Munters
Your Perfect Climate

Humidity control and microbial growth

Martin Ginty, Industry Manager – Pharmaceutical
May 2017

Munters Group

Key facts

- Munters began trading in 1946 and incorporated in 1955
- 3,500+ employees
- 17 major Manufacturing Plants
- 7 Logistics and Assembly Hubs
- 53 sales and service centres serving customers in more than 30 countries
- Headquarters in Stockholm, Sweden
- Over 300,000 air treatment systems installed

Munters Group


Agriculture


Automotive


Chemical Processing


Commercial & Public Buildings


Construction


Data Center & Telecom Cooling


Defense & Aerospace


Education


Electronics


Food & beverage


General Industry/Production


Greenhouse


Healthcare


Oil, Gas & Petroleum


Pharmaceutical


Power Generation & Distribution


Pulp, Paper & Printing


Recreation & Leisure


Retail & Supermarkets


Shipbuilding & Marine


Steel Industry

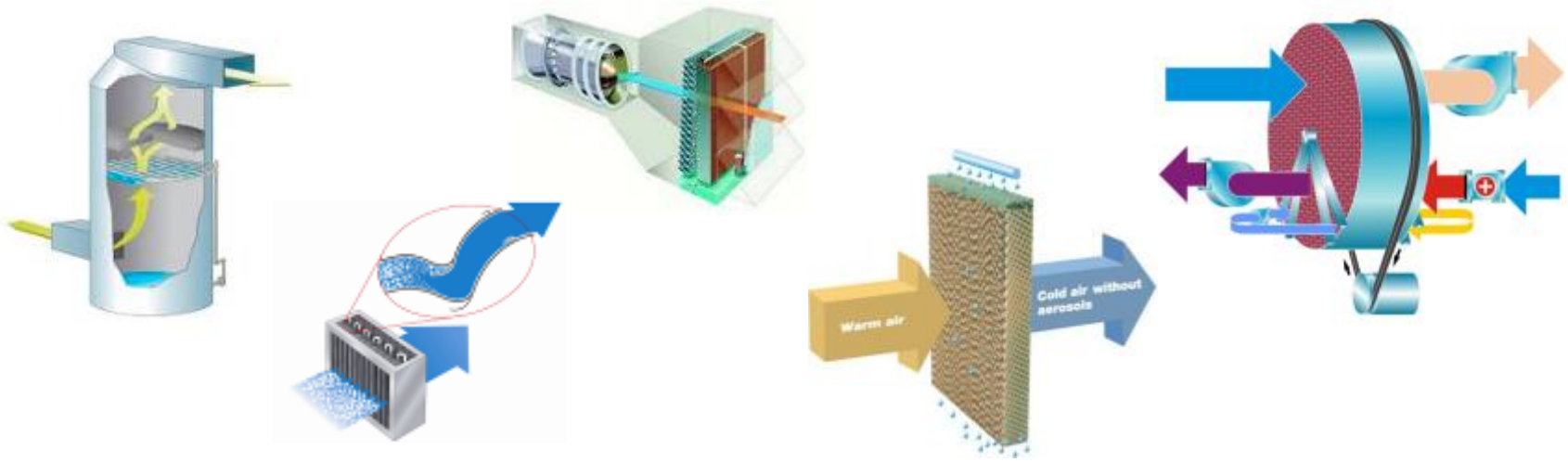

Storage, Preservation & Archives


Temporary Structures

Water & Waste Water

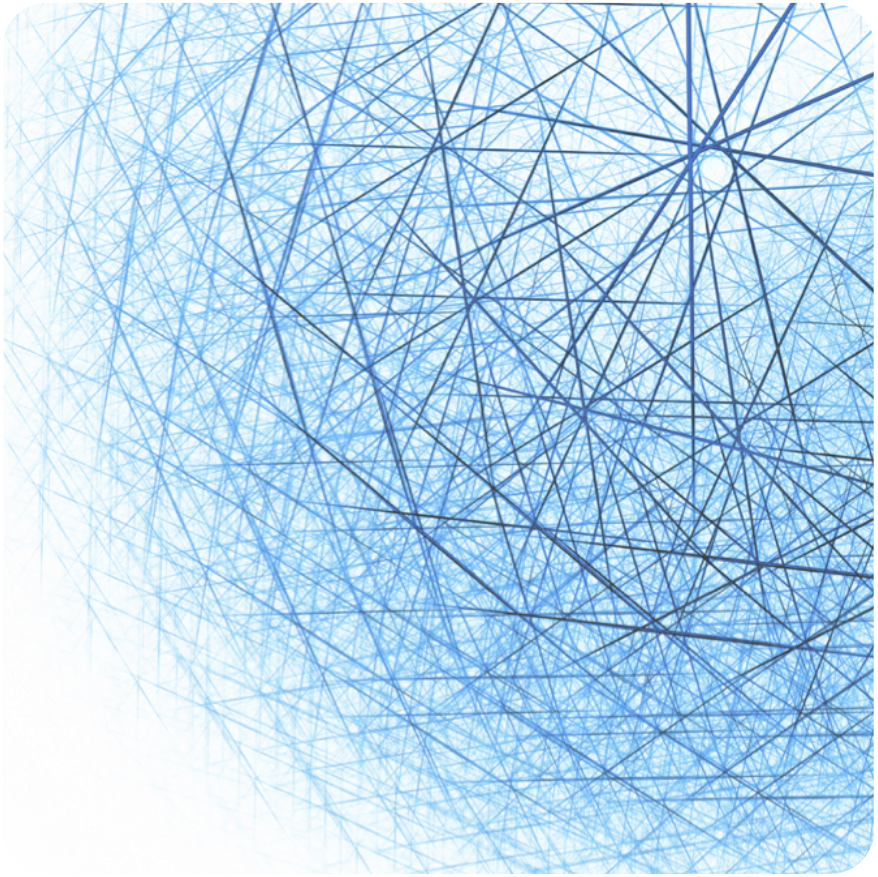
Munters Core Competencies

- Dehumidification
- Humidification
- Evaporative cooling
- Refrigeration
- Heating
- Energy recovery
- Mechanical separation liquid from gas



Overview

- Types of microorganisms
- How humidity and moisture levels affect growth of microorganisms
- Water activity - a_w
- Microorganisms in ambient and chilled spaces



Common types of microorganisms

- Microorganisms occur everywhere
  - In the atmosphere, in water, on plants, animals and in soil,
- They occur most where they find food, moisture, and a temperature suitable for their growth.

Groups	Range of size
Protozoa	5 – 200 µm
Algae	5 µm – a few metres
Yeast	5 – 10 µm
Mould	5–10 µm by metres
Bacteria	0.5 – 5 µm
Viruses	0.015 – 0.2 µm

Which microorganisms can we treat with humidity control?

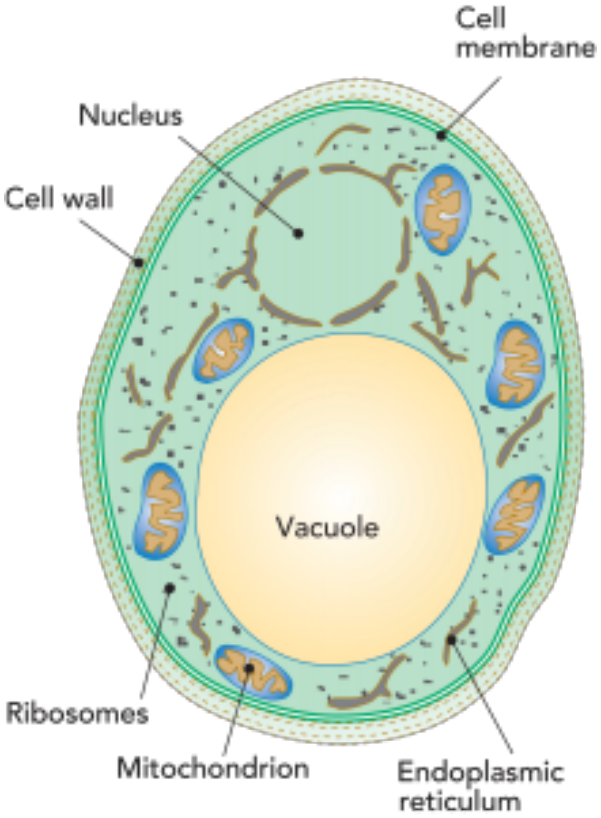
Dehumidification is effective against the following:

- Fungi
  - Moulds
  - Yeasts
- Bacteria

- Reducing the amount of available water and water vapour reduces or stops growth

Dehumidification is not effective against the following

- Viruses
  - Most viruses prefer dry conditions to spread.


Cell membrane
Nucleus
Cell wall
Vacuole
Ribosomes
Mitochondrion
Endoplasmic reticulum

Yeasts

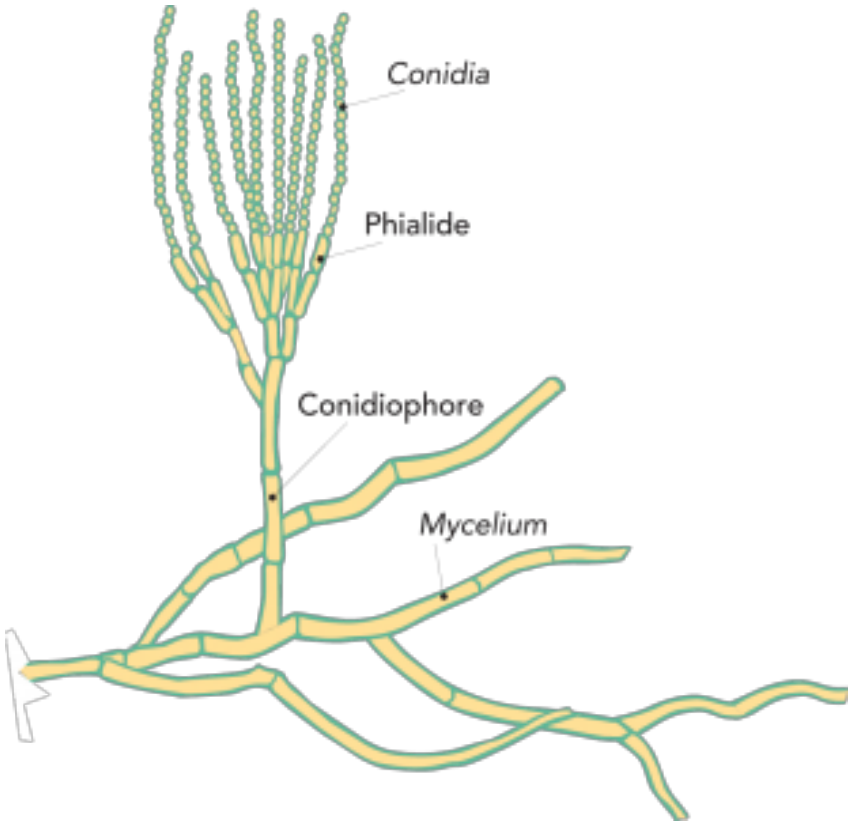
Yeasts

- Unicellular, oval or round in shape - Single cellular type of fungi.
- Found in many environments: soil, plants and fruits.
- Used as food supplement and in the production of alcoholic beverages.
- Food spoilage organisms, especially of high acid foods.
- Most susceptible foods/beverages for yeast spoilage have:
  - Low pH (5.0 or lower) which restricts the growth of competing bacteria.
  - High sugar & organic acid content (easily metabolized carbon sources).

