Woher kam COVID19 - wie Wildniszerstörung und Pandemien zusammenhängen

How does environmental change drive zoonotic diseases affecting wildlife and human health?

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Some facts first…

60%

of all human infections are zoonotic, i.e. can be transmitted between humans & animals and vice versa

(e.g. HIV, Hantavirus, Adenovirus, Astrovirus, Ebola, bird flu, rabies, lyme disease)

Taylor et al. 2001, Jones et al. 2008

70% originated in wildlife

60%

Taylor et al. 2001, Jones et al. 2008

…as a reminder! Also wildlife suffers from emerging infectious diseases…

Chytridiomycosis

White-Nose-Syndrome

Saiga antilopes: *Pasteurella multocida*

Infectious facial cancer

What drives a zoonotic disease?

Some background information …

- Pathogens (e.g. virus, bacteria) are natural parts of our ecosystems.

- Pathogens have a long-term co-evolution with their hosts, and usually do not kill their hosts.

- Emerging Infectious disease / zoonotic diseases are epidemic events in naïve species / populations with **not** sufficient immune competence to fight against an unfamiliar pathogen.

New zoonotic diseases are driven by shifts in contact probability between potential host species and their pathogens that do not have a co-evolutionary history.

What drives a zoonotic disease?

Shifts in contact probability between potential host species and their pathogens may occur due to:

1. **Commercial wildlife trade**
   → e.g. Ebola, SARS, Covid 19

2. **Industrial livestock farming / intensive animal husbandry**
   → e.g. Bird flu, Swine flu

3. **Loss of biodiversity and associated changes in species community and abundance pattern**
   → e.g. Lyme disease, Hantavirus, West Nile virus, blood-borne trypanosomes

What drives a zoonotic disease?

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Species' responses to habitat disturbance differ

Loss of biodiversity is **not** a random process

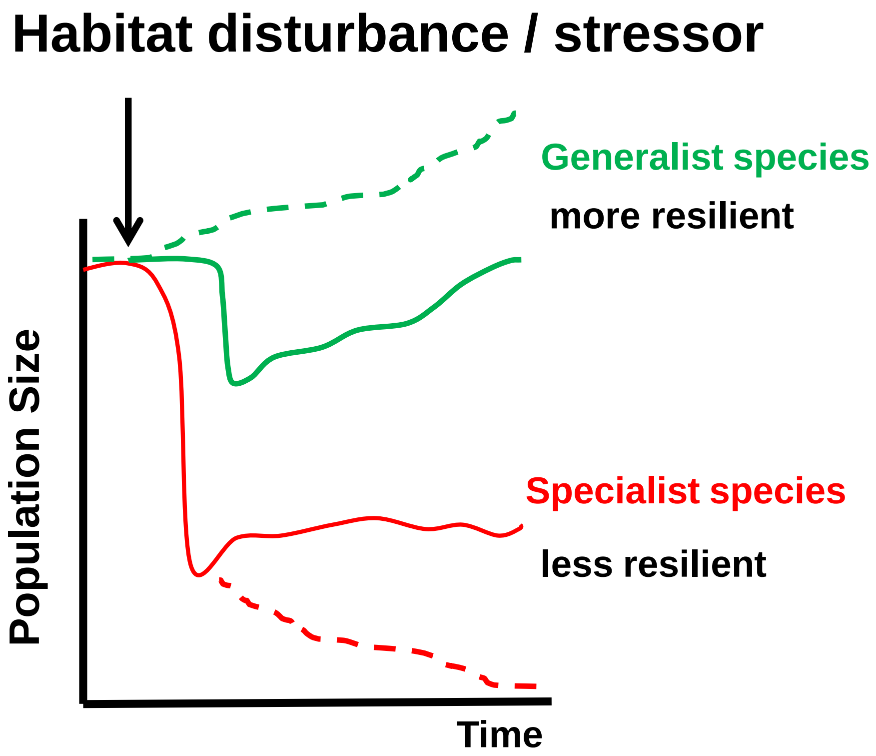
→ Specialist & generalist species

→ Decreased abundance / loss of specialists

→ Increased abundance and density of generalistic species

Ostfeld & Keesing 2012
Civitello et al. 2015
Schmidt et al. 2018

Species' responses to habitat disturbance differ



Generalist species: less sensitive to stress → large phenotypic plasticity

Specialist species: very sensitive to changing conditions & human impact

How might ecological factors associated with environmental change affect animal and human health?

…let‘s start with the **generalist species**

How might shifts in species abundance and contact probability drive zoonotic infections?

How might ecological factors associated with environmental change affect animal and human health?

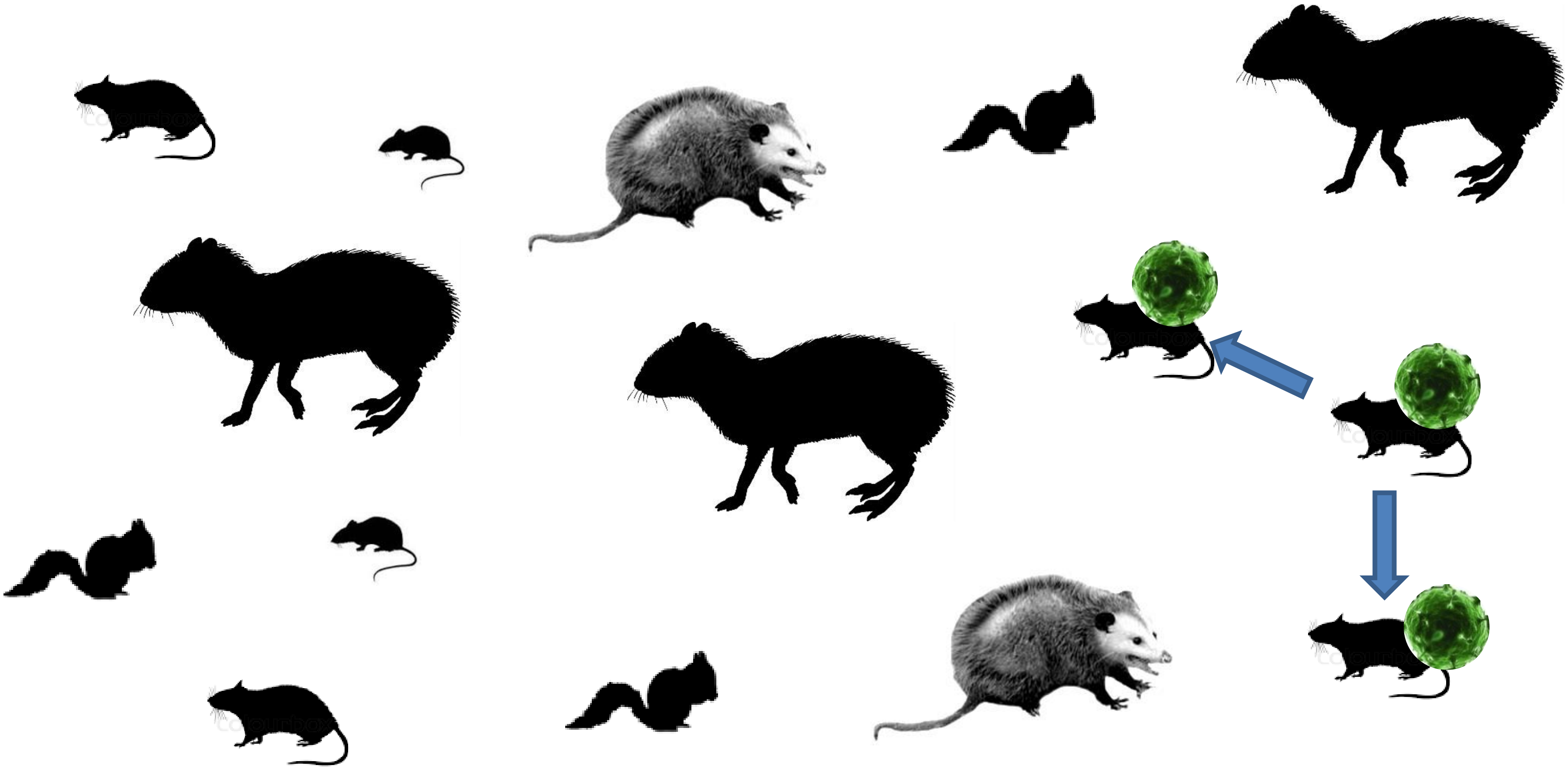
Dilution effect

Decrease in ***host diversity*** and associated ***shifts in species abundance*** may lead to an ***increase*** in the ***prevalence of pathogens*** and vice versa (e.g. Lyme disease, Hantavirus, West Nile virus, blood-borne trypanosomes).

