Microbial growth in buildings – general aspects

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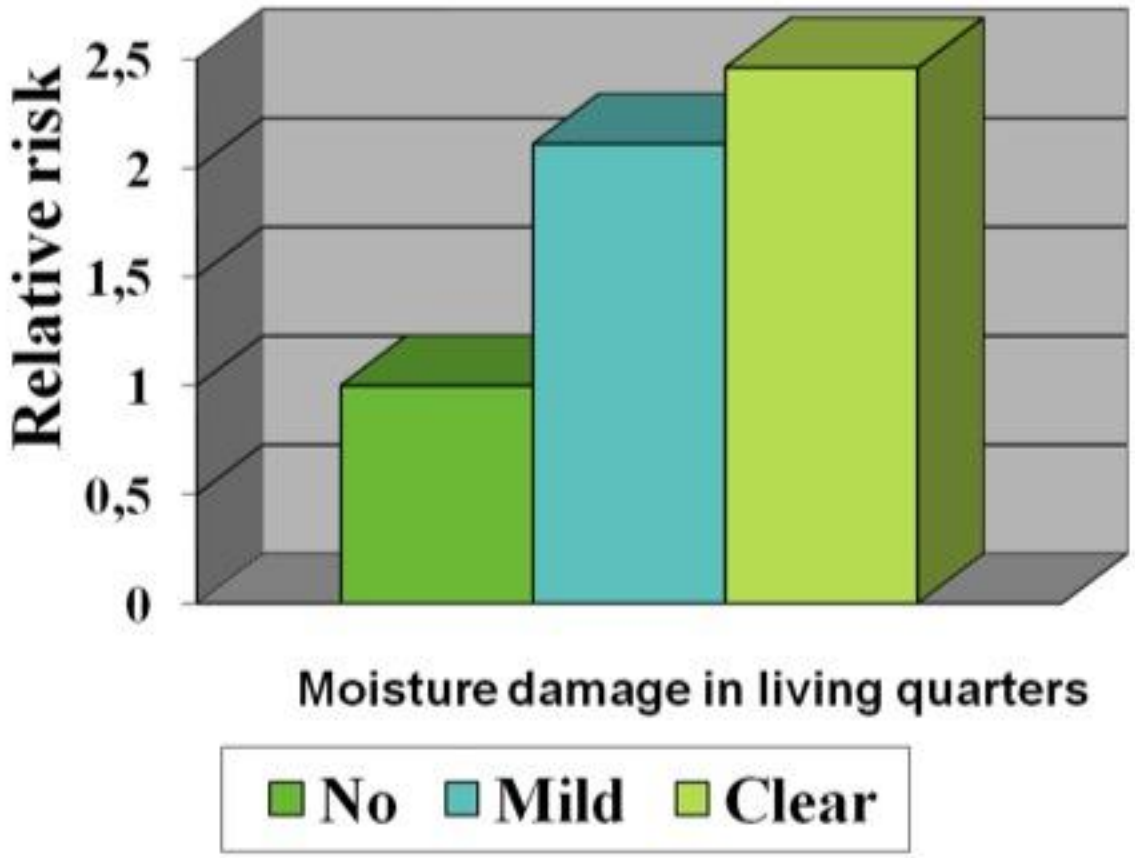
Sources of indoor fungi

- Outdoor air
- Foodstuff, firewood
- Pets' food and bedding
- House dust (reservoir)
- Transport on peoples' clothes, on pets' fur
- Colonies on wet surfaces, microcolonies on temporarily wet surfaces
- Microbial growth on damp or wet surfaces (one source among others, but has more health relevance than others)

Why the interest in damp and mold?

- Dampness and mold in indoor environments is associated with many health effects
- Respiratory, skin, neurological symptoms
- Elevated risk of asthma
- Possible risk for other conditions
- Evidence is strong, details not well known
- Cost of disease enormous
- Remediation decreases symptoms

Moisture damage and children's health



Pekkanen et al. 2007

A microbiologically healthy house?

