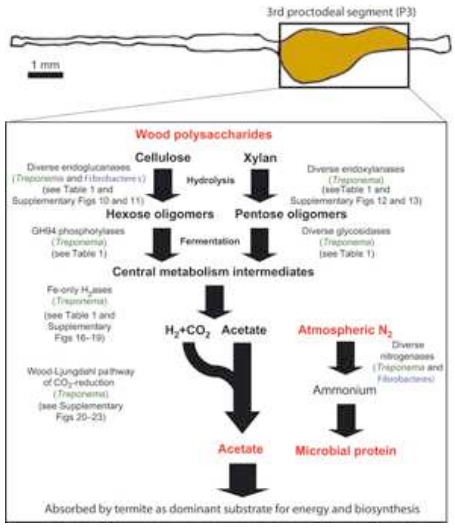
The termite gut as bioreactor



A. Brune

The termite gut as bioreactor
-Another metagenome-





F. Warnecke et al. 2007

Global methane emission from different habitats

Ruminant animals	80-100 T/anno
Termites	25-150 T/ anno
Rice fields	70-120 T/ anno
Ocean & lakes	1-20 T/ anno
Biogenic	300-820 T/ anno
Abiogenic	48-155 T/ anno