Keesing et al 2006; Ostfeld & Keesing 2012, Civitello et al. 2015

Relationship between species diversity, host abundance and pathogen prevalence

Habitat with high species diversity

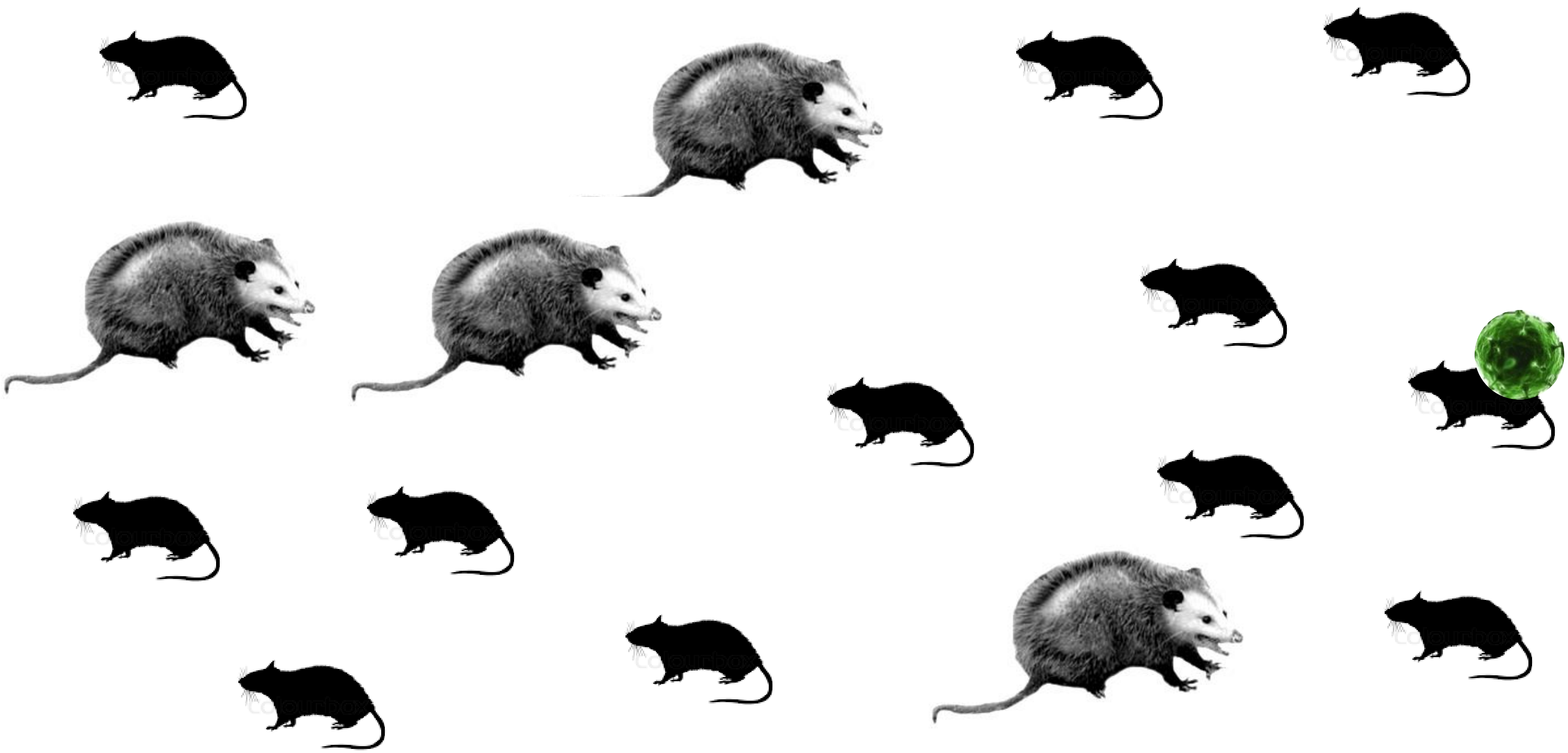


Low prevalence

*no vector involved

Relationship between species diversity, host abundance and pathogen prevalence

Habitat with low species diversity



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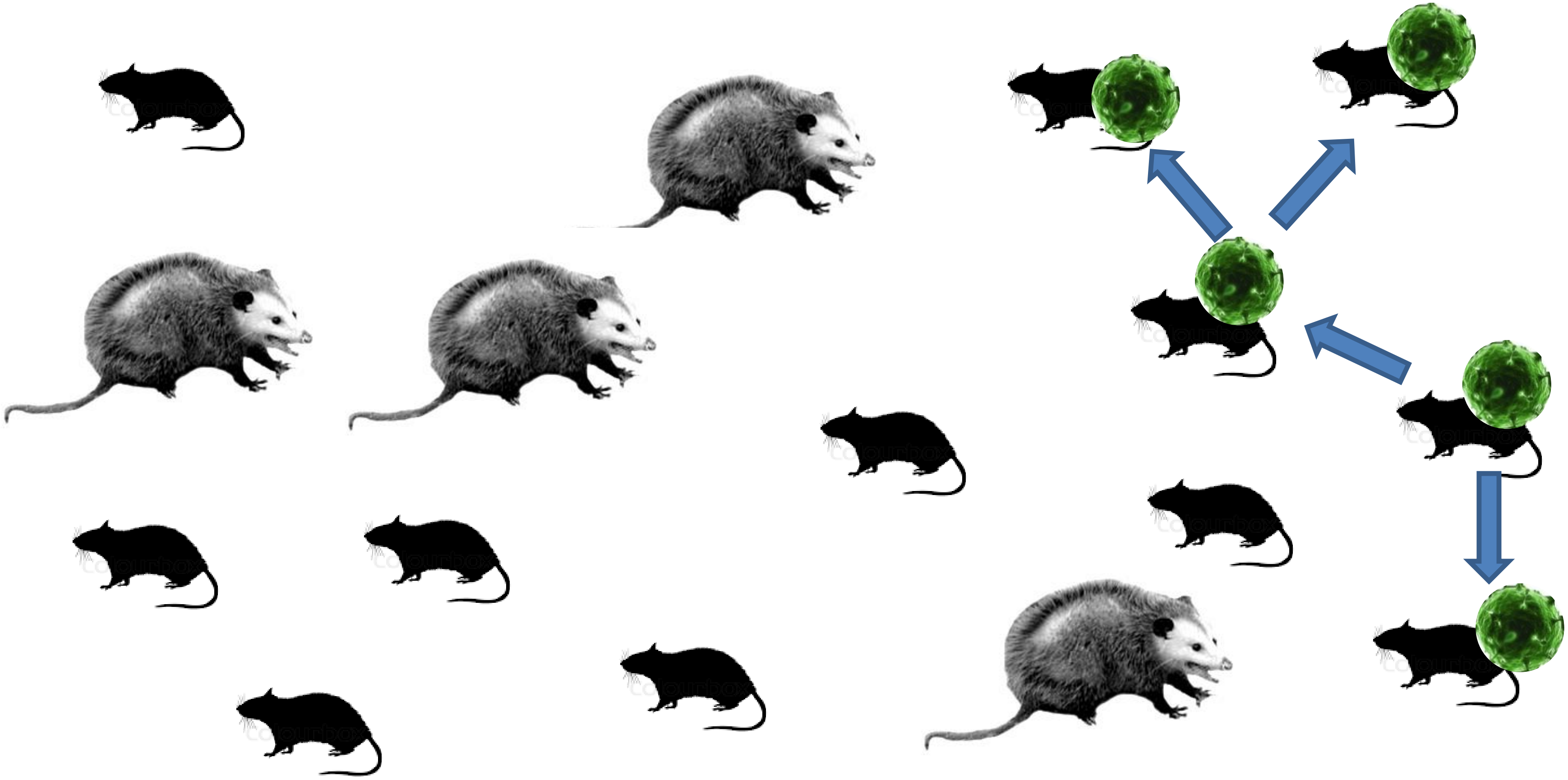
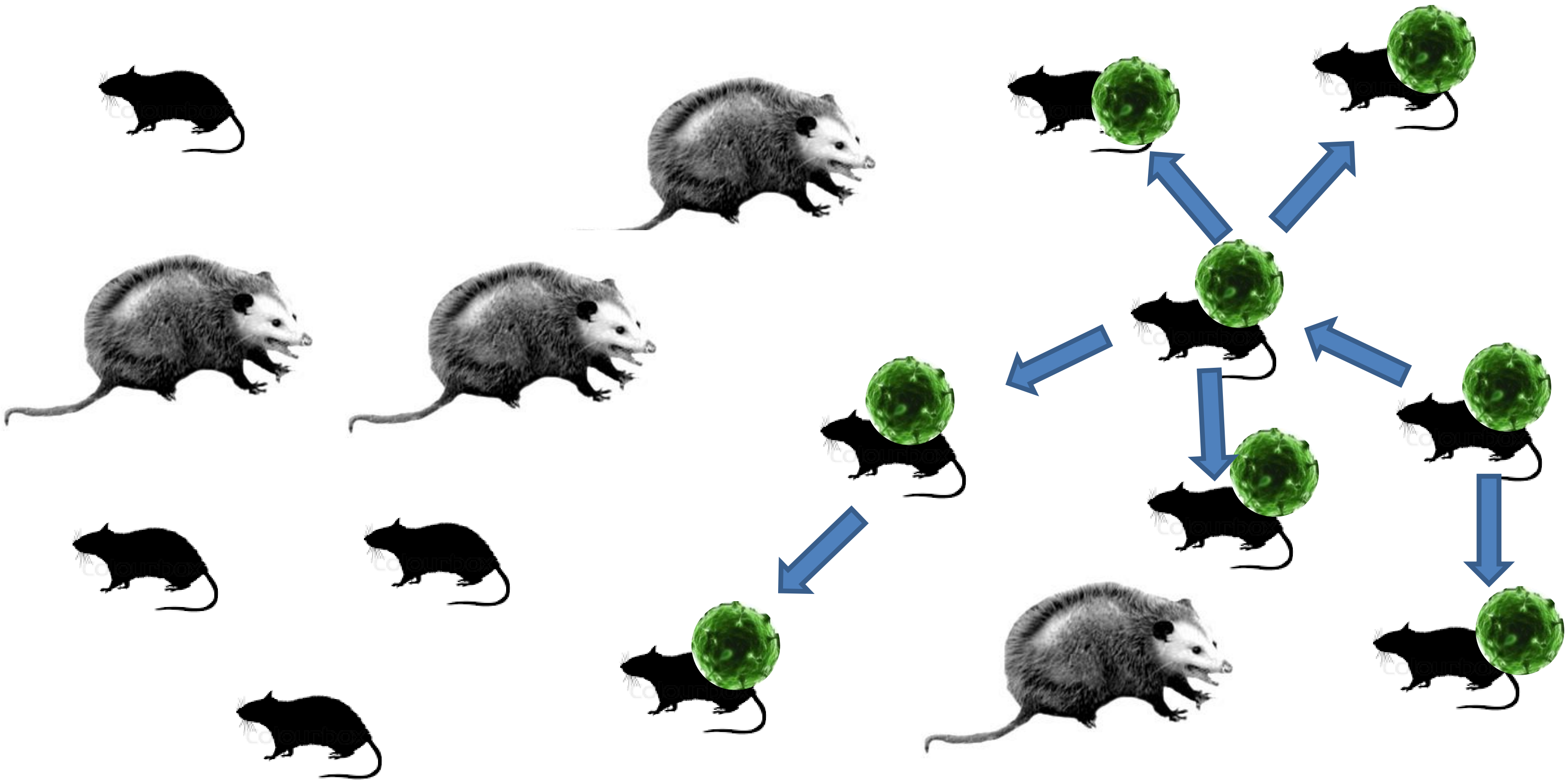
Relationship between species diversity, host abundance and pathogen prevalence