- Does not mean absence of microbes
- Normal microbes
  - bacteria of human skin
  - fungal and bacterial species of outdoor air
  - microbes from normal sources: plants, foodstuff, firewood, pets
- Concentrations kept reasonable with cleaning and ventilation
- No microbial growth due to unusual dampness

Outdoor air is the main source of indoor fungi

- Remarkable seasonal variation in outdoor concentrations (10^2 – 10^6 cfu/m^3)
- If I/O>1, indoor sources exist
- In winter, counts lower both outdoors and indoors
- In temperate and warm climates, seasonal variation not as clear

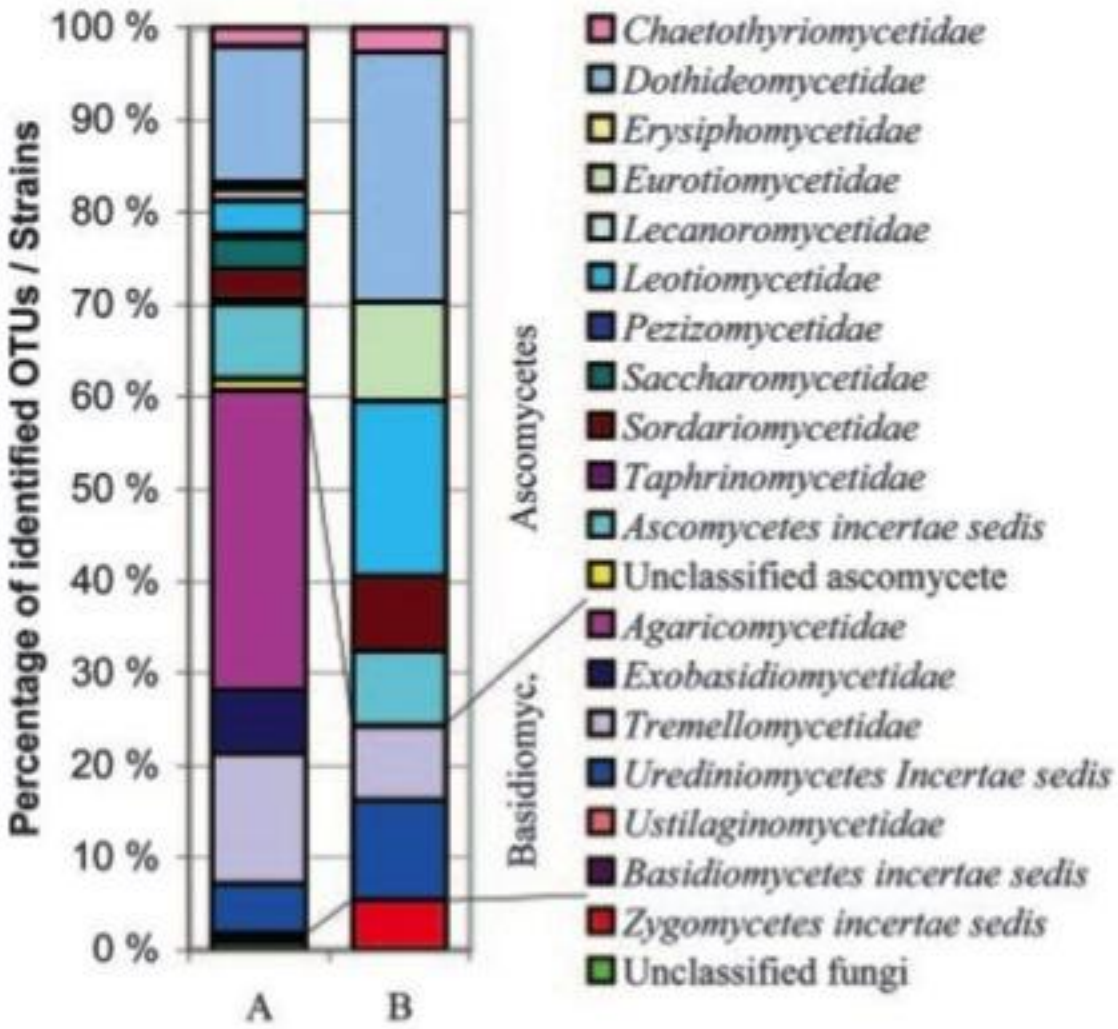
"Normal" mycobiota of indoor air

- *Penicillium spp.*
- *Aspergillus spp.*
- *Cladosporium spp.*
- Yeasts
- Mainly originating from outdoor air and normal sources