Health issues

- Some species of yeast can cause infection in people with weak immune systems.
  - Cryptococcus neoformans
  - Cryptococcus gattii

- Yeasts of the Candida genus cause infections in humans, known as candidiasis. Candida is commonly found in the mucous membranes of humans and other warm-blooded animals.
  - Candida albicans
  - Candida tropicalis
  - Candida stellatoidea
  - Candida glabrata
  - Candida krusei
  - Candida parapsilosis
  - Candida guilliermondii
  - Candida viswanathii
  - Candida lusitaniae
  - Rhodotorula mucilaginosa



Moulds and fungi

Moulds and fungi

- Multicellular.
- Always found in soil, but can also be found in water and air - present in almost all materials.
  - There are between 10000 to 1000000 per m^3 fungi spores in the air you are breathing right now!
- They can survive without moisture, remaining dormant for decades, even centuries.
- Multiply rapidly when moisture and a food source become available
  - They don't need liquid water to grow, they can even use moisture present in solid materials.
- Responsible for the decomposition of many materials.
- Useful for industrial production of many chemicals, including penicillin.
- Can cause diseases in humans, animals, and plants.
- Many thousands of known species, the five most common types of indoor moulds are Cladosporium, Penicillium, Aspergillus, Alternaria and Trichoderma.

Health effects

- People who are sensitive, already suffer from allergies, asthma, or weak immune systems and occupy damp or mouldy buildings are at an increased risk of health problems such as inflammatory and toxic responses to mould spores, their by-products and other components.
- A person's reaction to mould depends on:
  - Their sensitivity and other health conditions.
  - The amount of mould present.
  - Length of exposure.
  - The type of mould or mould products.
- The most common health problem is an allergic reaction. Severe reactions are rare but possible.
- Some moulds, such as Stachybotrys chartarum, also produce mycotoxins that can pose serious health risks.
- Exposure to high levels of mycotoxins can lead to neurological problems and in some cases death.

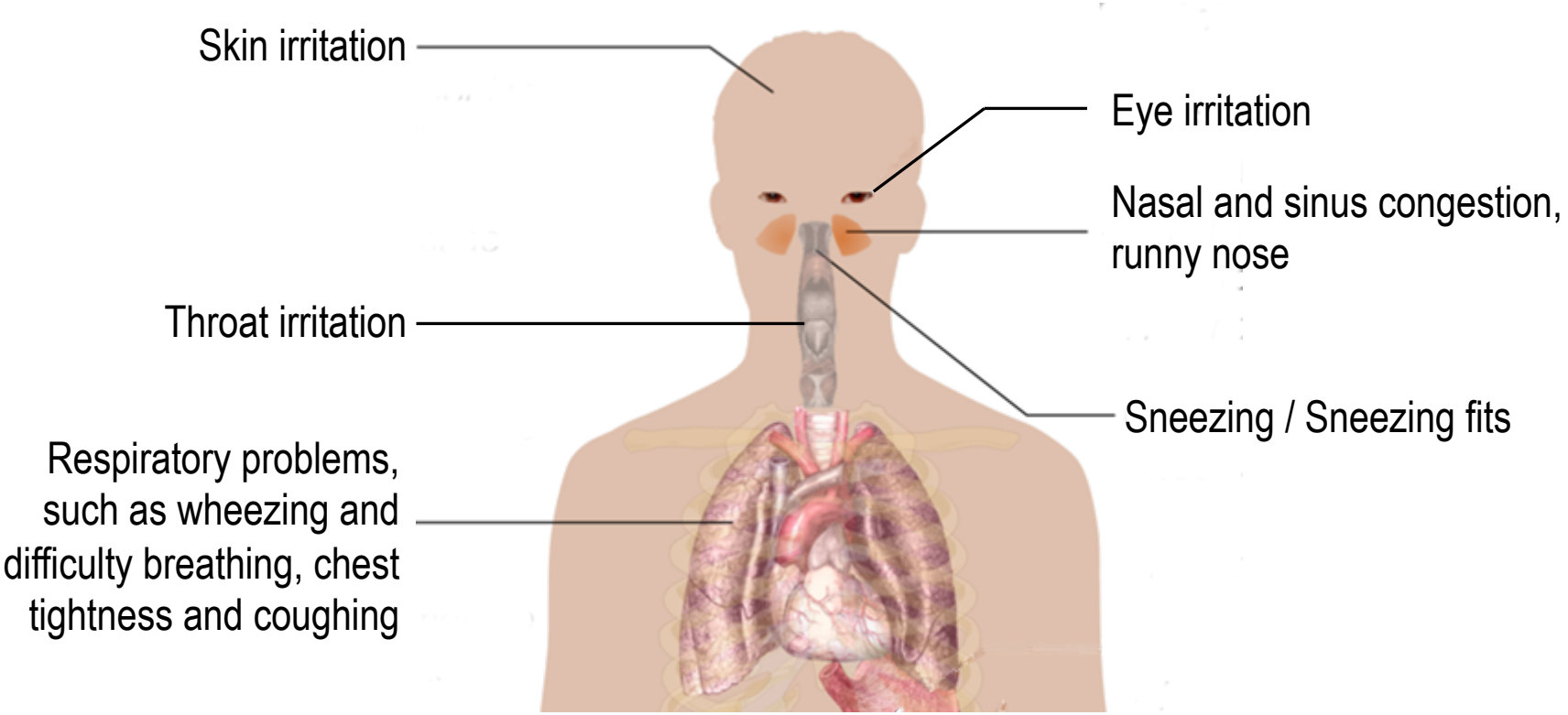
Health effects - Sick Building Syndrome (SBS) and Building Related Illness (BRI)

- Sick Building Syndrome (SBS) and Building Related Illness (BRI) are several nonspecific symptoms (e.g. mucosal irritations, smarting eyes, repeated common colds, but also fatigue and weakness of concentration) when persons stay in certain buildings, without finding a clear cause.

- Factors that can contribute to SBS and BRI are viruses, pollen, mites, nitrogen oxides, carbon monoxide, ozone, radon, emissions from building and facility materials and electromagnetic fields and also “Microbial Volatile Organic Compounds” (MVOC) and fungus spores.

- There is a connection between increased indoor concentrations of penicillium spores and SBS.

Symptoms of mould exposure

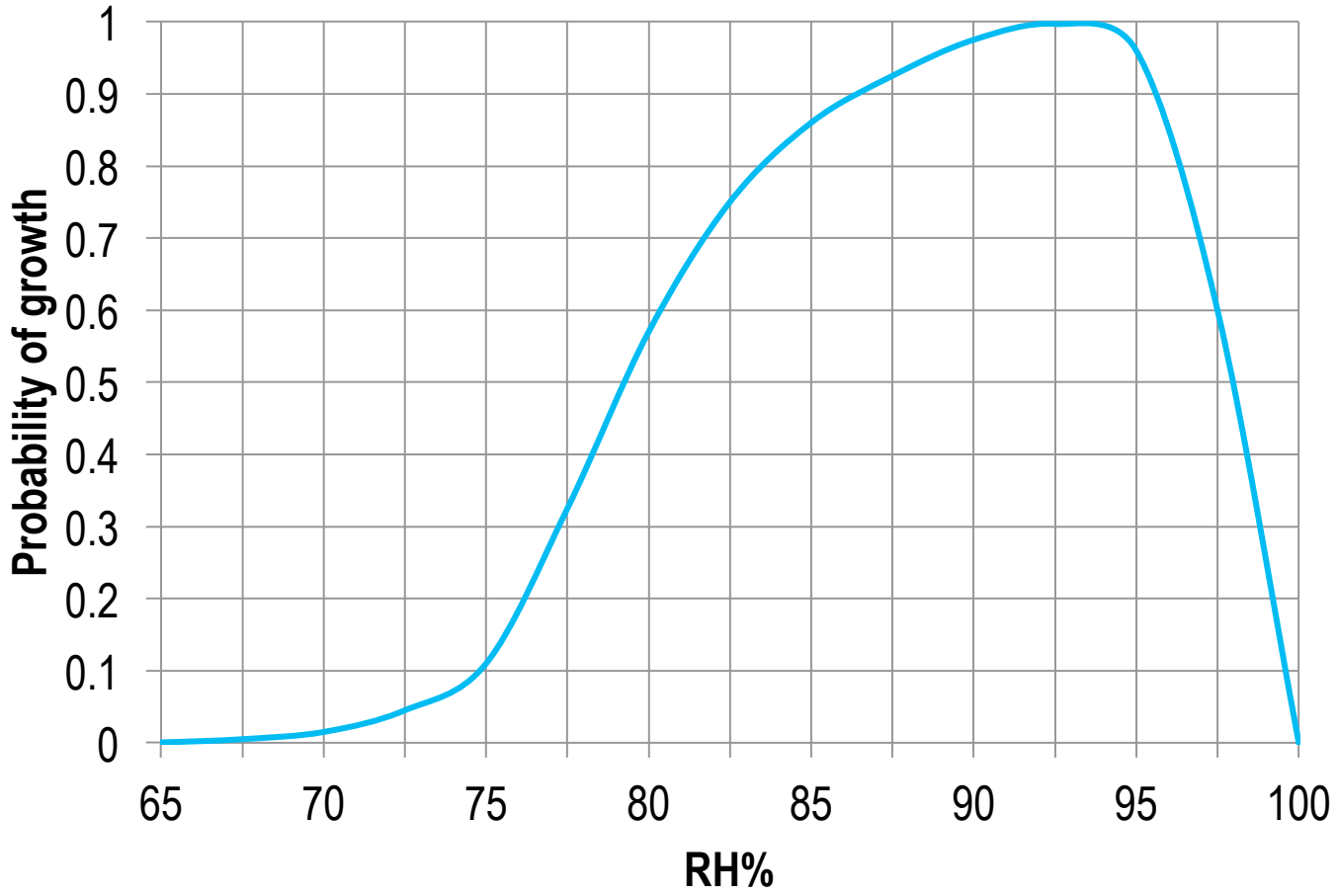


Mould growth

Mould growth

- Moisture is needed for any growth to occur.
- Moulds do not need droplets of water to form - water vapor concentrations of > 80% relative humidity are sufficient.
- Once established, some moulds can transport free water to dry areas. (e.g. dry rot)
- Moulds can be highly hygroscopic due to large surface area. The result is that water molecules are filtered from the air (thawing effect). This process is particularly enhanced when mould develops on cold walls.