Habitat with low species diversity



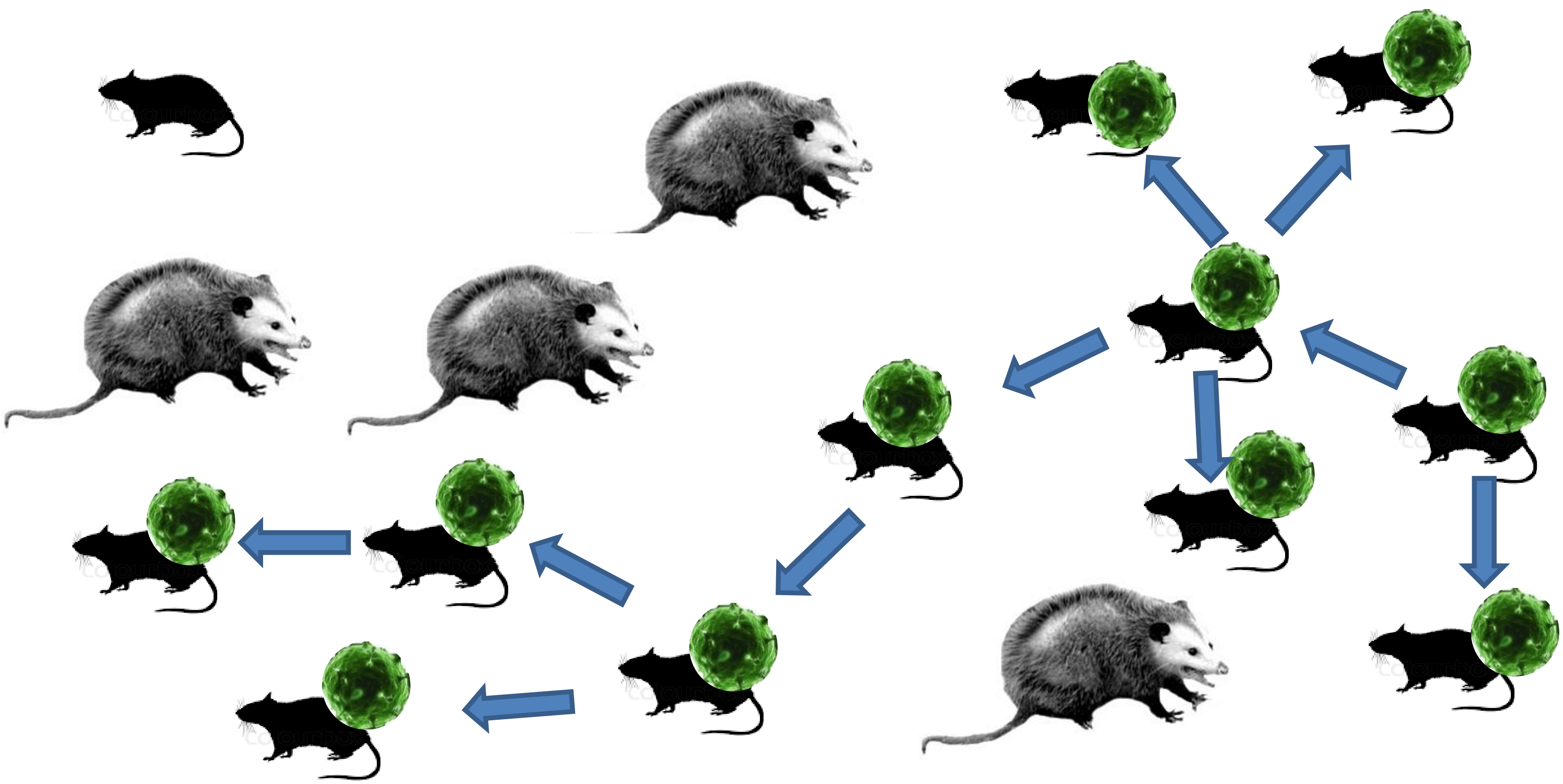
Relationship between species diversity, host abundance and pathogen prevalence