Community analyses of indoor microbes

- With culture analyses appr. 1% of the microbes are seen, community analyses show all the microbial DNA
- So far, little help for practical applications
- Microbial communities have wide diversity in indoor environments (as elsewhere)
- Differences between damp and normal environments not clearly seen
- ”indicator microbes”: needles in a haystack!

Fungal diversity in house dust



Clone libraries:

- 1339 sequences
- 394 OTUs
- Most common: yeasts, *Cladosporium*, *Aureobasidium*

Culture:

- 72 isolates
- 23 species
- Most common: yeasts, sterile mycelium, *Cladosporium*

Pitkäranta et al. 2008, AEM 74:233-244

Bacteria of the indoor environment

- Human-derived bacterial species dominate the indoor environment
- Also outdoor bacteria present
- Pets, foodstuff, plants
- Regularly wetted surfaces (bathroom, kitchen)
- Actinomycetes are indicators of ”mold” growth
- Especially genus *Streptomyces* produces earthy cellar odor and numerous toxins; is worth watching

What is the role of skin bacteria in indoor bacterial communities?

- Samples were taken from the individual's (N=4) skin, from her/his mattress dust and from floor dust
- Bacterial communities were analyzed with sequencing
- The aim was to observe, how much the individual contributes to the bacteria of the indoor environment