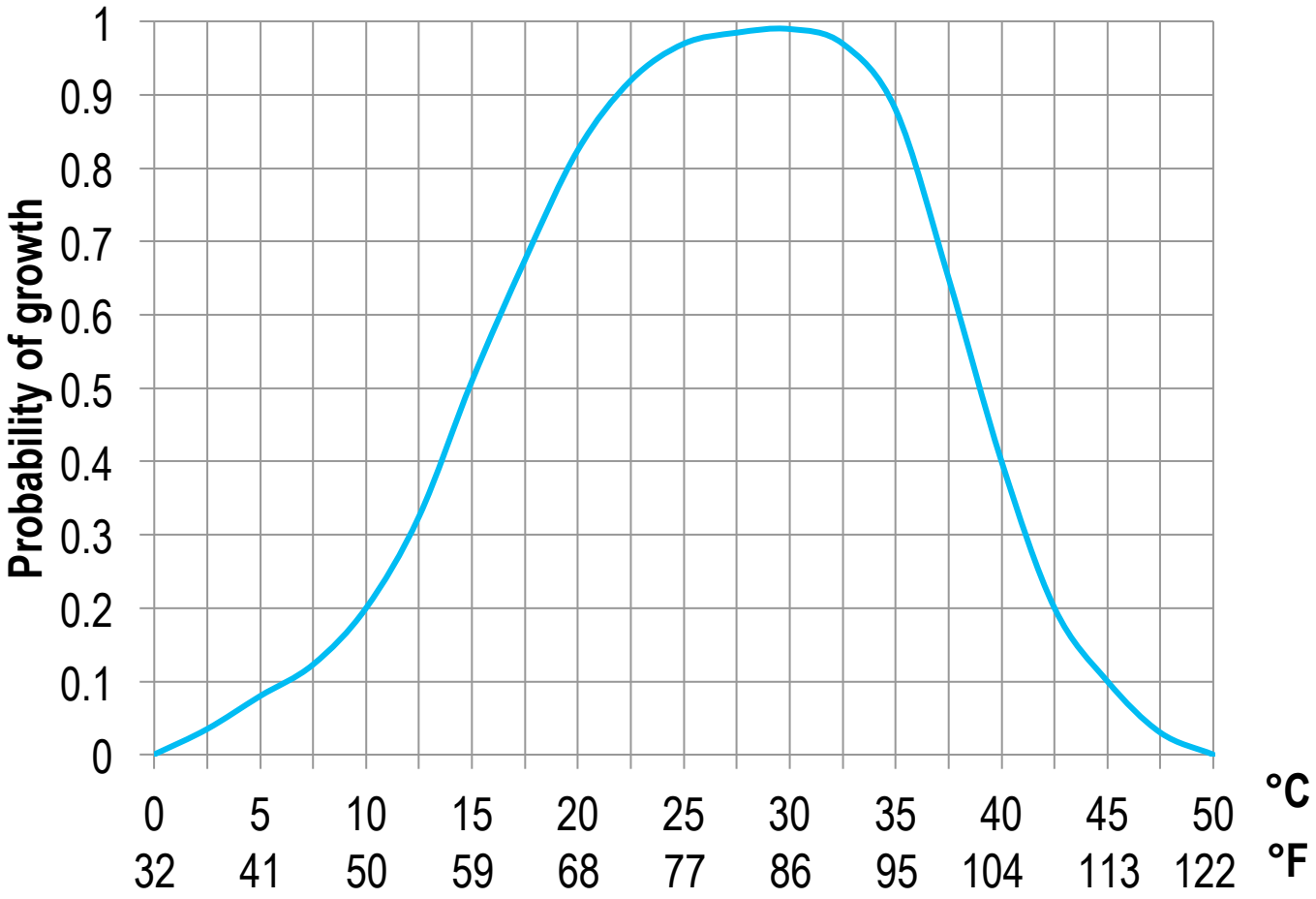
Effect of Relative Humidity on mould growth



Source: http://www.ibp.fraunhofer.de/content/dam/ibp/de/documents/Publikationen/Fachzeitschriften/mold_growth_predictiontcm45-35017.pdf

Munters

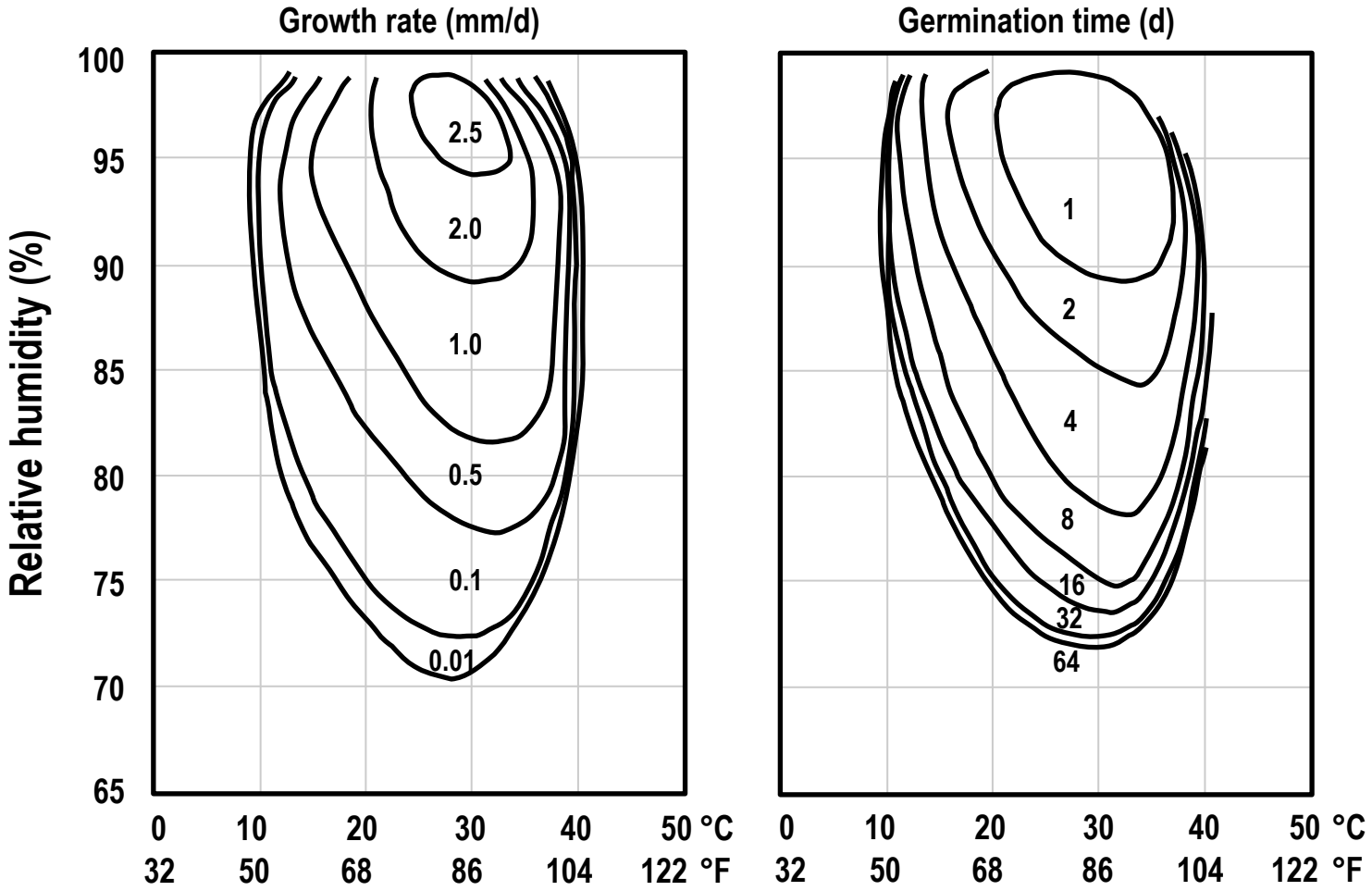
Effect of temperature on mould growth



Source: http://www.ibp.fraunhofer.de/content/dam/ibp/de/documents/Publikationen/Fachzeitschriften/mold_growth_predictiontcm45-35017.pdf

Munters

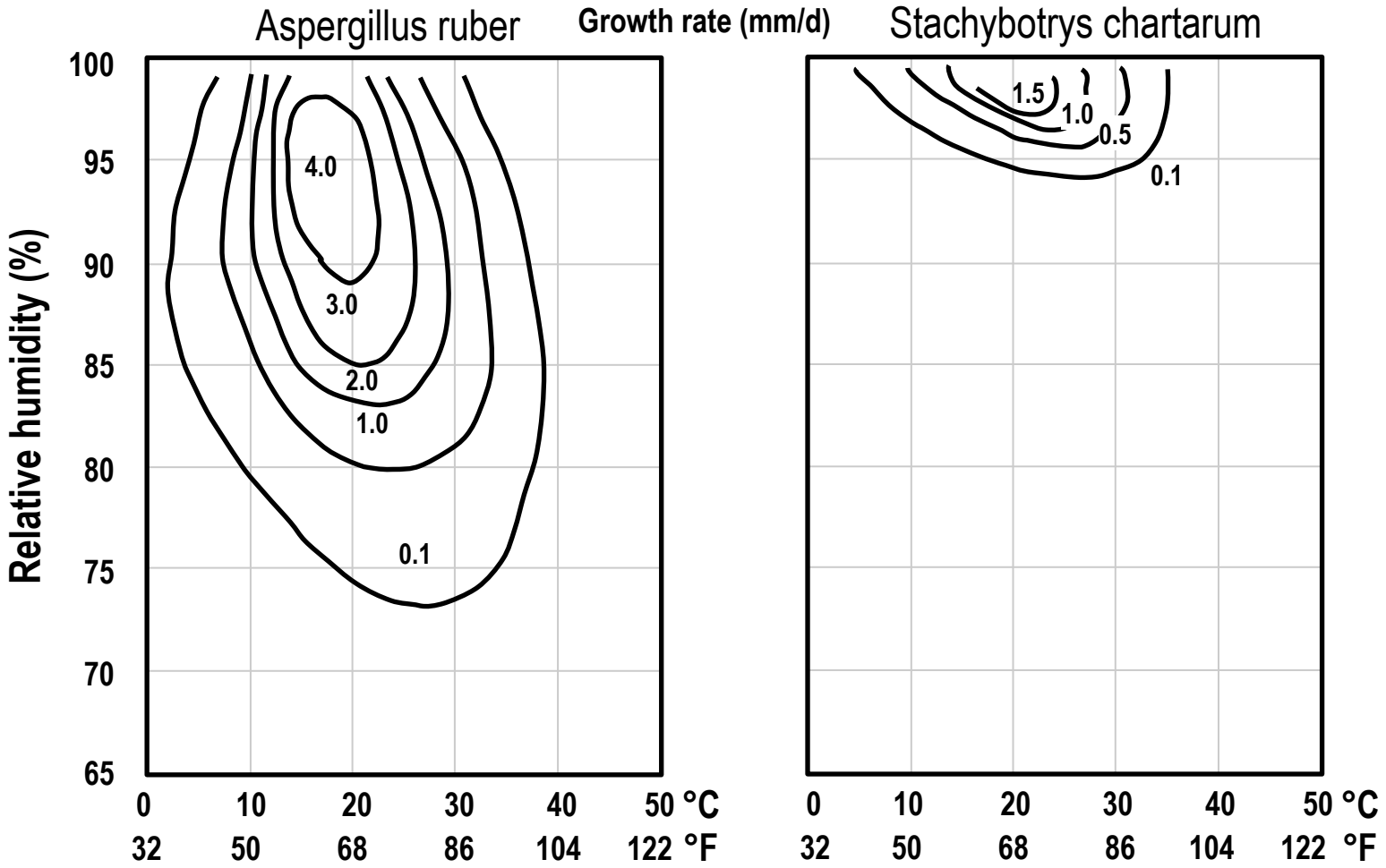
Isopleths of growth rate and germination for Aspergillus restrictus