Habitat with low species diversity



Relationship between species diversity, host abundance and pathogen prevalence

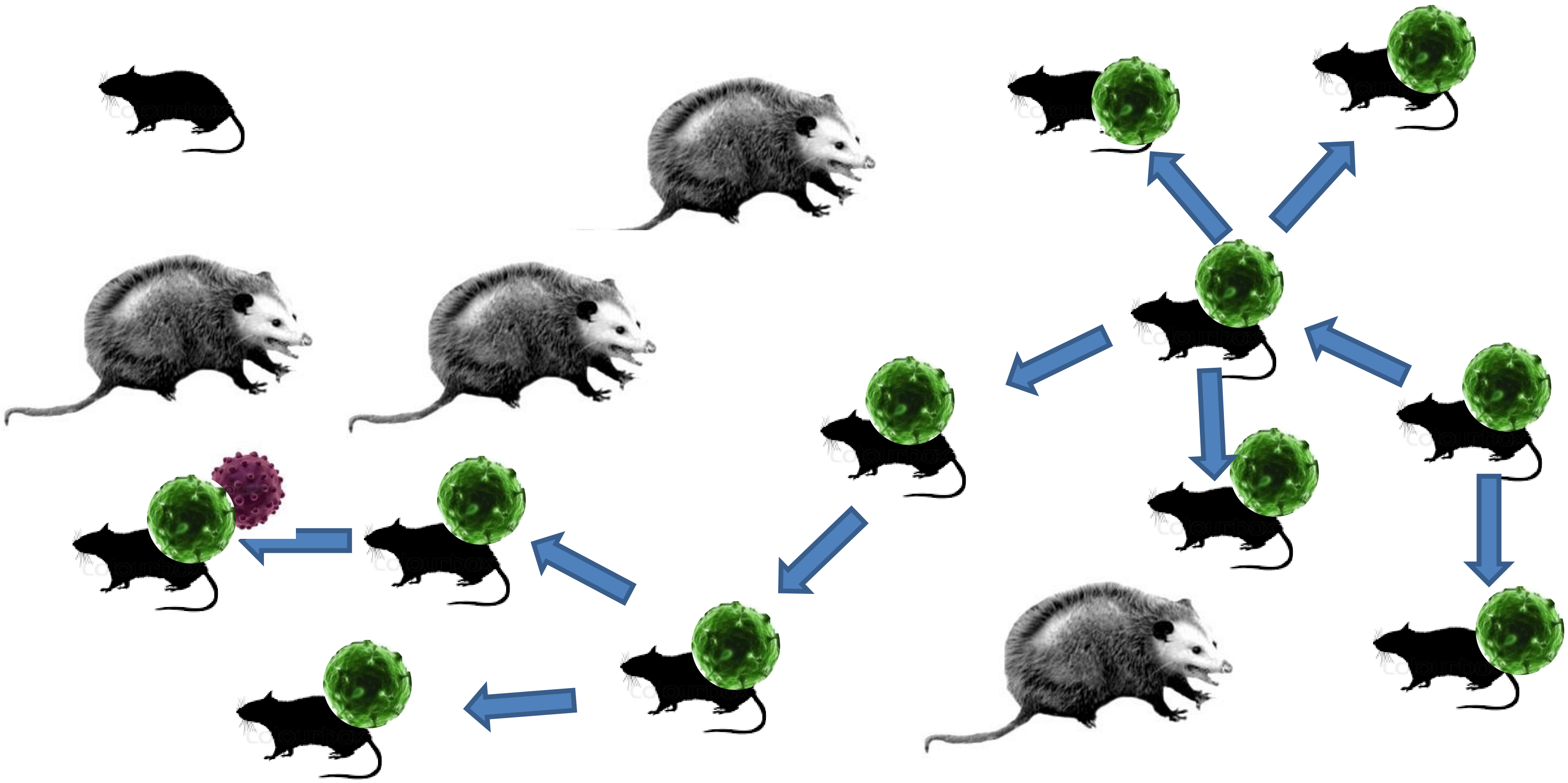
Habitat with low species diversity



High prevalence

Relationship between species diversity, host abundance and pathogen prevalence

Habitat with low species diversity



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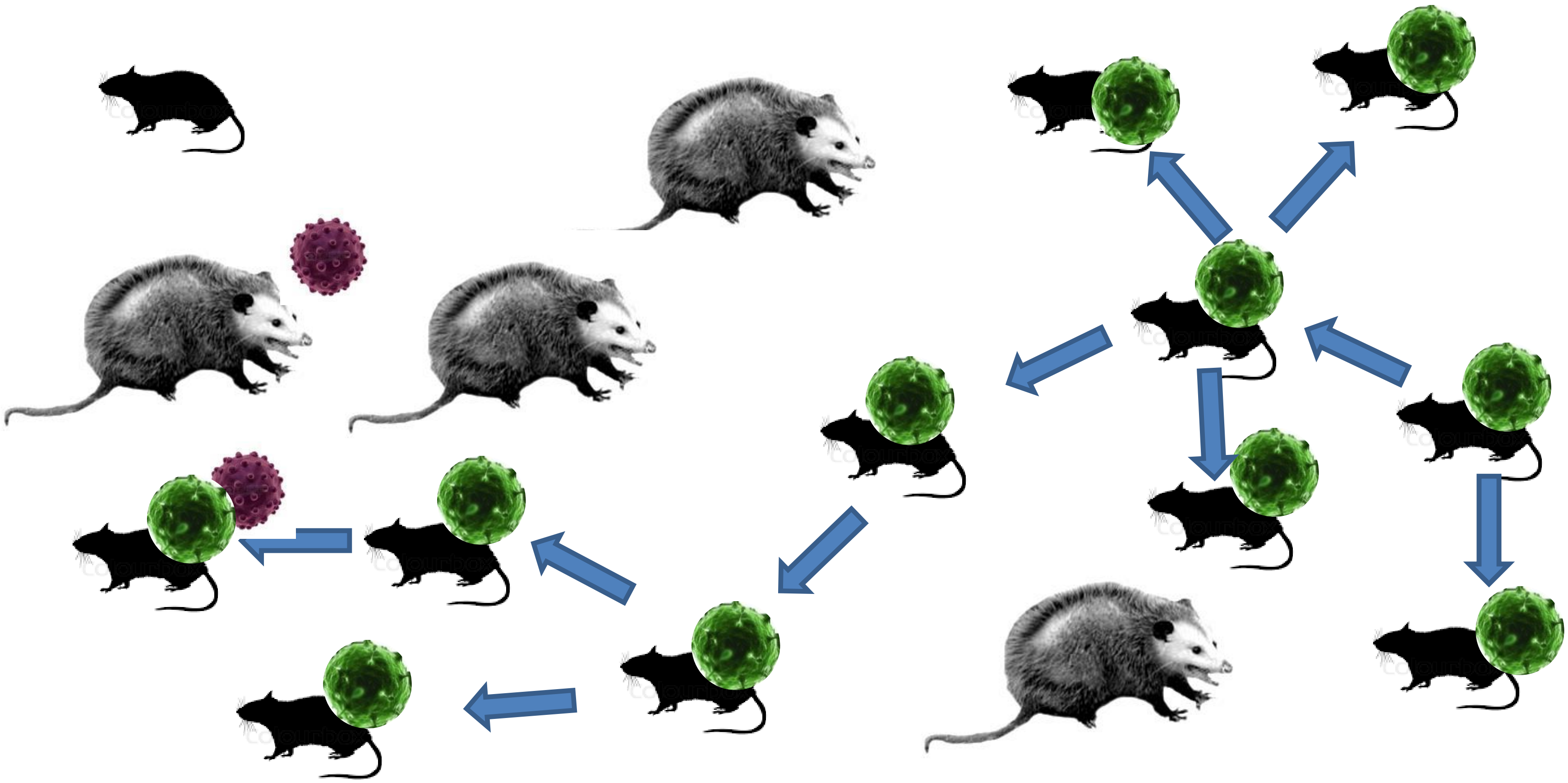