Mattress dust reflects the occupant

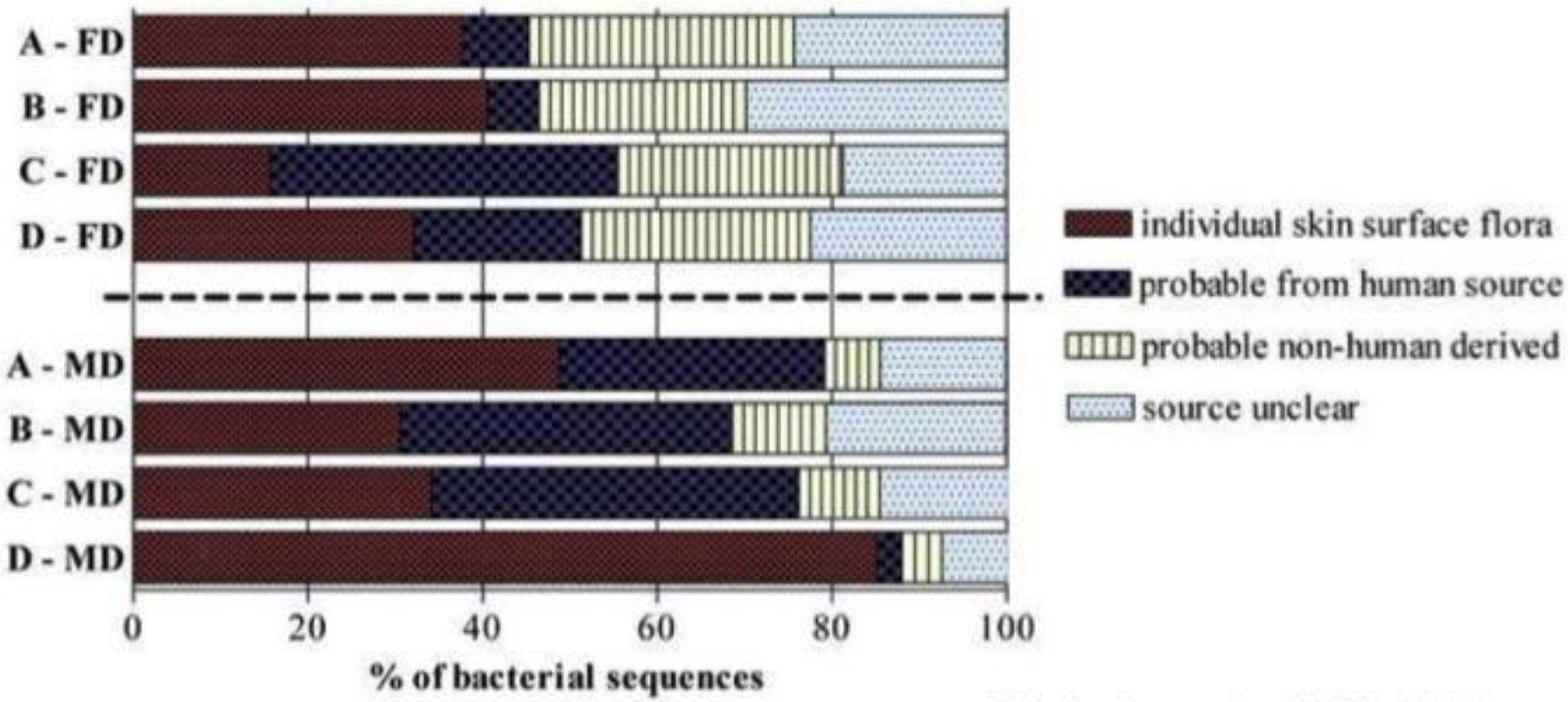
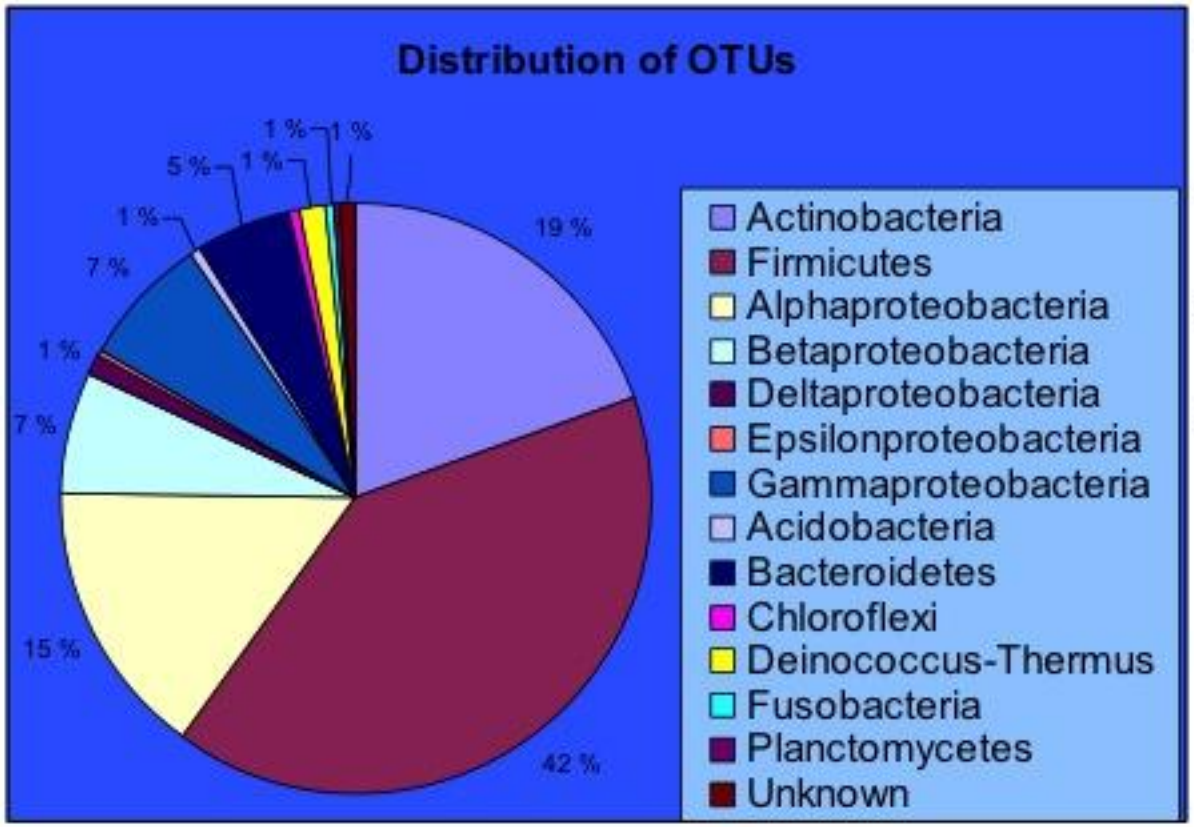