Source: http://www.ibp.fraunhofer.de/content/dam/ibp/de/documents/Publikationen/Fachzeitschriften/mold_growth_predictiontcm45-35017.pdf

Munters

Isopleths of growth rate for Aspergillus ruber & Stachybotrys chartarum

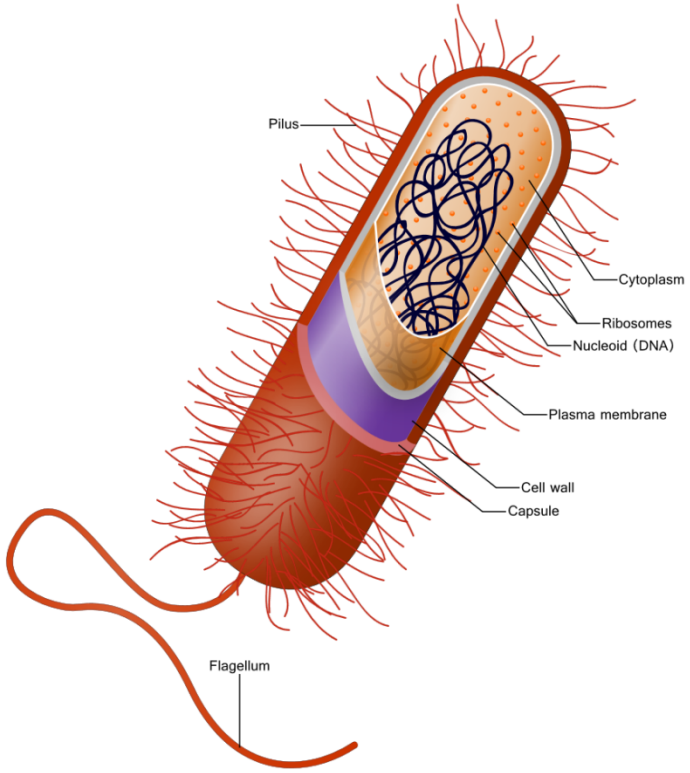


Source: http://www.ibp.fraunhofer.de/content/dam/ibp/de/documents/Publikationen/Fachzeitschriften/mold_growth_predictiontcm45-35017.pdf

Munters

Isopleth systems for different building products / surfaces

Substrate-group	0: Optimum culture medium	I: Biologically recycable building materials	II: Biologically adverse re-cycable building materials
	Agar or gelatine culture (petri dish)	Wall paper, plaster cardboard, building materials made of biologically degradable raw materials, material for permanently elastic joints	Building materials with porous structure such as renderings, mineral building material, certain wood as well as insulation material not covered by I


Pilus
Cytoplasm
Ribosomes
Nucleoid (DNA)
Plasma membrane
Cell wall
Capsule
Flagellum

Bacteria

Bacteria

- A highly variable group of microorganisms.
- Found in almost all environments.
- Some cause diseases, others perform important roles in the natural recycling of elements, and thus contribute to soil fertility.
- Useful in industries for the manufacture of valuable compounds.
- Some are surrounded by a capsule of mucus. This makes them resistant against dry conditions.

Bacteria

- Bacteria require certain nutrients for their growth.
  - The need for nutrients varies widely among different bacteria.
  - The main sources of food are organic compounds
    - e.g. Proteins, fats and carbohydrates.
  - In addition, small amounts of trace elements and vitamins are necessary for growth.

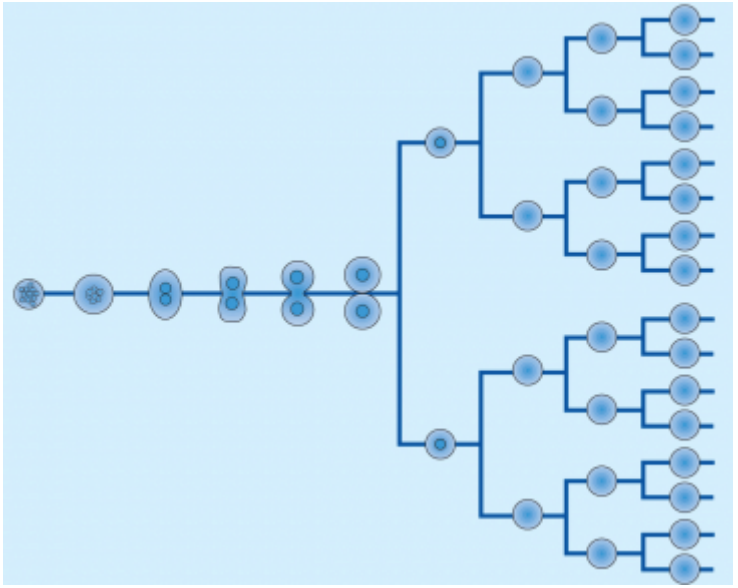
- As well as material for cell formation, organic matter also contains energy.

- Such matter must be soluble in water and have a low molecular weight
  - i.e. It must be broken down into very small molecules in order to be able to pass through the outer skin and be metabolized by the bacterium.

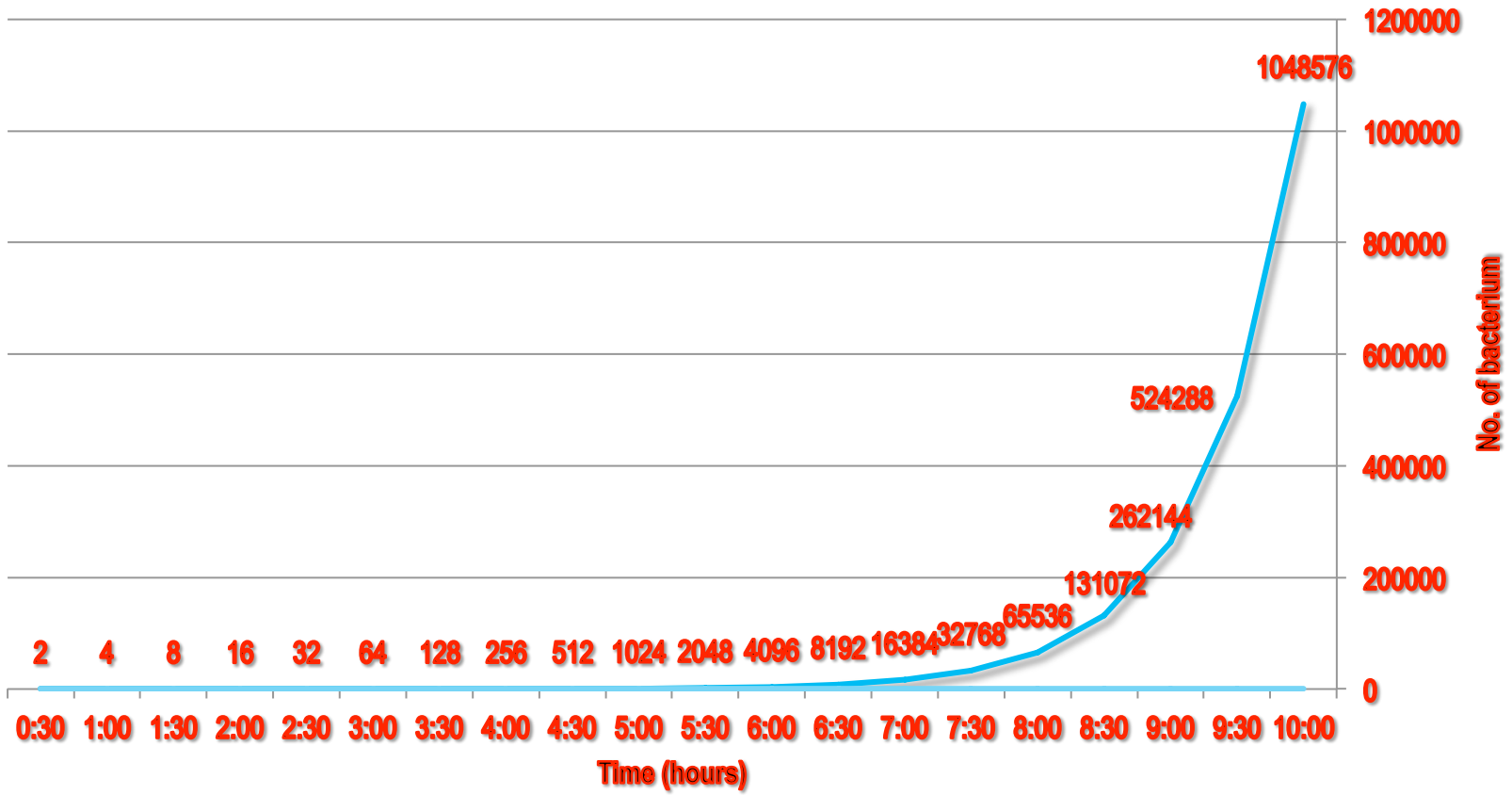
- **Bacteria need access to water.**

Multiplication of Bacteria

- Bacteria normally multiply by binary fission.
- Each individual cell grows and after reaching a critical size, it divides into two identical cells. The type of cell arrangement, which results in a characteristic cell grouping, is usually constant for a given species of bacteria.
- Cell grouping can take the forms of chains, pairs and clumps. This characteristic is therefore used in the description of different species.
- In favourable conditions, multiplication of bacteria can occur at intervals of 20 – 30 minutes.