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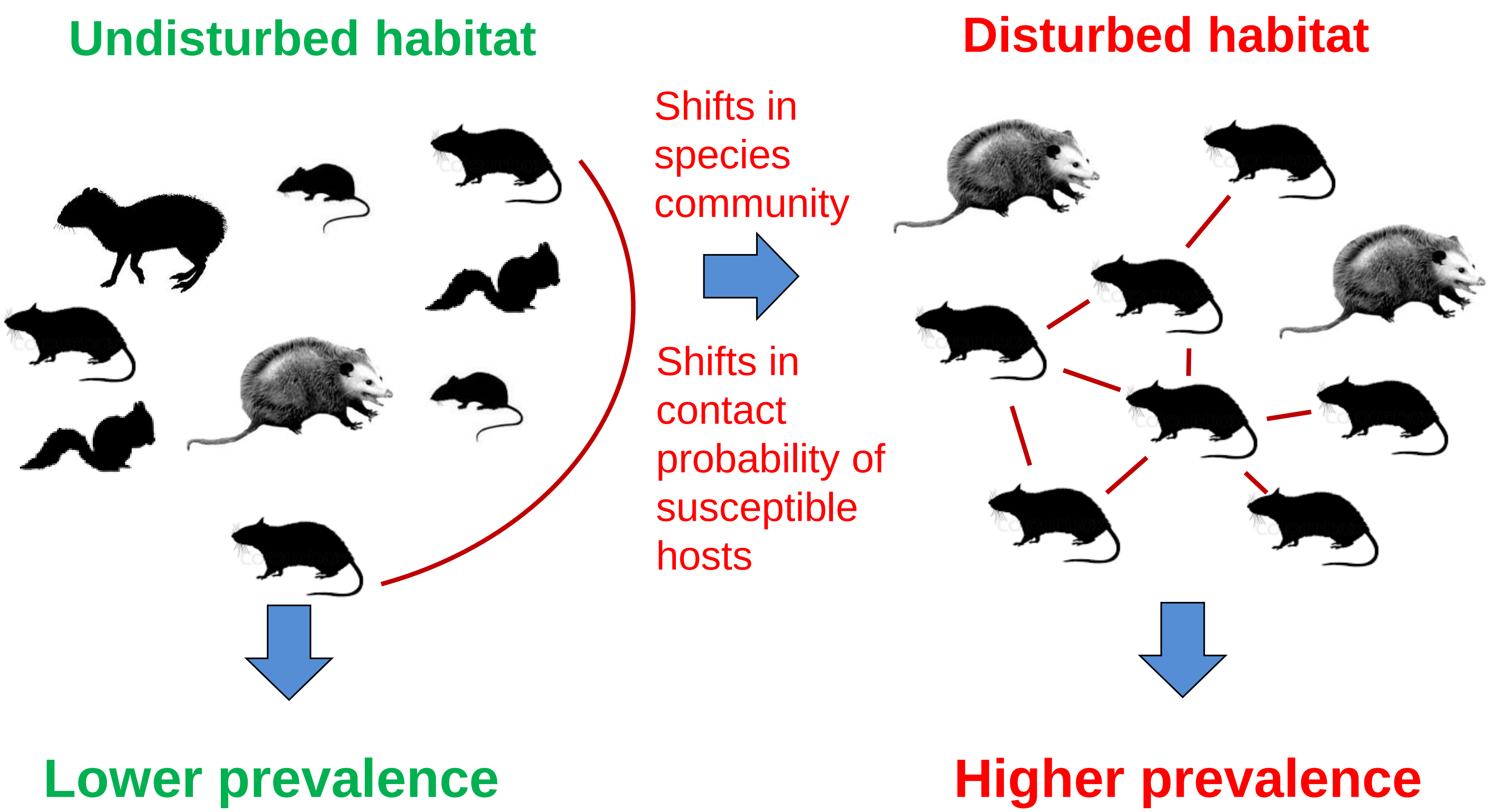
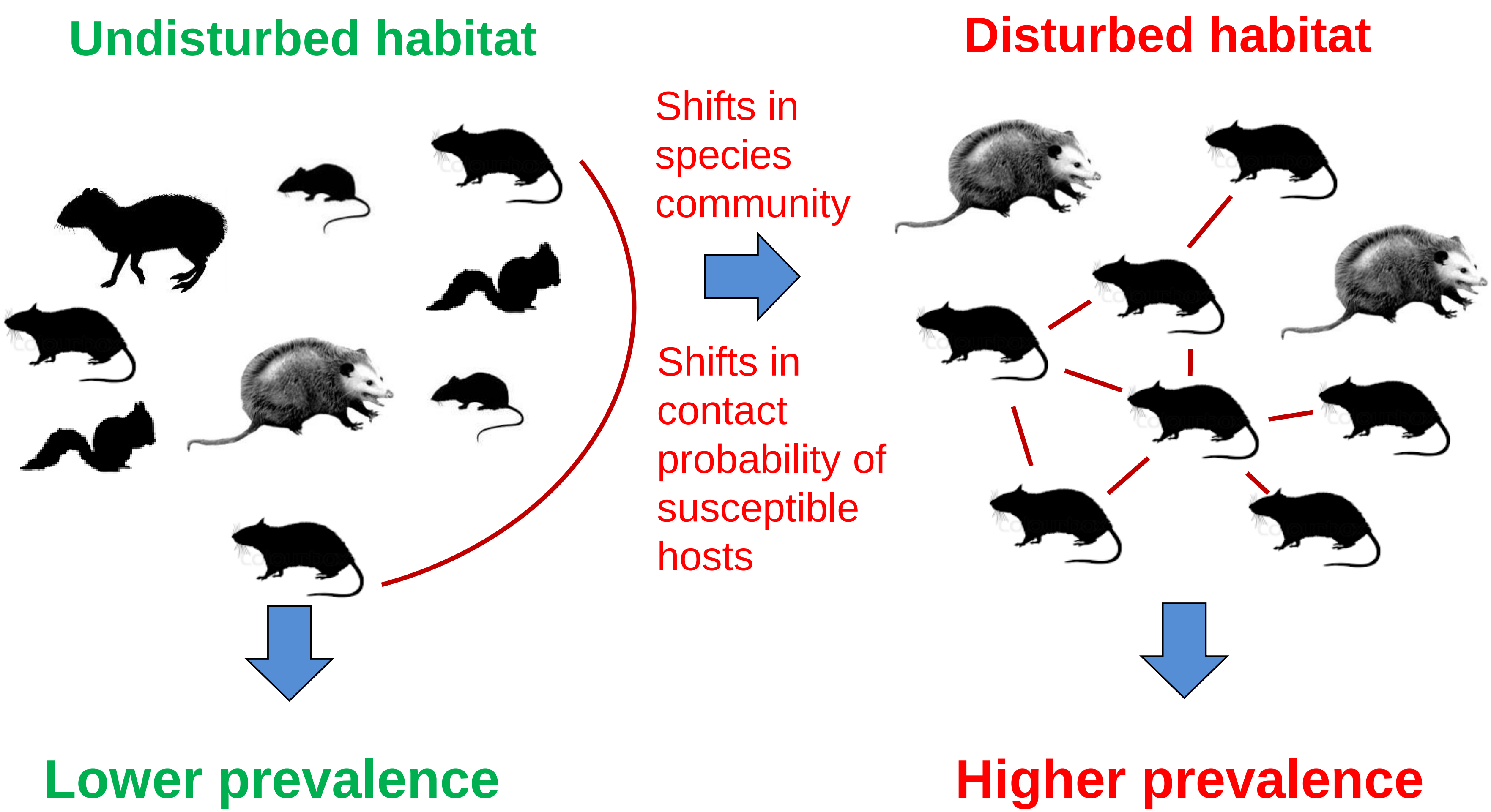
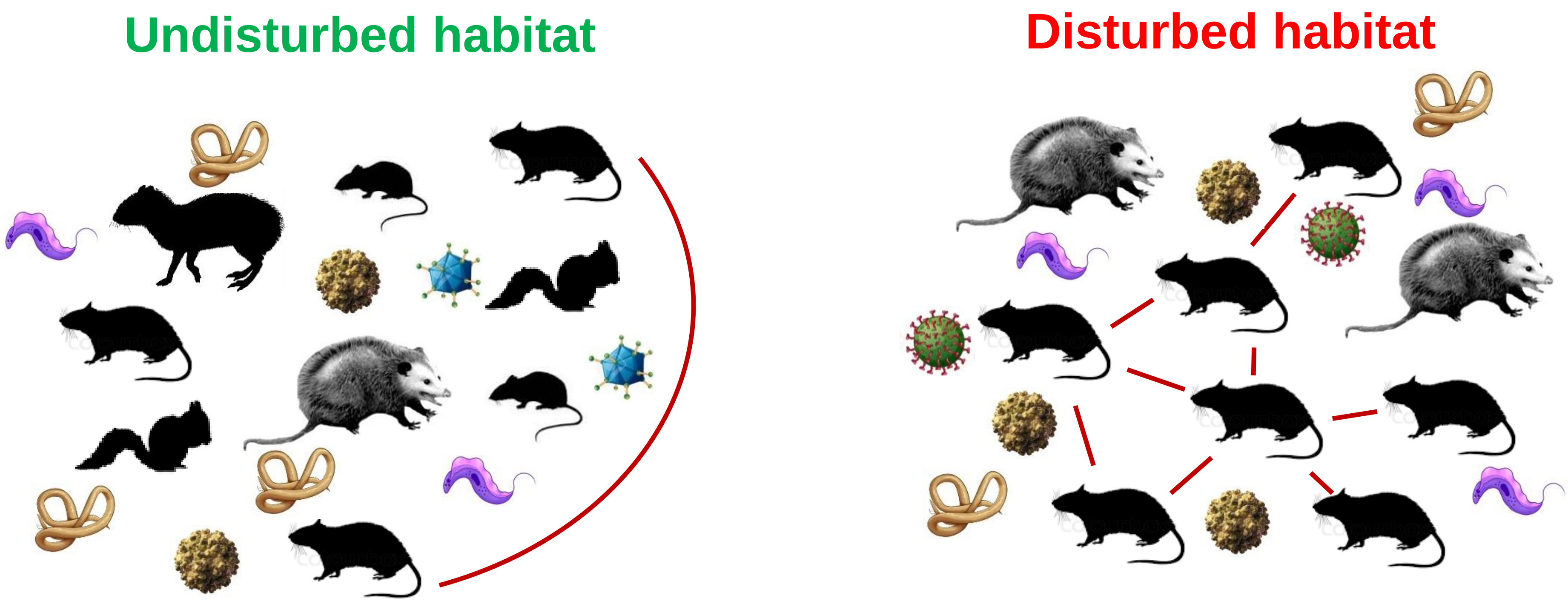