Figure 2

Täubel *et al.*, JACI 2009

Bacterial diversity in house dust



- 893 sequences, 283 distinct OTUs detected (97% seq. identity)
- Gram-positive species dominated
- Human-associated OTUs were the most abundant
- Differences between water-damaged and non-damaged building not detected

Conclusions of the microbial community studies

- Indoor dust microbial communities diverse
- Occupants / users of the building influence the community composition strongly
- Seasonal variation is extensive
- Difficult to identify, which species are "important" = associated with health or other factors
- Quantitative data is needed for exposure assessment

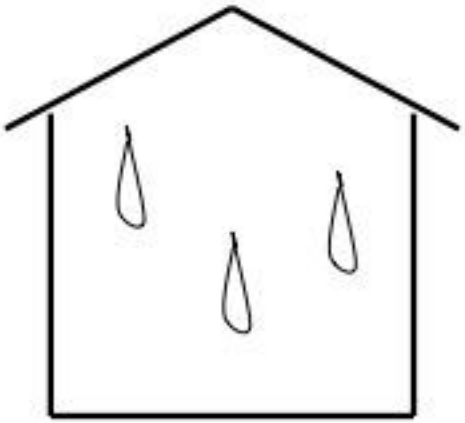
Indoor environments as microbial habitats

- Microbial habitats indoors; act as sources
  - Wet areas: bath, kitchen, toilet, sinks, plumbing, plants, food, fruit, vegetables, any organic material
  - Dry areas: surfaces, materials, textiles, house dust, ventilation ducts
  - House dust: a reservoir

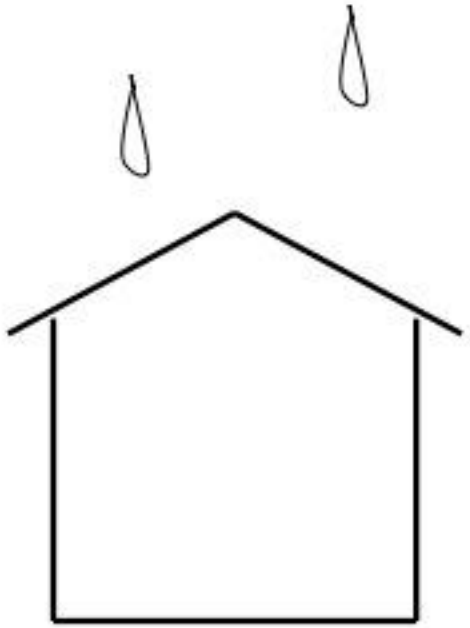
Dampness and moisture in buildings - the causal factor behind mold growth

- Dampness and moisture problems common in all climates, in all types of buildings
- Causes and consequences vary according to climate, building technology etc.
- Everywhere, traditional building styles and techniques aim at control of moisture
- Modern buildings, new problems!