Growth curve of bacteria

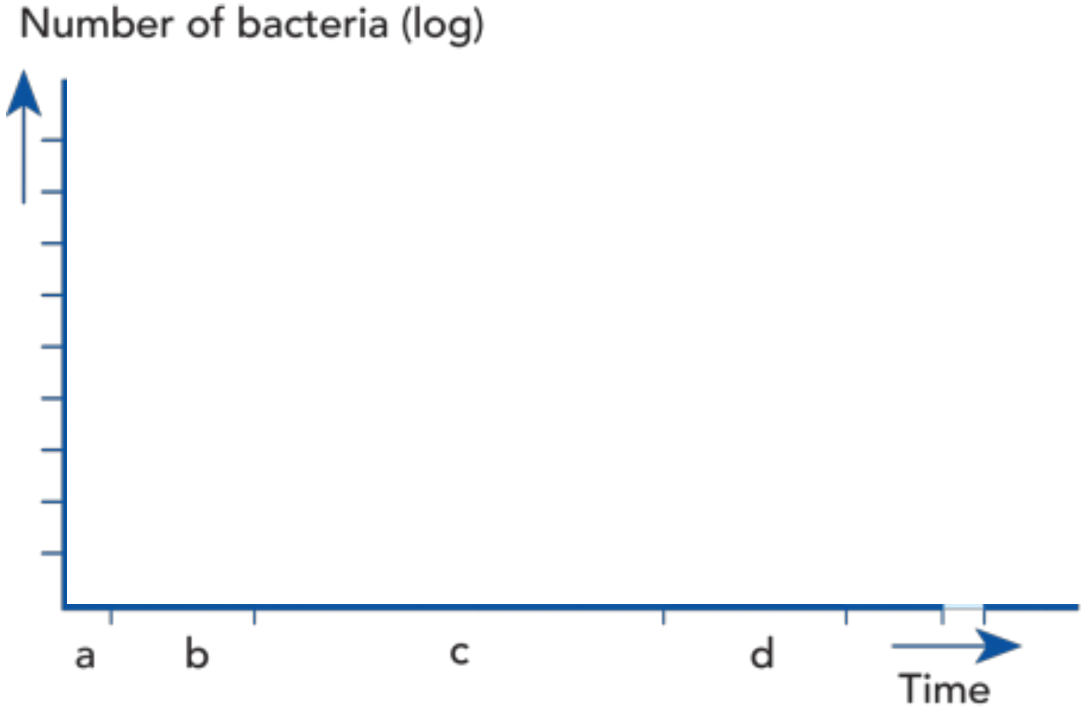


Munters

Lifecycle of bacteria

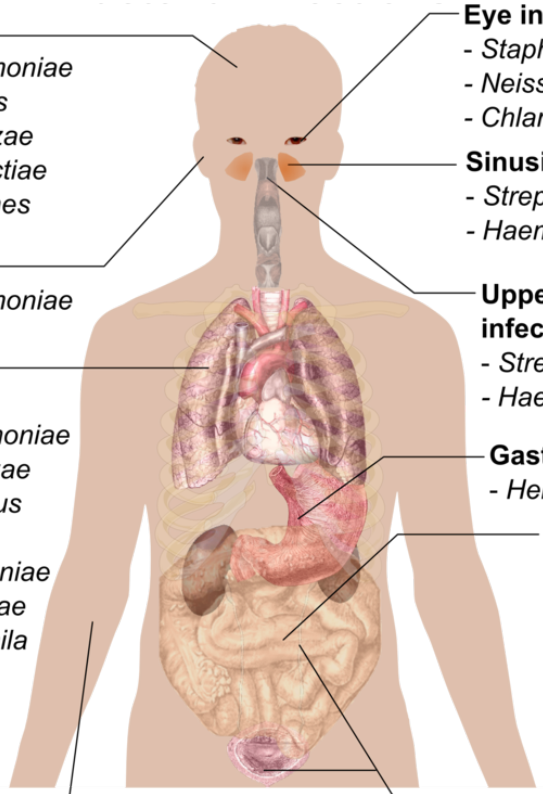
[illegible] environment.

[illegible] involved in DNA repair, antioxidant metabolism and nutrient transport.



Munters

Bacterial Infections



Bacterial meningitis
- *Streptococcus pneumoniae*
- *Neisseria meningitidis*
- *Haemophilus influenzae*
- *Streptococcus agalactiae*
- *Listeria monocytogenes*

Otitis media
- *Streptococcus pneumoniae*

Pneumonia
Community-acquired:
- *Streptococcus pneumoniae*
- *Haemophilus influenzae*
- *Staphylococcus aureus*

Atypical:
- *Mycoplasma pneumoniae*
- *Chlamydia pneumoniae*
- *Legionella pneumophila*

Tuberculosis
- *Mycobacterium tuberculosis*

Skin infections
- *Staphylococcus aureus*
- *Streptococcus pyogenes*
- *Pseudomonas aeruginosa*

Sexually transmitted diseases
- *Chlamydia trachomatis*
- *Neisseria gonorrhoeae*
- *Treponema pallidum*
- *Ureaplasma urealyticum*
- *Haemophilus ducreyi*

Eye infections
- *Staphylococcus aureus*
- *Neisseria gonorrhoeae*
- *Chlamydia trachomatis*

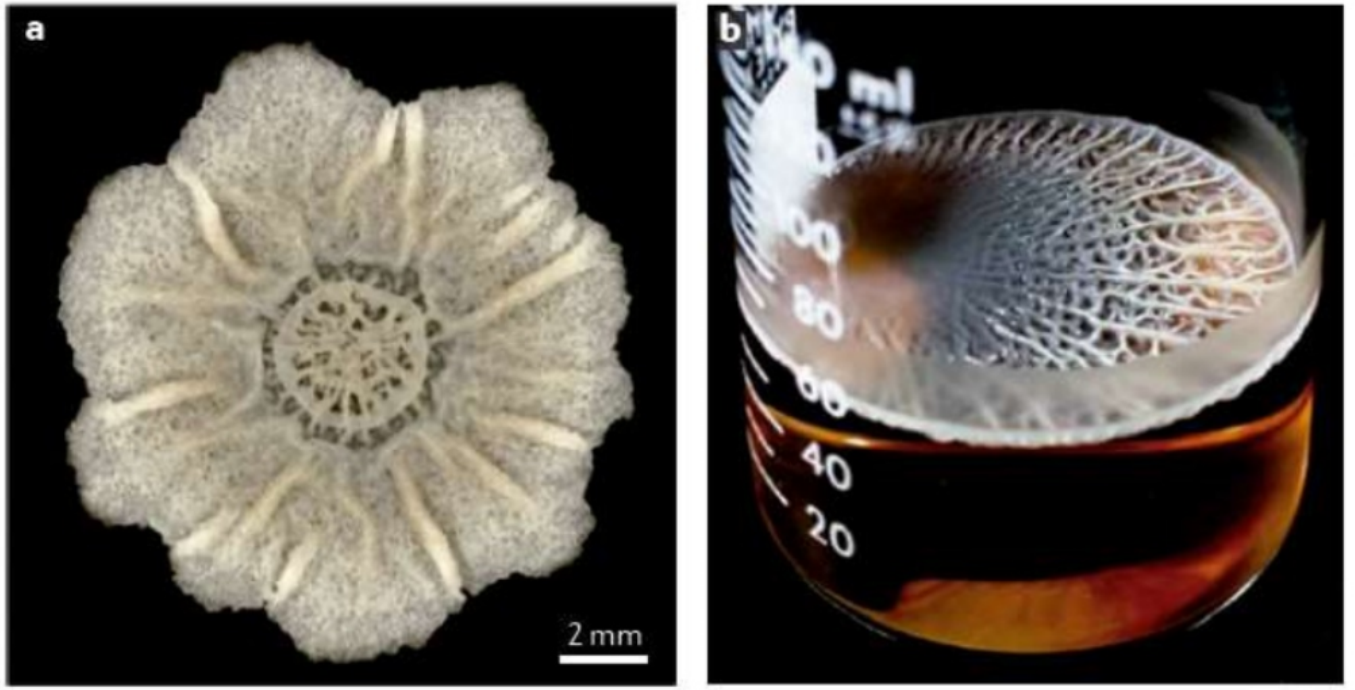
Sinusitis
- *Streptococcus pneumoniae*
- *Haemophilus influenzae*

Upper respiratory tract infection
- *Streptococcus pyogenes*
- *Haemophilus influenzae*

Gastritis
- *Helicobacter pylori*

Food poisoning
- *Campylobacter jejuni*
- *Salmonella*
- *Shigella*
- *Clostridium*
- *Staphylococcus aureus*
- *Escherichia coli*

Urinary tract infections
- *Escherichia coli*
- Other Enterobacteriaceae
- *Staphylococcus saprophyticus*
- *Pseudomonas aeruginosa*



Biofilms

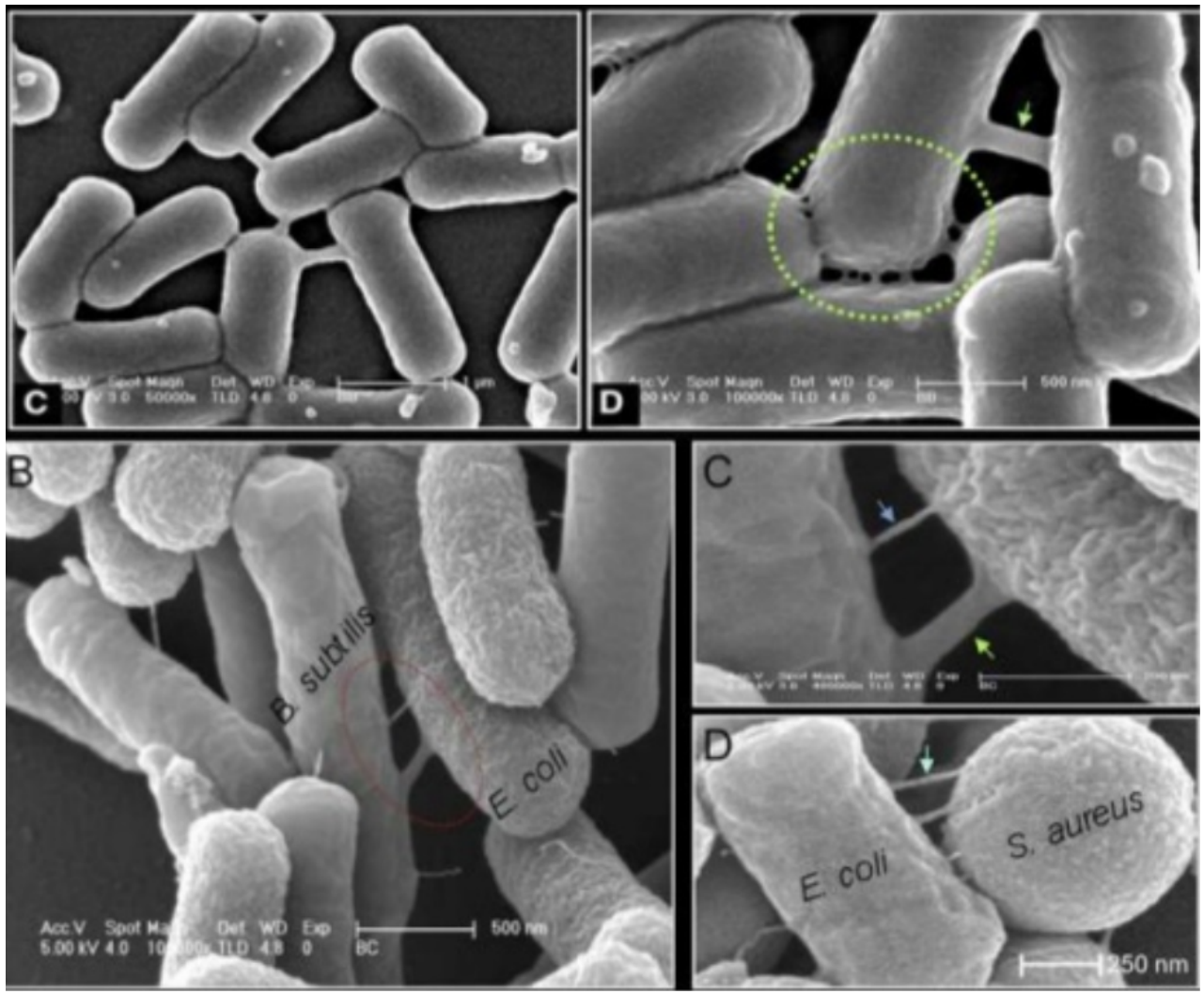
Biofilms

- A biofilm is any group of microorganisms in which cells stick to each other - often these cells stick to a surface.
- These stuck together cells are frequently embedded within a self-produced matrix of extracellular polymeric substance (EPS), which is also referred to as slime.
- Biofilms may form on living or non-living surfaces and can be found in natural, industrial and hospital settings. The cells growing in a biofilm are physiologically distinct from single-cells of the same organism that may float or swim in a liquid medium.
- Microbes form a biofilm in response to many factors,
  - Cellular recognition of specific or non-specific attachment sites on a surface.
  - Available food.
  - Antibiotics not killing the microbe.
- When a cell switches to the biofilm mode of growth, it behaves differently compared to isolated cells.
  - Faster growth.
  - Resistance to detergents and antibiotics.