Relationship between species diversity, host abundance and pathogen prevalence



…simplified model, depends also on..

Relationship between species diversity, host abundance and pathogen prevalence

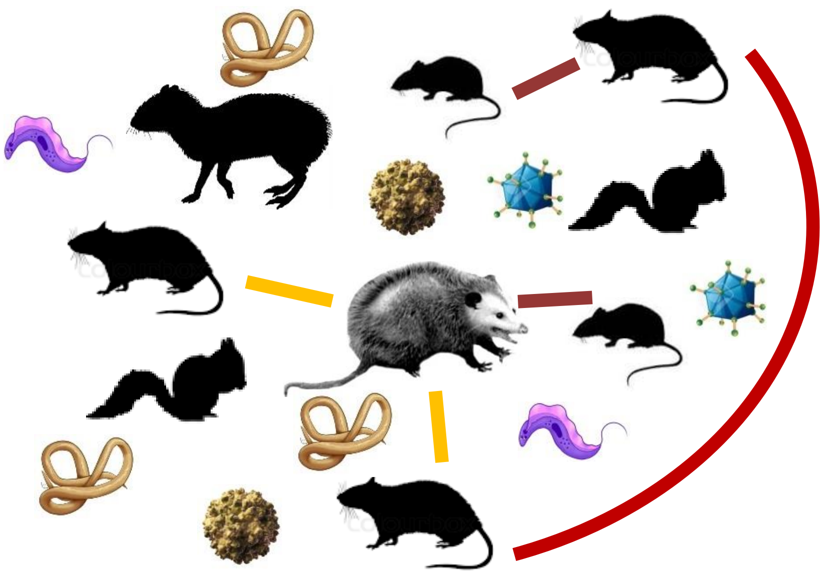


- Kind of pathogen?
- Transmission mode (e.g. vectors involved)?

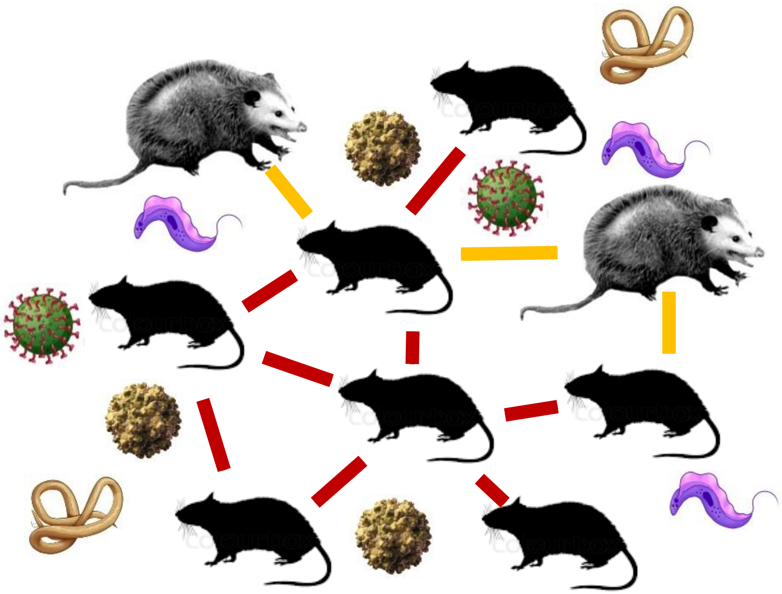
Huang et al 2016; Kiene et al 2020; Schmidt et al 2018, in review, Sommer 2005

Relationship between species diversity, host abundance and pathogen prevalence

Undisturbed habitat



Disturbed habitat



- Kind of pathogen?
- Transmission mode (e.g. vectors involved)?
- Transmission between host species?

Huang et al 2016; Kiene et al 2020; Schmidt et al 2018, in review, Sommer 2005

Relationship between species diversity, host abundance and pathogen prevalence

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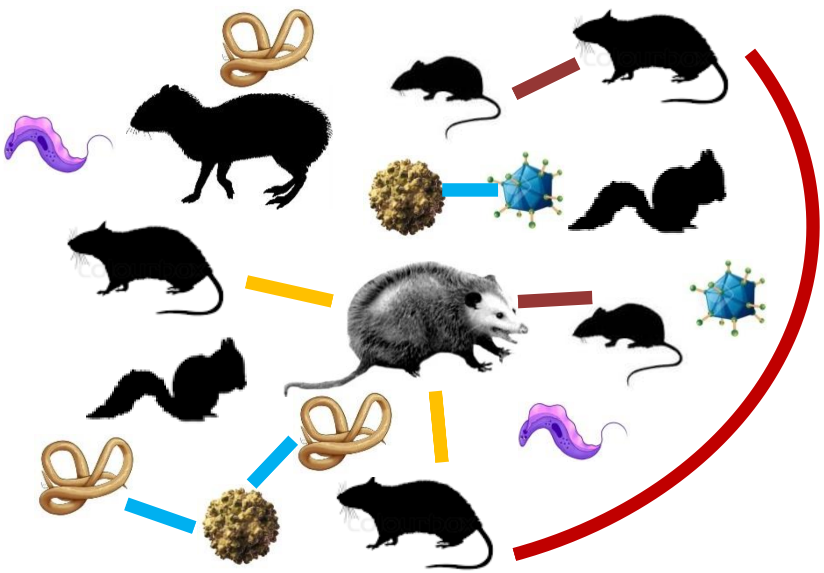
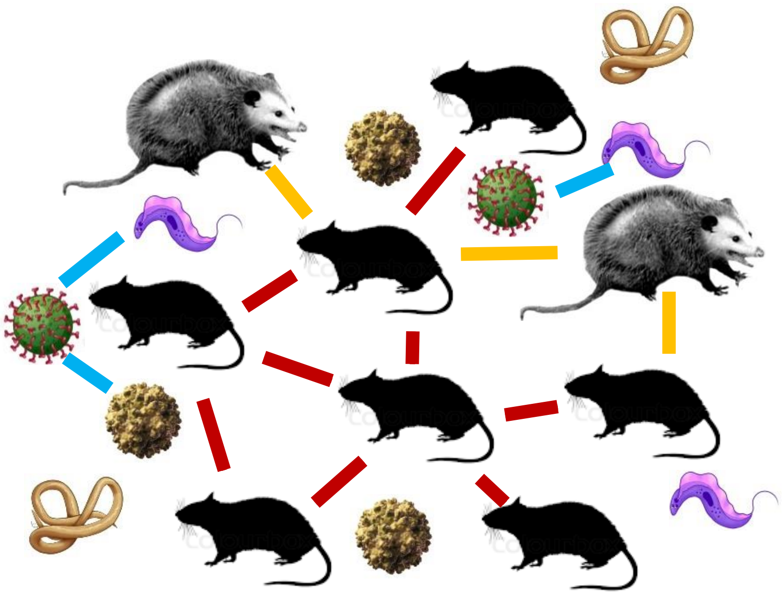