Unhealthy



Healthy



Water is the key factor in microbial growth

- No mold growth without water
- Dampness and moisture allow the growth of specific fungi and bacteria
- Water available for molds may be a result of
  - Condensation, leakage, flooding or capillary movement
- Moisture conditions may fluctuate
  - Fungi can survive dry conditions with their spores

Other organisms present in damp conditions

- Continuously or temporarily wetted surfaces (materials) allow microbial growth
- First colonizers are molds, bacteria and yeasts
- Other organisms follow: amoebae, rot fungi, nematodes, insects, ants…
- Presence of water allows development of an ecosystem

Wood-decaying basidiomycetes (rot fungi)

- Destroy the structural integrity of wood
- Less linked with human health than molds, but harmful to the house
- Need high moisture and RH during a prolonged time
- Appr. 80 species, e.g., dry rot *Serpula lacrymans* (brown rot), *Meruliporia incrassata* (warm temperature fungus)
- Wet-rot (cellar) fungi: *Coniophora*

Amoebae on building materials

- Belong to Protozoa; single-cell organisms with a nucleus
- May form cysts which are resistant to environmental stress
- Presence of amoebae facilitates the occurrence of bacteria that do not otherwise manage on building materials

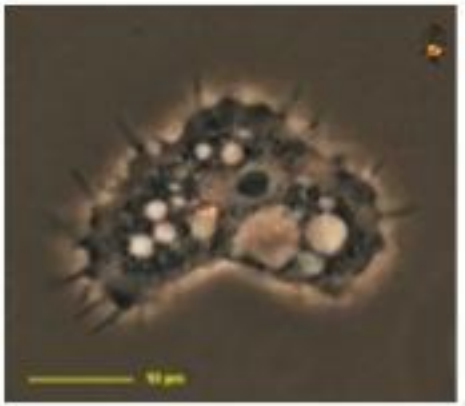
Amoebae in moisture-damaged buildings

(Yli-Pirilä et al. 2004, 2006, 2007)

- Amoebae...
  - were found on 22 % of moldy building material samples
  - can grow on many building materials in excess
  - generally increase bacterial growth, effects on fungi vary
  - co-cultivation with amoebae increases the cytotoxicity & proinflammatory potential of *Streptomyces* and *Penicillium*
  - can harbour pathogenic bacteria that would not otherwise survive in moisture-damaged buildings

Amoebae and bacteria

- Amoebae may protect bacteria inside their cells
- Examples of bacteria isolated from amoebae
  - *Legionella*
  - *Chlamydia, Parachlamydia* and other *Chlamydiales*
  - *Burkholderia*
  - *Pseudomonas aeruginosa*
  - *Mycobacterium*
  - *Vibrio cholerae*
  - *Burkholderia*



...

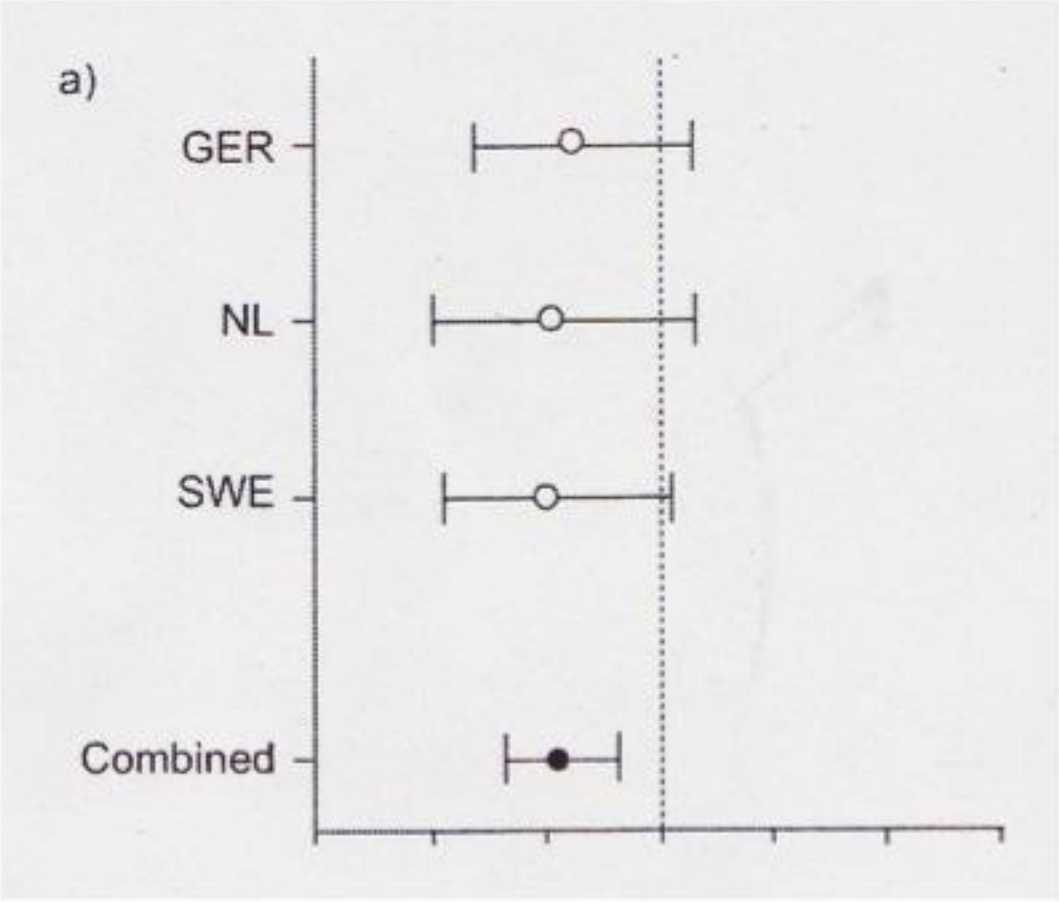
- Several unculturable and unidentified bacteria