Biofilms

- Biofilms will form on virtually every non-shedding surface in a non-sterile wet (or very humid) environment.
- Biofilms can grow in showers very easily since they provide a moist and warm environment for the biofilm to thrive.
- Biofilms are more resistant to disinfectants, cleaning, antibiotics and changes in environment than isolated bacteria.
- They are mainly made up of bacteria but depending on conditions (e.g. moisture) they may also contain algae, yeasts and moulds.
  - Worst case as there could be multiple health risks.

Biofilms in action



Munters

Biofilms in action

Water Activity - a_w

Water Activity

- The growth and metabolism of microorganisms need water in an available form, which is measured as water activity, a_w

- The a_w of a solution equals the ratio of the water vapour pressure of the solution (p) to that of pure water (p0) at the same temperature. When a solution becomes more concentrated, vapour pressure decreases and the a_w drops from a maximum value of 1 for pure water.

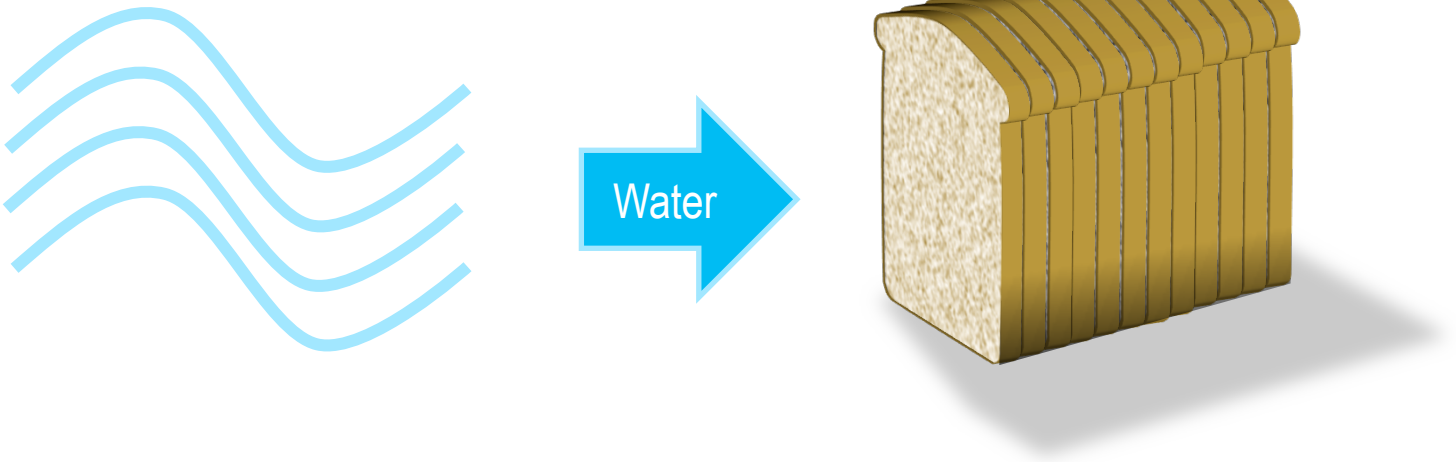
- **A material's "water activity" is equivalent to the relative humidity of the air that would be in equilibrium with the material at that material moisture content.**

Substance	a_w
Distilled Water	1.00
Tap water	0.99
Saturated NaCl solution	0.75
Typical indoor air	0.5 - 0.7

Water Activity – Food Example

Ambient air
RH: >95%

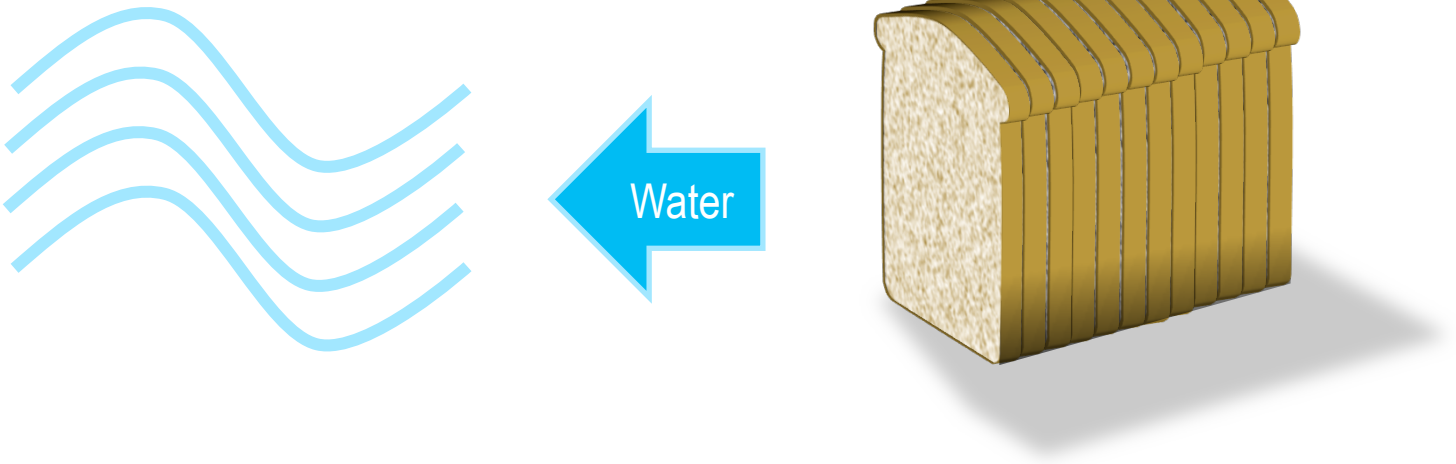
Bread
Typical a_w: 0.95



Water Activity – Food Example

Ambient air
RH: <95%

Bread
Typical a_w: 0.95

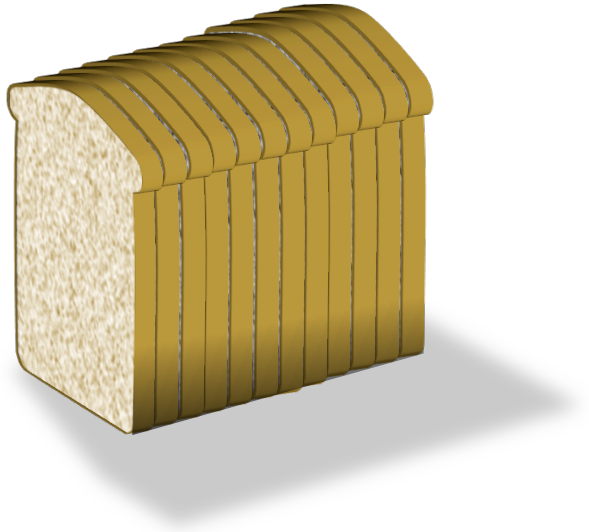


Water Activity – Food Example

Ambient air
RH: 95%

No water exchange

Bread
Typical a_w: 0.95



Examples of Water Activity and Microbial Growth

Many microorganisms, including pathogenic bacteria, grow most rapidly at levels of a_w in the range of 0.99 – 0.98. Below this the growth rate decreases.

Microorganism	Range of a_w
Most bacteria	0.85 - 0.97
Most moulds	0.80 – 0.95
Most yeasts	0.75 - 0.88
Xerophilic Yeasts	0.70 - 0.75
Osmophilic yeasts	0.60 - 0.70
Xerophilic moulds	0.60 - 0.75
No microbial proliferation	0.50

No microorganisms can grow at an $a_w < 0.50$

Munters
Your Perfect Climate

Micro-organisms in ambient conditions

Sources of moisture in manufacturing environments

- Moisture is essential for microbes to grow, so we should always be looking for any sources.

- From the air
- Ingression
- Construction moisture
- Cleaning processes
- Product and production process
- By-product of combustion (gas heating, engines)
- Packaging
- Raw materials
- Production staff
- Excess moisture due to insufficient heating and ventilation
- Bad heat insulation, especially in the area of thermal bridges
- Accidents and unplanned incidences
  - Spillages
  - Leaks
  - Rain on delivered products
  - Driving rain and extreme weather