Disturbed habitat

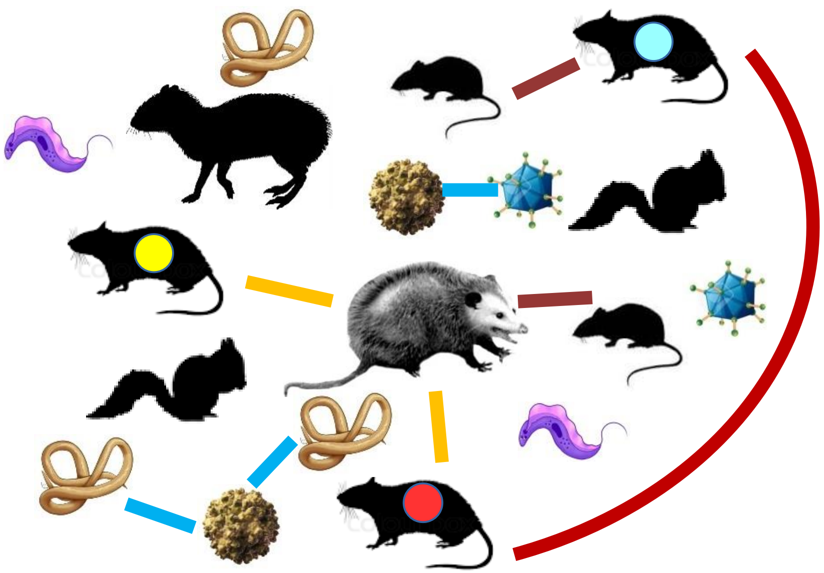


- Kind of pathogen?
- Transmission mode?
- Transmission between host species?
- Interactions between pathogen species?

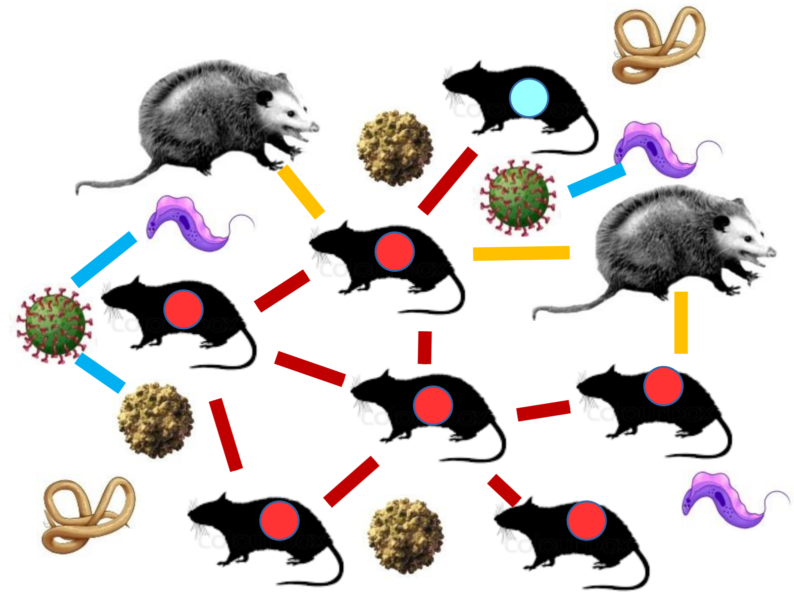
Huang et al 2016; Kiene et al 2020; Schmidt et al 2018, in review, Sommer 2005

Relationship between species diversity, host abundance and pathogen prevalence

Undisturbed habitat



Disturbed habitat



- Kind of pathogen?
- Transmission mode?
- Transmission between host species?
- Interactions between pathogen species?

- Host immune competence?

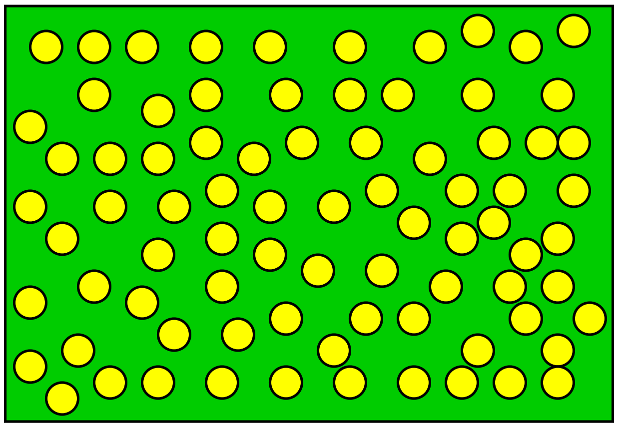
Huang et al 2016; Kiene et al 2020; Schmidt et al 2018, in review, Sommer 2005

How might **ecological factors** associated with environmental change affect animal and human health?

…and now **specialist species**

Consequences of environmental change on genetic diversity

‘Undisturbed’ habitat

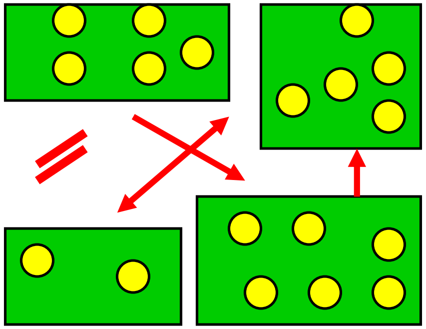


increasing fragmentation

degradation

isolation

Fragmented habitat

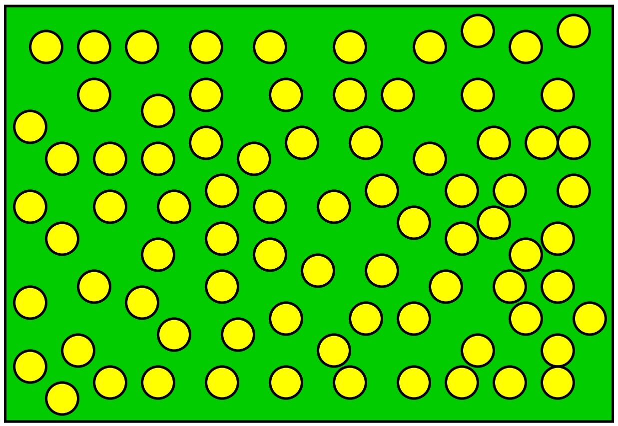


reduction of population size
(gene pool)

restricted or limited movement
(gene flow)