Nevalainen 2012

Protective effect of early exposure to microbes?

- Farming and rural children have less allergy than urban children (e.g. von Ehrenstein et al. 2000, Braun-Fahrländer et al. 1999, Riedler et al. 2000)
- Protective effect of early exposure to environmental microbes?
- Effect shown for endotoxin, EPS-*Pen/Asp* (Douwes et al. 2006), 1,3-ß-glucan and dust (Gehring et al. 2007)
- Also contradictory findings
- Several birth-cohort studies going on

Early exposure to endotoxin and allergic sensitization at 2-4yrs of age (Gehring et al. ERJ 2007;29:1144-53)



How common a problem?

- common causes: faults in design, construction, lack of maintenance
- mold problems develop in ~20 % of buildings?
- a remarkable portion of the population gets exposed

Is it a real public health issue? – Prevalence of dampness

- WHO (Europe) dampness data from the member countries 2011
- In average, 18% of population is exposed to dampness (range 5-37%)
- Weaknesses of data:
  - No good metrics to measure/quantify dampness
  - Process from dampness to health problems still poorly understood
  - Data only from Europe
- Strengths:
  - Data collected in a uniform way across Europe

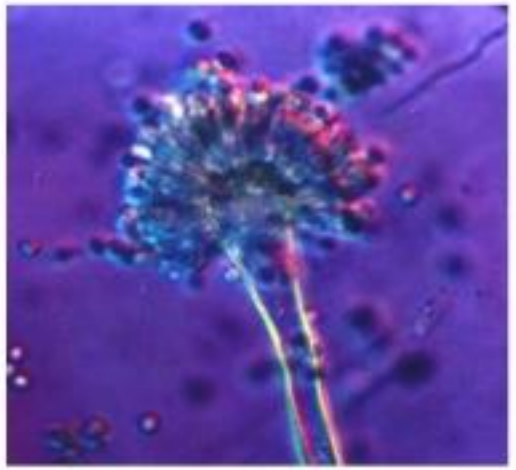
Examples of reported prevalence of dampness

Reference	Country	Dampness Metric	Prevalence %
Residential buildings			
Brunekreef et al. (1989)	United States	Ever mold or mildew on any surface Any damage	21-38 46-58
Dales et al. (1999)	Canada	Visible mold in last 2 years Any damage	24 25
Kilpeläinen et al. (2001)	Finland	Visible mold Any damage	5 15
Nevalainen et al. (1998)	Finland	Any damage now or previously	80
Norbäck et al. (1999)	Sweden	Water damage in last year Visible mold in last year	16 9
Zock et al. (2002)	14 European countries, Australia, India, NZ, USA	Water damage in last year Mold or mildew in last year	12 22

Are there health-based guideline values for building microbes?

- Not possible to give health based TLVs or other numerical guideline values for biological particles
  - Causal links between exposing agents and health efffects not known
  - Dose-response not known
- Guideline values for result interpretation

  Help to conclude if concentrations and species are normal or not



Economic importance of building mold

(Mudarri and Fisk 2007)

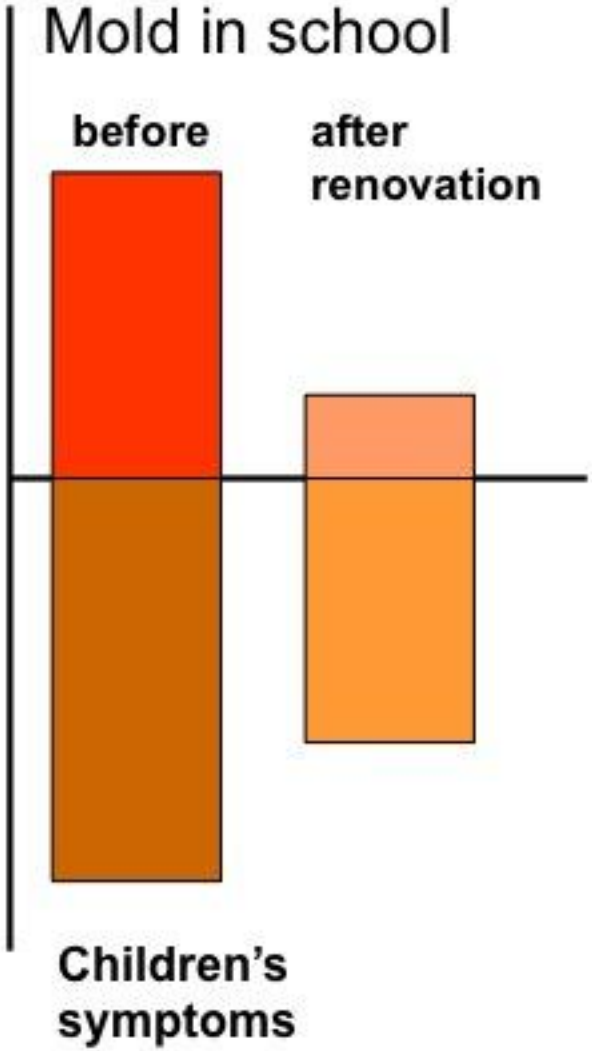
- In US, asthma cases attributable to mold 21% (95% CI 12-29%)
- 4.6 (2.7-6.3) million cases of asthma attributable to mold
- Annual cost of ”mold asthma” 3.5 billion USD
- Conclusion: exposure to dampness and mold in buildings poses a significant public health and economic risk in the US

Policy aspects

- Moisture control regulation of buildings
  - Usually in building codes
- Ventilation regulation
  - Usually specific regulations/codes
- Maintenance of buildings
  - Good practices needed
- Guidance of health officials, physicians, laypeople
- General dissemination of information
  - Mold should be eliminated… Media, training courses, www pages

Remediation pays back

- Remediation eliminates the exposure
- Most symptoms relieve
- In successful cases, occupants may return to the remediated facilities
- Not-so-successful cases:
  - Not all mold removed?
  - The cause of mold renewed?
  - Sensitization, psychosocial factors?



Policy aspects

- Guidelines needed for verification of success of repairs
- Economical aspects
  - cost of disease vs. cost of repair
- Ethical aspects
  - recovery from symptoms may take years
  - evacuation
  - reoccupancy

Open issues – urgent and relevant

- Understanding the exposures
  - Multifactorial, interactions of various agents
  - Role of microbial toxins should be revealed
- Understanding the health outcomes
  - Autoimmune diseases?
  - Reproductive toxicity, carcinogenicity?
  - Biomarkers of exposure
- Effective remediation, cleanliness testing