Sources of moisture can lead to microbial growth

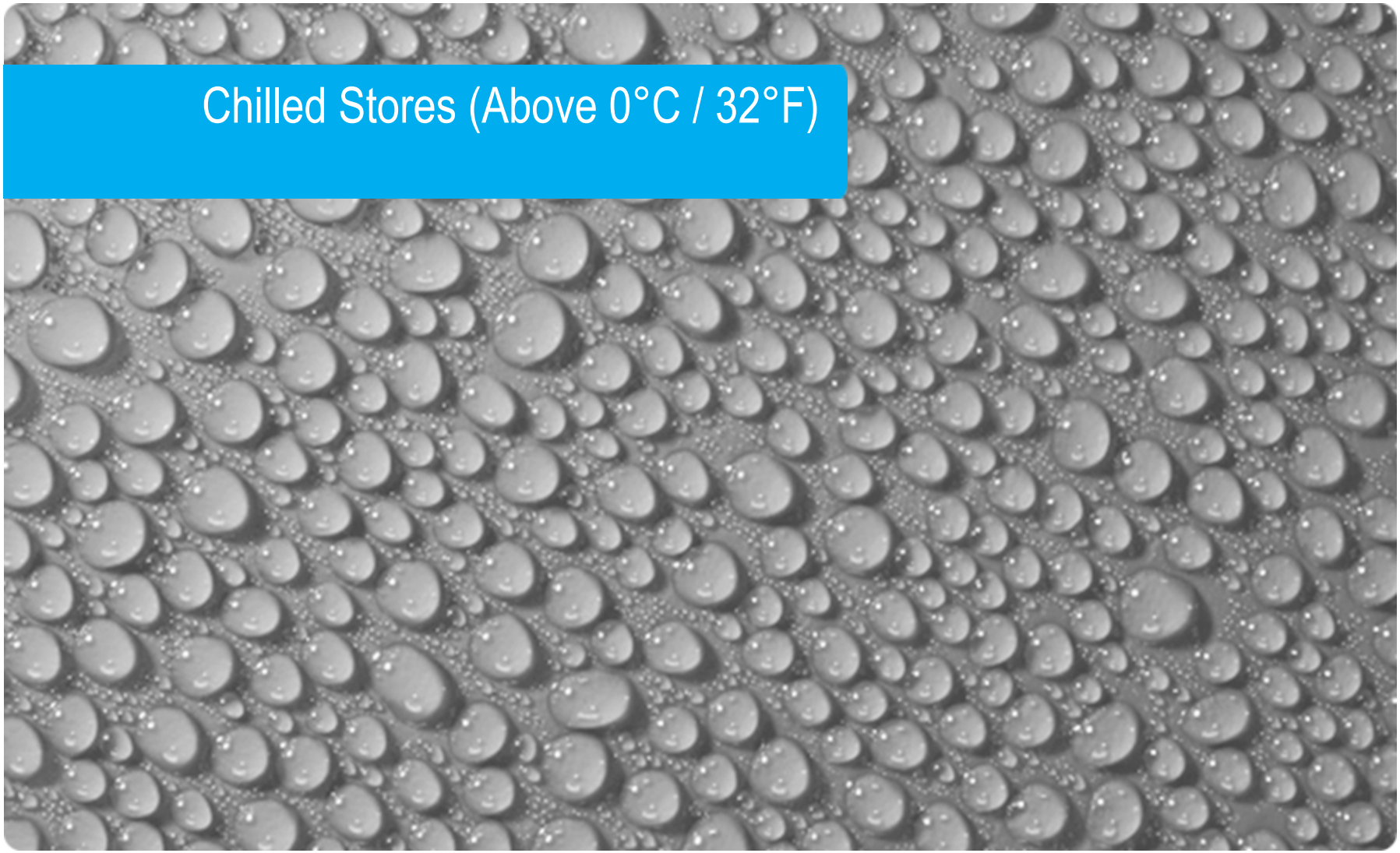
- In general, ambient or treated air above 50% RH will allow some level of microbial growth to take place.
- Condensation on cold surfaces will increase this growth as a_w exceeds 0.9.
- Mould growth happens anywhere when there is moisture and a food source available, and often this is in hard to reach places…
  - Cold water piping behind equipment, cabinets or partitions.
  - Air handling ductwork with either 70%+ RH or water droplets from excessive cooling.
  - Under plant and storage equipment .
  - In clumps of dirt, dust and waste that might accumulate out of sight.
  - In ceiling tiles.
- …and in easy to reach places
  - On exterior walls and doors.
  - Around windows.

Controlling moisture in manufacturing environments

- Humidity control below 50% RH will stop all microbial growth.
- Higher RH levels (up to 70%) will slow growth, and this may be acceptable.
- Temperature control alone is not sufficient as some microbes are specialised to survive temperature extremes.
- Dehumidification and normal air treatment will not remove existing microbes or spores in the environment .

Munters
Your Perfect Climate

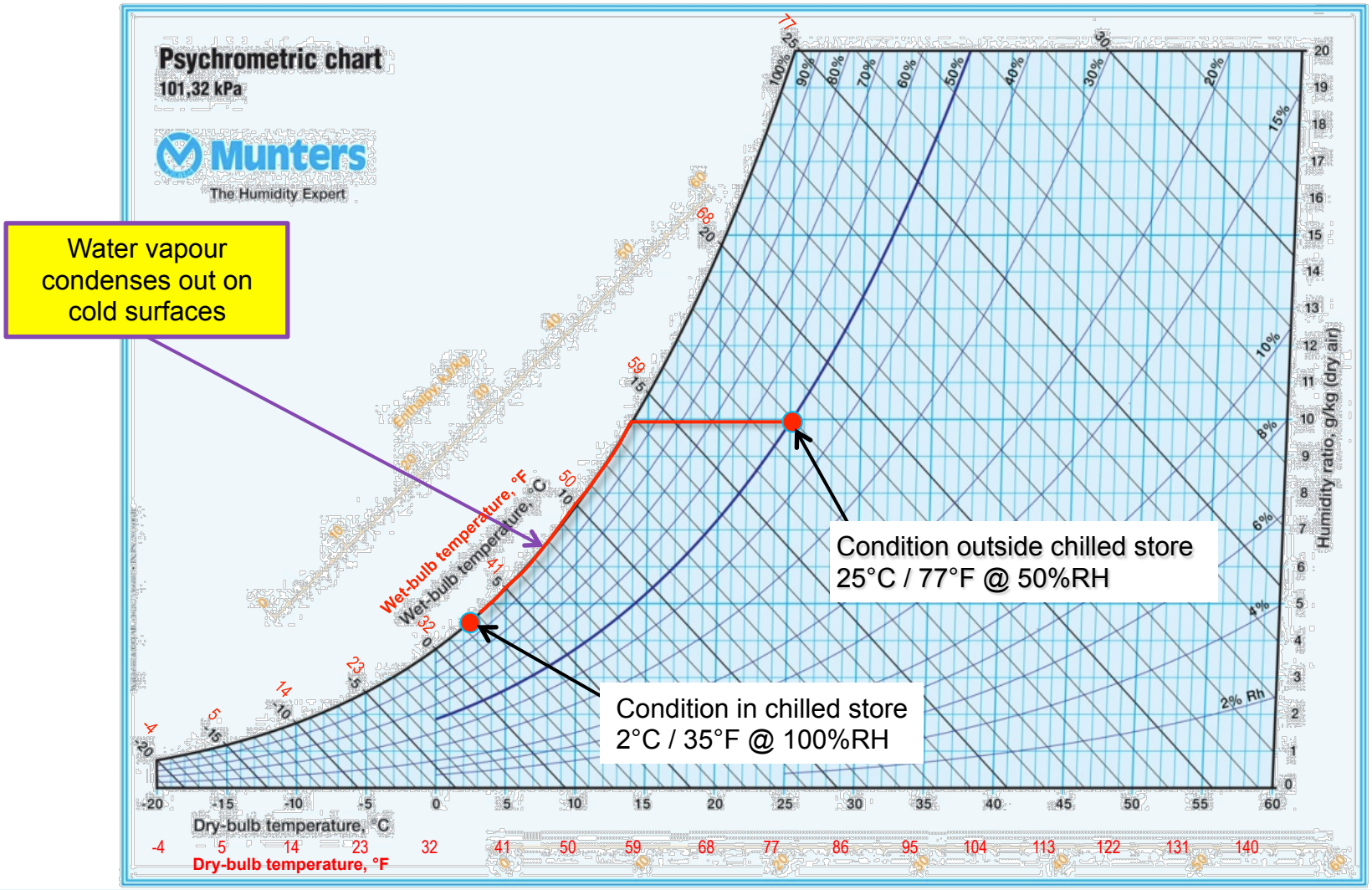
Chilled Stores (Above 0°C / 32°F)



Particular Challenges with Chilled Stores

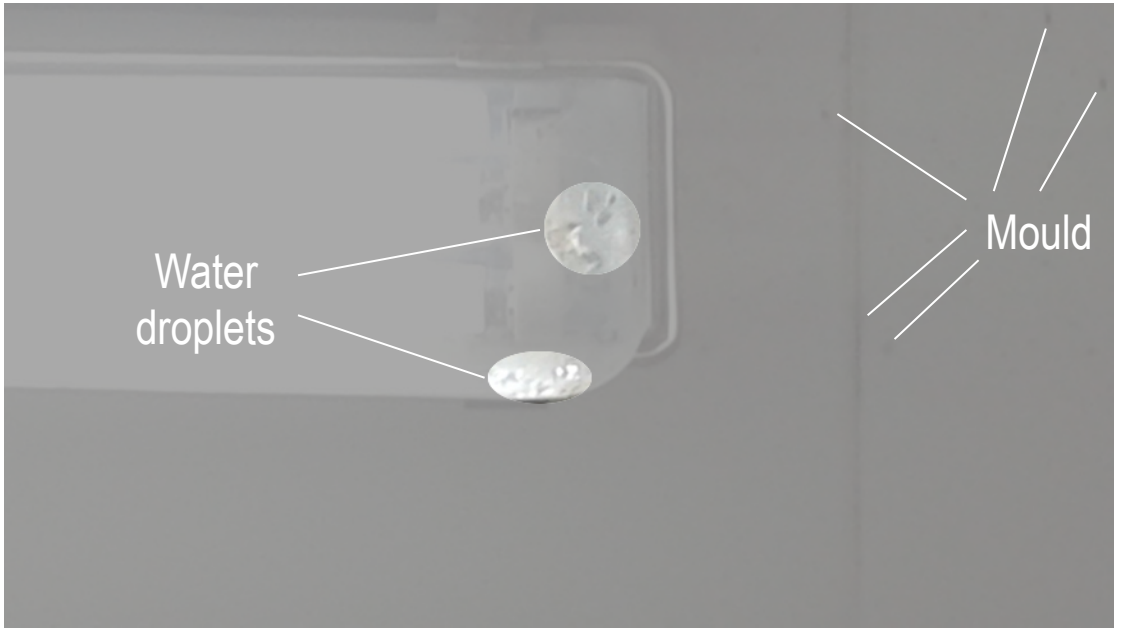
- Chilled stores are in the 2 to 8°C / 35 to 46 °F temperature range.
- If humidity is not controlled then RH within the chilled space can be >90%.
- Cold surfaces will allow condensation to occur.
- If this condensation is left untreated additional issues can arise.
- Easy to treat with dehumidification.

Condensation in Chilled Stores



Munters

Chillers, Humidity and Cold Surfaces



- Water droplets form on the lighting fittings, ceiling or chiller units
- These droplets occasionally drop onto boxes or surfaces below.
- Mould, bacteria or yeast growths in the water droplets would be transferred.
- If enough droplets were to fall on a particular box in the same location over time, micro-organisms could enter the box and come in contact with the contents.

In closing

Suitability of Munters rotors in Pharma production

SIK – The Swedish Institute for Food and Biotechnology

Hereby declares that the products

Quantum™ and HPS Rotors

From Munters

Have been evaluated regarding emission of micro organisms and particles

Report No PX00398

The evaluation report findings regarding air emission of micro organisms and particles from Munters Quantum™ and HPS desiccant rotor showed that the Quantum™ and HPS are bactericidal to contaminants on the rotor surface and in tested air streams. Quantum™ is also fungicidal regarding yeast contaminating the rotor surface. HPS is microbiologically neutral to yeast contamination thus does not increase growth.