Consequences of environmental change on genetic diversity

'Undisturbed' habitat



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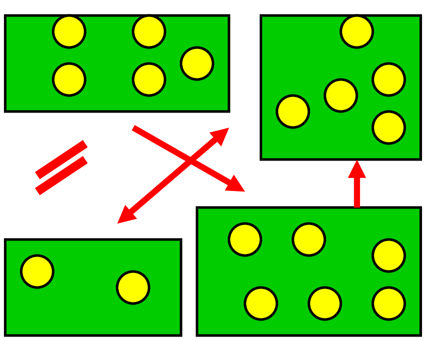
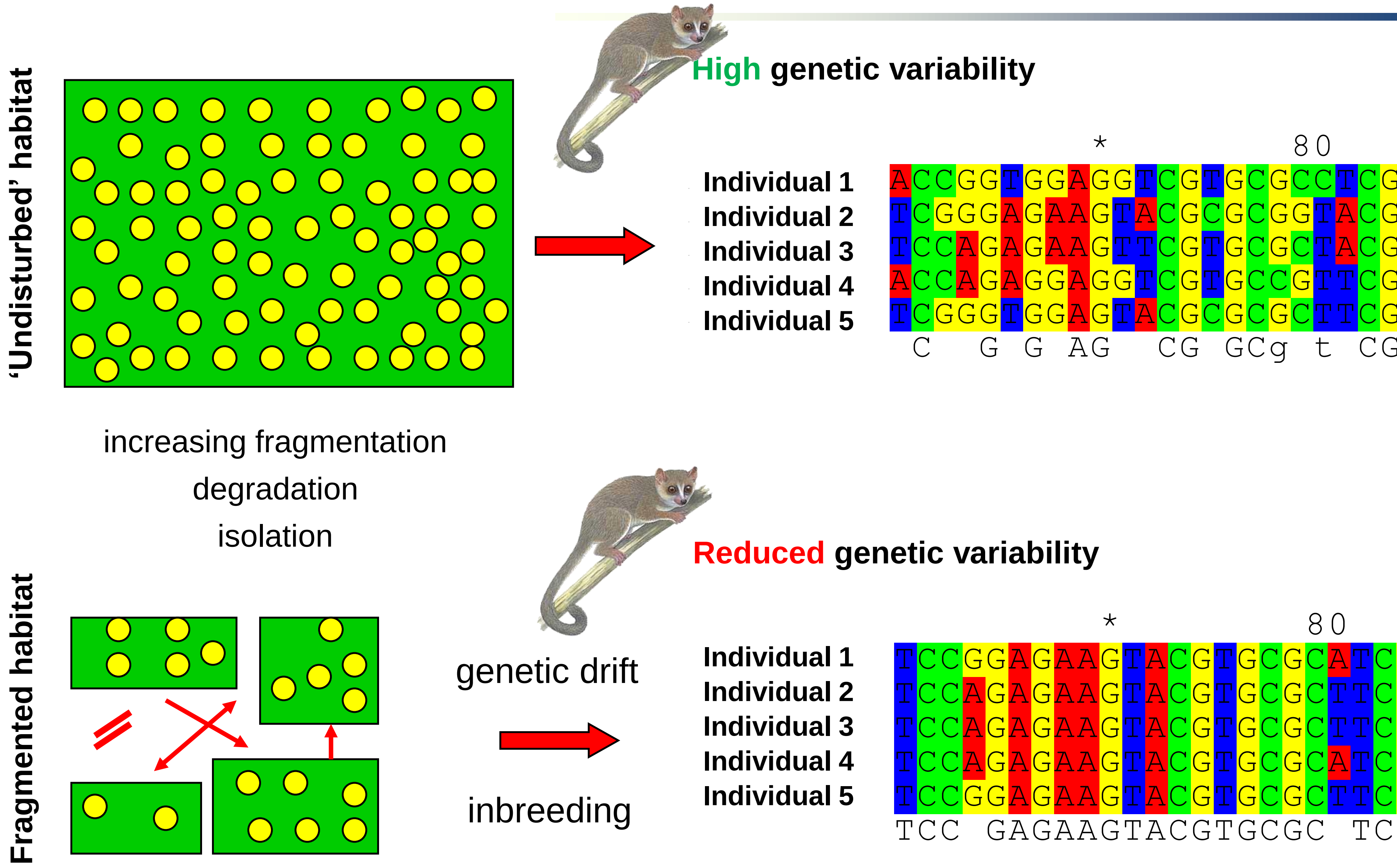
Fragmented habitat

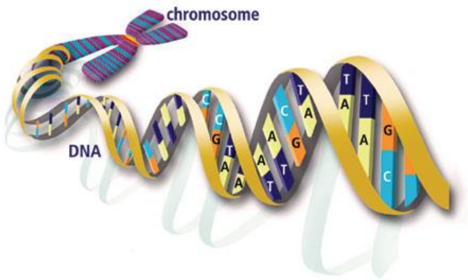


genetic drift

inbreeding

Consequences of environmental change on genetic diversity



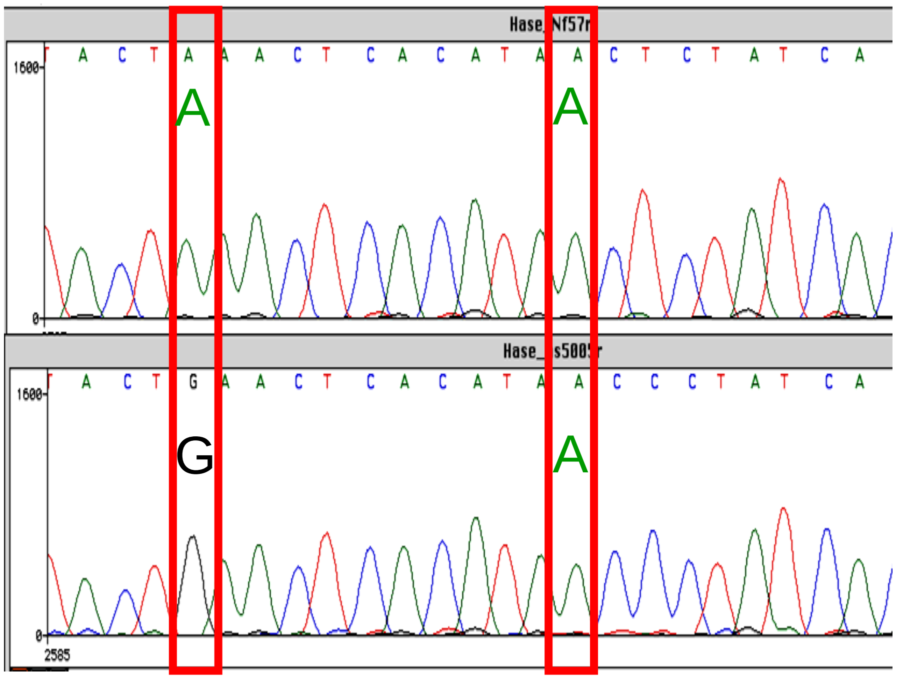


What is genetic diversity?

Performance of the two alleles

Heterozygote: both alleles are different

Homozygote: both alleles are identical



→ **Genetic diversity of individuals are determined by their heterozygosity,**

i.e number of heterozygous loci

Consequences of reduced genetic variability

Reduced genetic variability can cause ...

- diminished allele diversity
- fixation of deleterious alleles
- limited levels of heterozygosity
- inbreeding depression

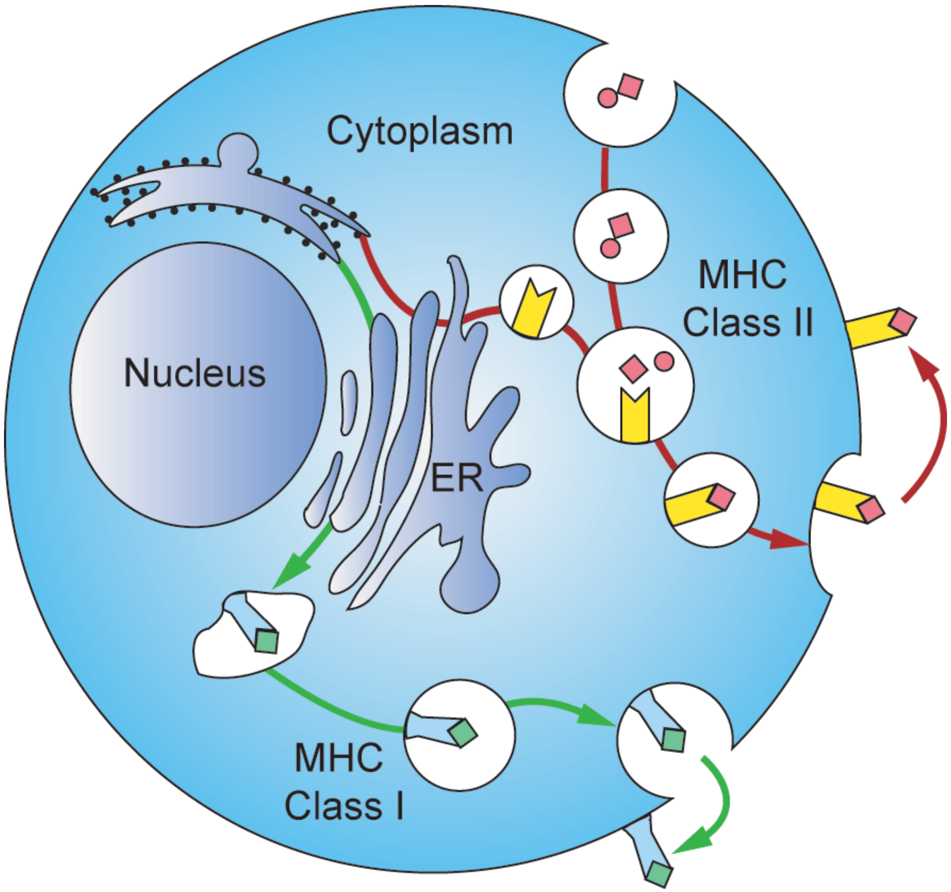
…with the consequences of ...

- reduced fitness, due to reduced fertility, offspring survival, **immune competence: pathogen and parasite resistance**
- **diminished adaptability to changing environment**

Sommer 2005 Frontiers Zoology;
Frankham 2010; