# 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 environment

Certain regions of the body provide constant chemical and physical conditions

Different environments 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



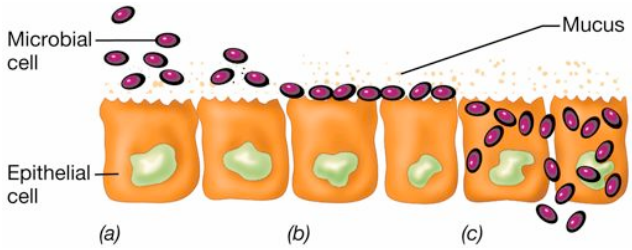
**Body surfaces with direct contact to the environment.**
(Usually no microbes in blood, lymph or neural system)

## Infection occurs often via mucosa

Consist of layers of epithelial 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 cause a disease in healthy individuals. A compromised immune system may be an opportunity for the pathogen to infect the body.

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

## Normal microbial flora of the skin

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

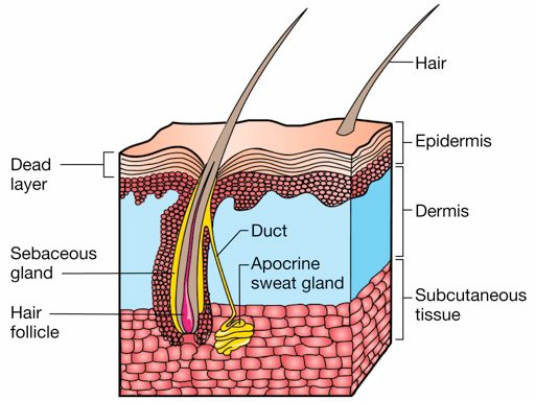
Local variation in chemical composition and moisture

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

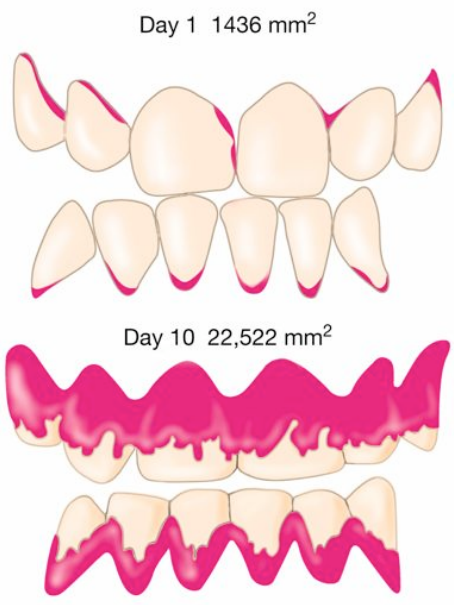
Consist of bacteria, archaea and fungi

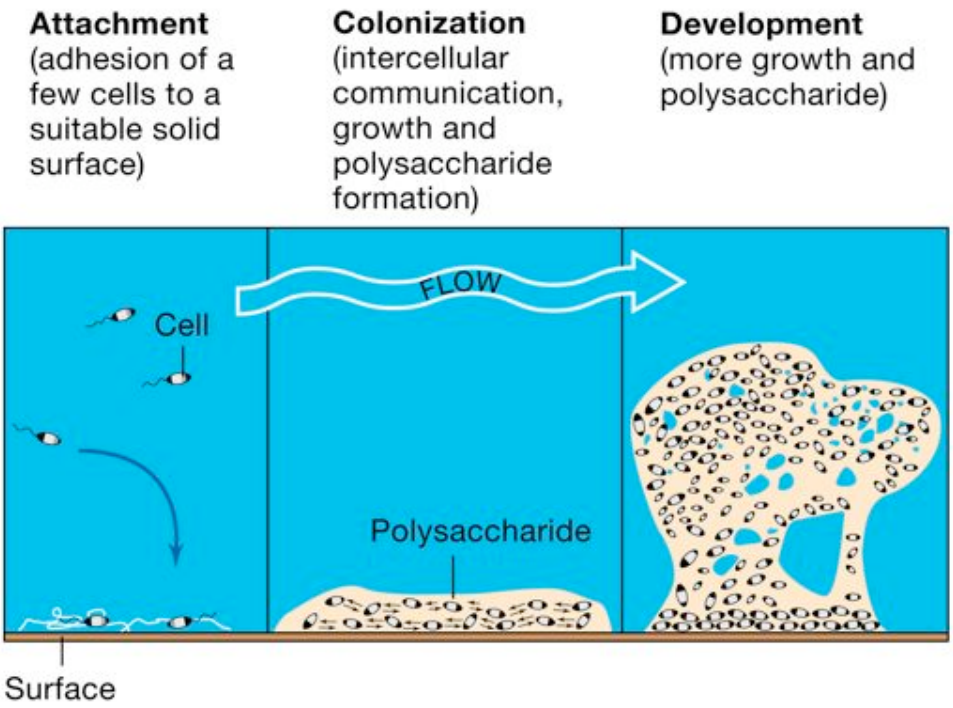
Colonization occurs with well organized biofilm formation

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)

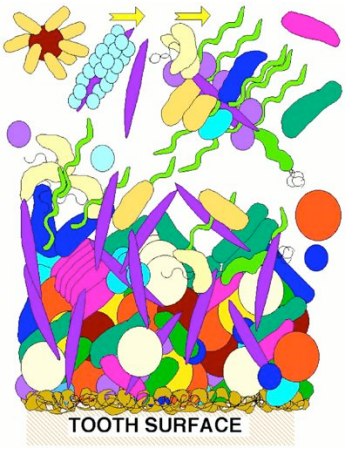
Formation of microcolonies and matrix

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



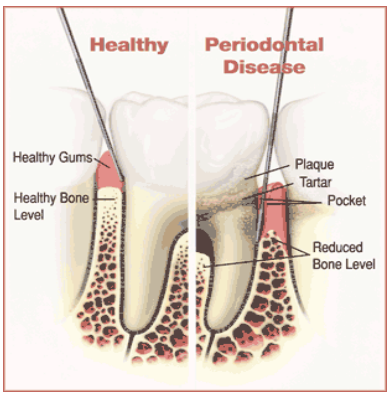
## Consequences of dental infection

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

Formation of deep pockets

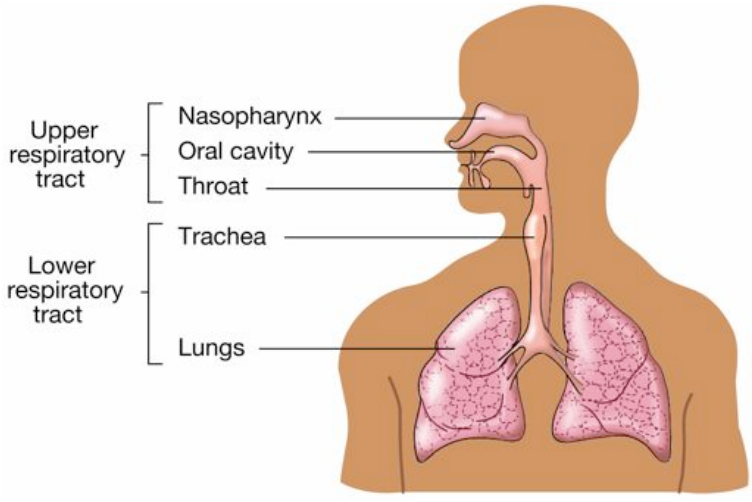
Accumulation of substrates and colonization of transient pathogens

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



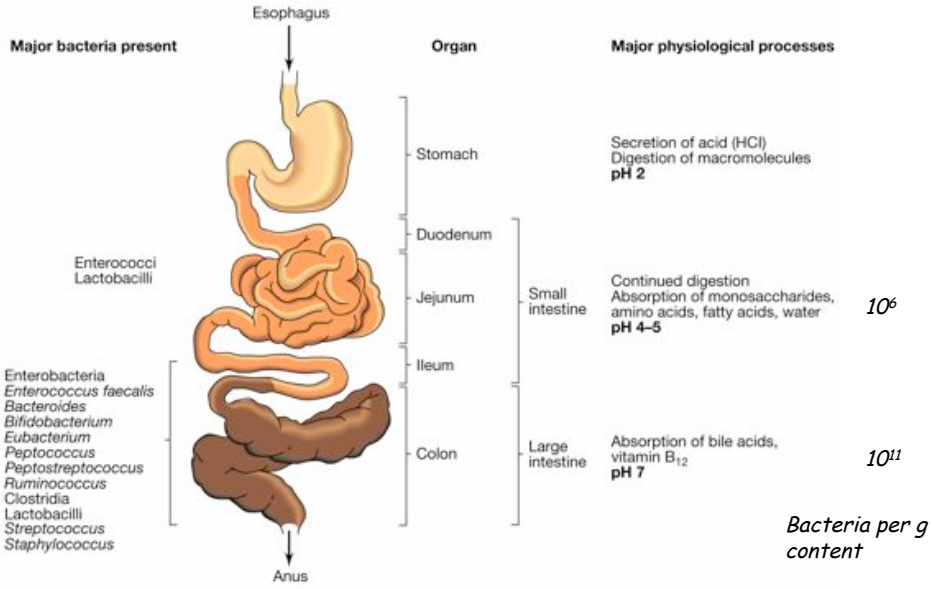

*Dental infections are dependent on age , hygiene, diet and health condition*

## The respiratory tract




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

# The intestinal tract




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

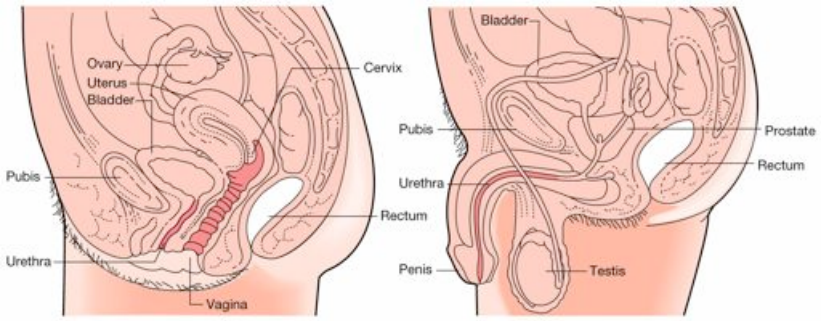
***Helicobacter pylori***
Chemolithoautotrophic Knallgasbacteria

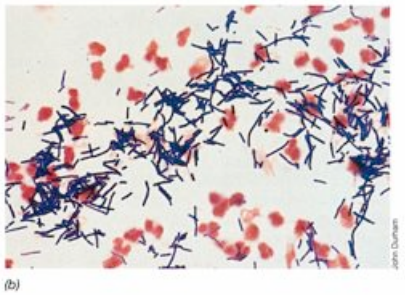
***Helicobacter pylori***

Infection may cause chronic gastritis

Isolated by Robin Warren and Barry Marschall (Nobelprize 2005)

## 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!

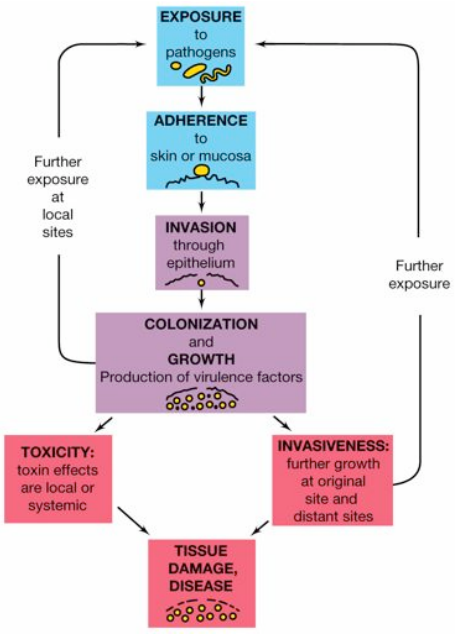
## Pathogenity of microorganisms

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*)

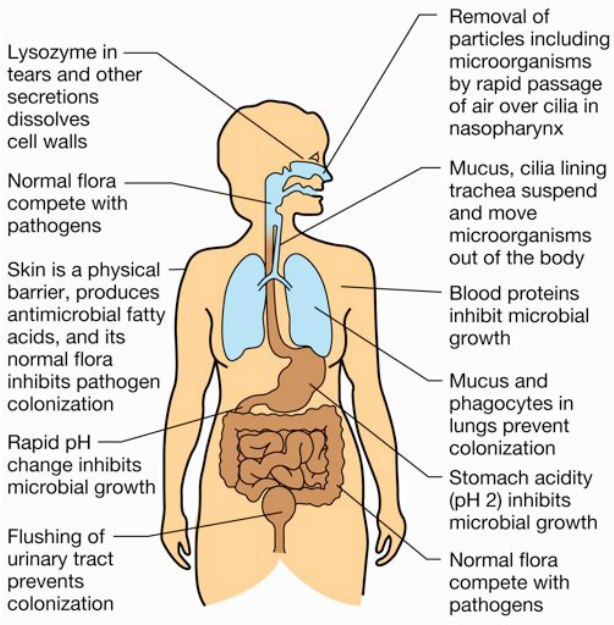


## Why do pathogens harm the body?

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

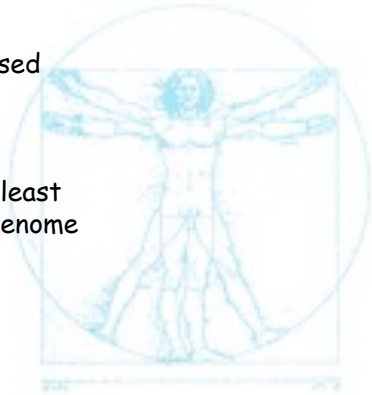


# Habitat Human

## A metagenomic approach

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

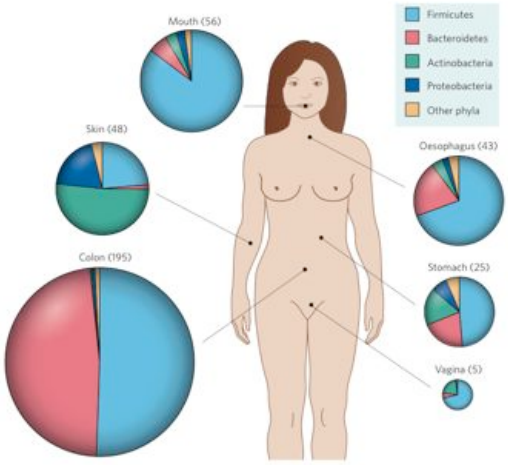
Whose collective genome contains at least 100 times as many genes as our own genome



**"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.

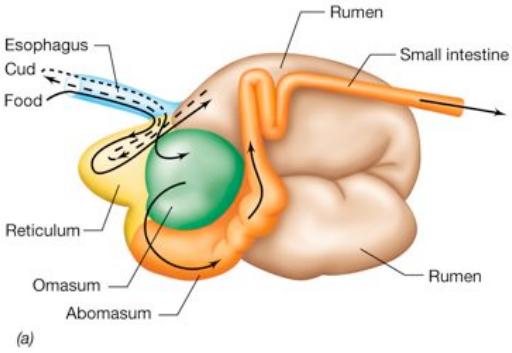
Rumen contain microorganisms that degrade cellulose and other hardly degradable plant polysaccharides

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

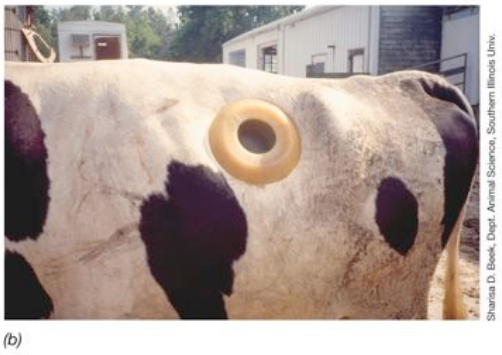
Bacterial cell concentration is $10^{10}$-$10^{11}$ cells per g rumen fluid

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

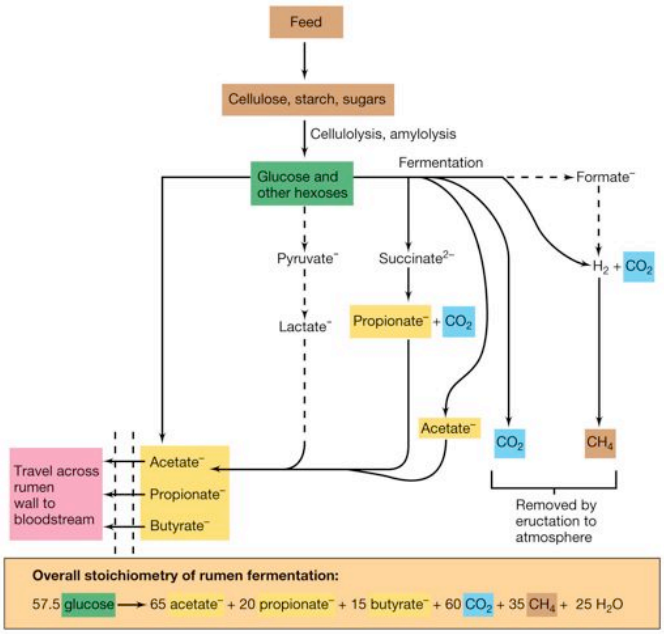
The omasum posses the reduction of the water content

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

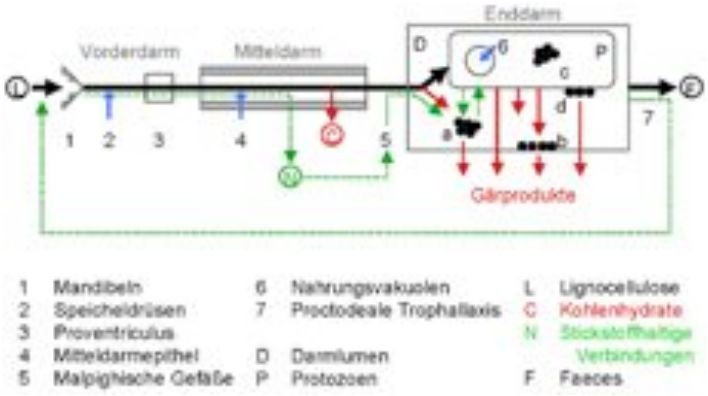
## Wood degradation by microbes in the termite gut

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



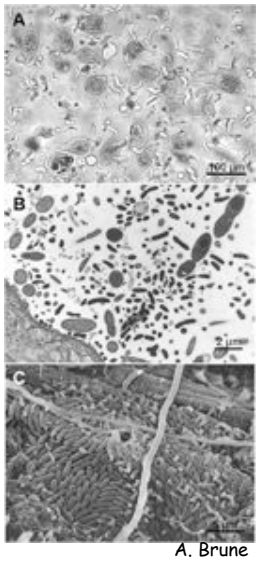

A. Brune

## Microbial symbionts in wood degrading termites

Anaerobic Flagellates

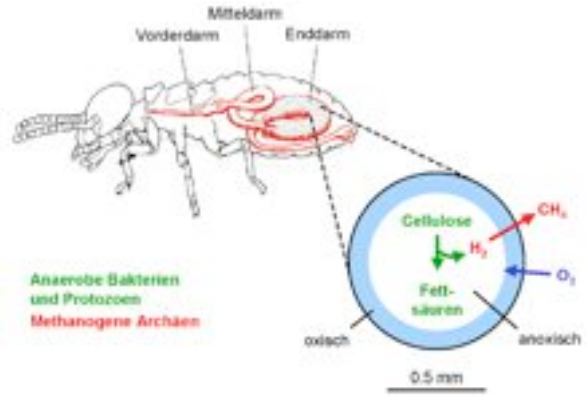
Prokaryotes in the periphery of the gut

Colonization on the gut wall (inside)




A. Brune

# The termite gut as bioreactor

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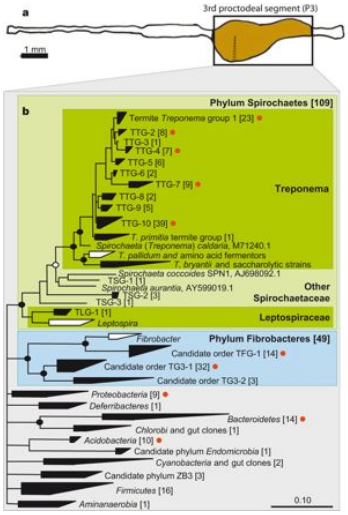
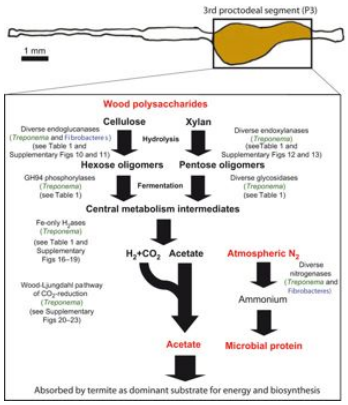
# The termite gut as bioreactor
# -Another metagenome-




F. Warnecke et al. 2007

# Global methane emission from different habitats

Estimates in $10^{12}$ g/year

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