During tested conditions Quantum™ and HPS do not increase the number of micro organisms in processed or regenerated air. The evaluation indicated that the number of micro organisms in processed and regenerated air are reduced compared to the inlet air. Quantum™ and HPS do not increase the number of particles in processed air. The evaluation reported that the number of particles in processed air is reduced compared to the inlet air. Quantum™ and HPS do not emit particles to the processed air.

The total concentrations of airborne bacteria on the inlet to Munters Quantum™ and HPS rotors compared to those in discharge air samples indicated that these desiccant wheels do not cause airborne bacteria and fungi to increase but reduce aerobic bacteria and fungi. Airborne bacteria and fungi on outlet conditions were significantly lower than test outdoor conditions. So bacteria and fungi concentrations immediately upstream and downstream of the dehumidification unit containing the rotors were significantly lower, showing the suitability of the rotors for employment in food situations.

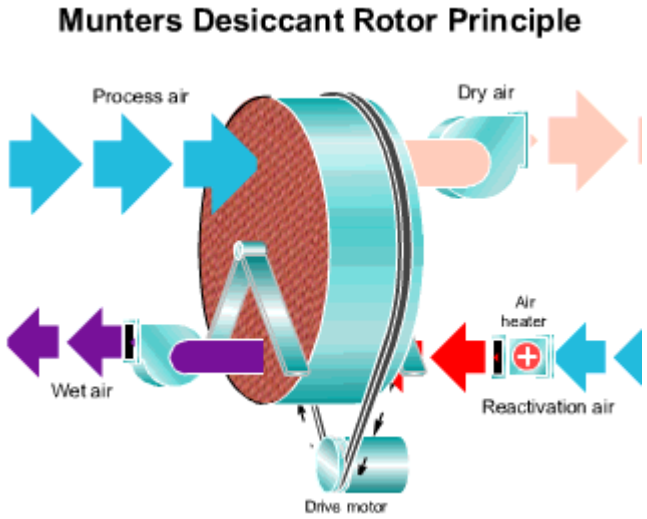
Göteborg 13 September 2011

Birgitta Bergström
Vice Head of Microbiology and Process Hygiene

Head Office:
SIK, Box 5401, SE-402 29 Göteborg, Sweden.
Telephone: +46 (0)10 516 66 00, fax: +46 (0)31 83 37 82.

Regional Offices:
SIK, Ideon, SE-223 70 Lund, Sweden. Telephone: +46 (0)10 516 66 00.
SIK, Forslunda 1, SE-905 91 Umeå, Sweden. Telephone: +46 (0)10 516 66 00.
SIK, c/o Almi, Box 1224, SE-581 12 Linköping, Sweden. Telephone: +46 (0)10 516 66 00.

www.sik.se



Reactivation air blows through 90° of the rotor at 120°C to 180°C, this segment stays in the heated airflow for approximately 2 minutes

"Quantum and HPS do not increase the number of micro organisms in processed or regenerated air. The evaluation indicated that the number of micro organisms in processed air is reduced compared to inlet air"

In General

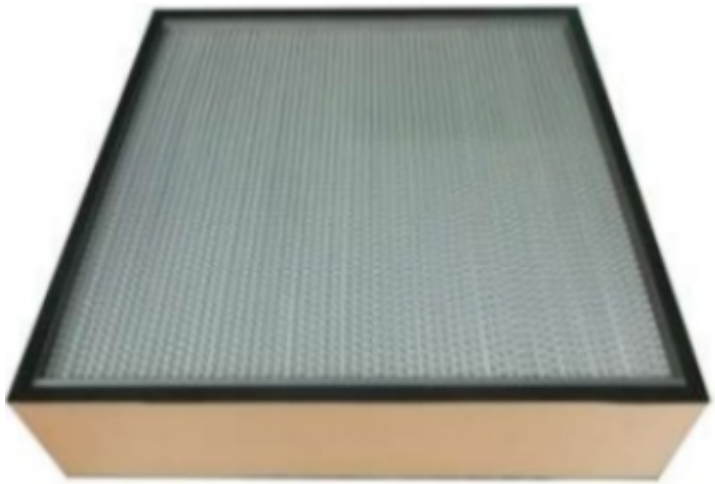
- Bacteria
  - Easily transferred from one environment to another.
  - The only reliable way to identify the presence of any type of bacteria is have it analysed in a lab = time + effort.

- Moulds
  - Spores are always present in ambient air.
  - The only reliable way to identify any type of mould is have it analysed in a lab = time + effort.
  - Even if mould does not appear to be present, it could be hidden inside ducts, in door seals, under pallets, on the ceiling.

Recommendations

- Humidity control solutions can benefit all areas of production and storage:
  - Before being used in production raw materials, containers and packaging must not be at risk from contamination.
  - Product storage areas should be free from excessive levels of micro-organisms, again to reduce contamination risk.

- In clean areas HEPA filters will remove close to 100% of bacteria and mould spores.
  - Careful handling is needed when removing filters as they will be loaded with micro-organisms.
  - Filters needed to be changed at least once a year in most clean areas, and regularly checked for integrity.



A few words about filters…

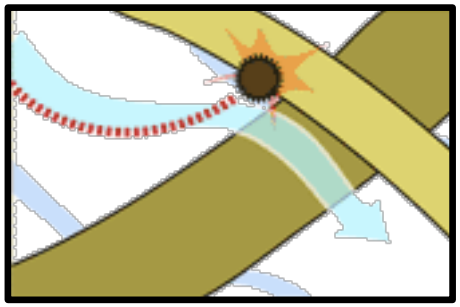
HEPA filters rely on a combination of three mechanisms to trap particles

Interception: Particles being carried in the airflow around the filter fibres adhere to the filter. Particles must be within one radius of the filter fibre to be captured

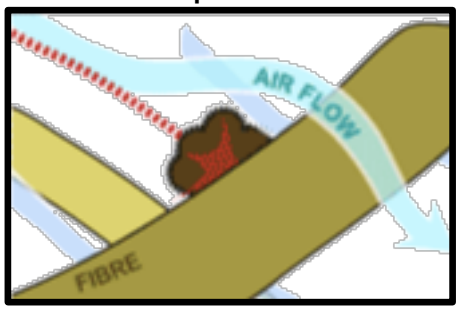
Impaction: Due to their size, larger particles cannot adjust to sudden changes in airflow around the filter and essentially run into the filter fibre and become embedded.

Diffusion: Occurs because of the way microscopic particles move and interact with surrounding molecules. This is described as Brownian motion, where molecules move in a random, zig-zag pattern because they collide with surrounding molecules. This motion slows down a particle's path through the HEPA filter and increases the probability that the particle will be captured by either interception or impaction.

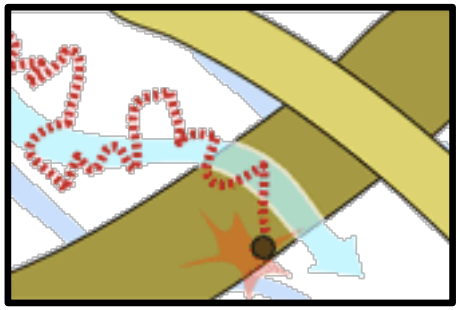
Interception



Impaction

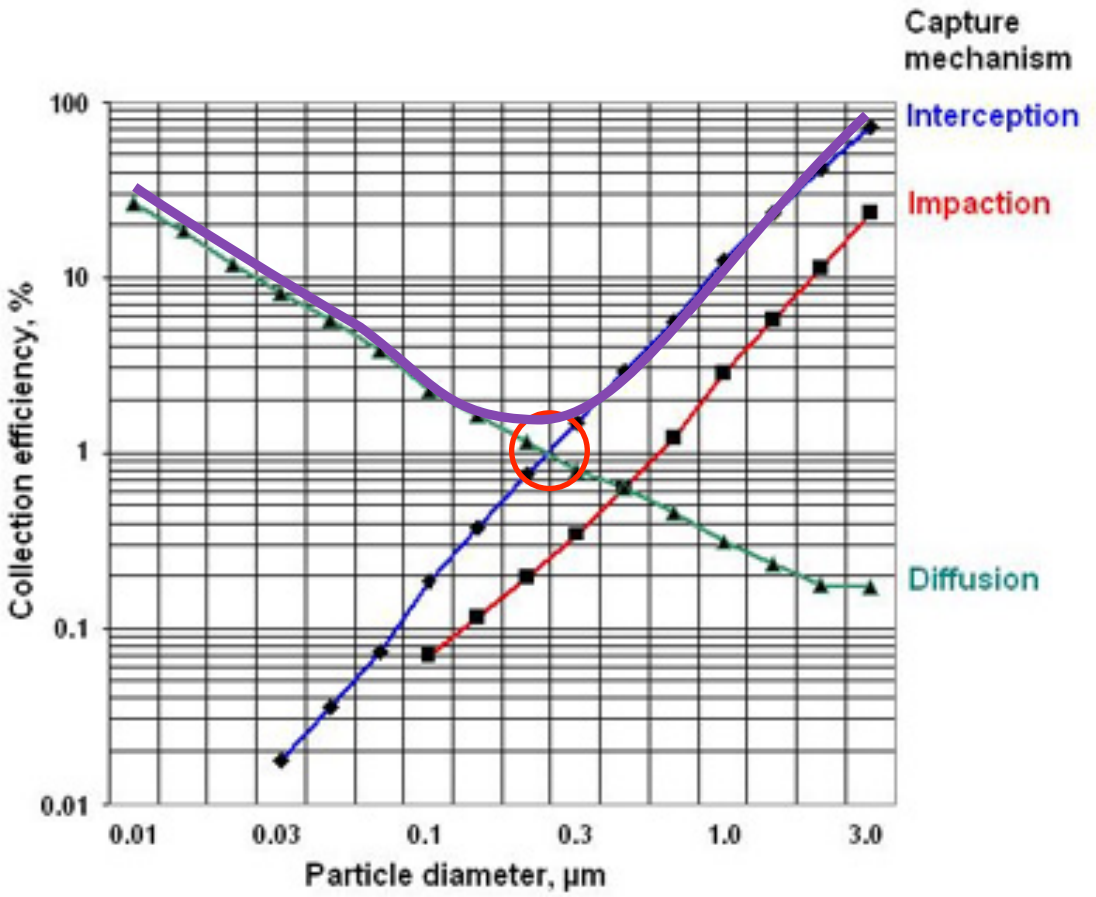


Diffusion



HEPA filter in operation

- HEPA filters do not have linear performance for all particle sizes.
- In the example on the left, particles with a diameter of 0.2µm are more likely to pass thorough the filter
- Filter performance will generally improve over time as trapped particles block the gaps, resulting in reduced airflow / pressure drop.
  - Loss of pressure could lead to the cleanroom or airlock going out of specification
- GMP guidelines recommend inspecting filters every 6 months to 1 year and replacing filters at least every 5 years.




MUNTERS
Munters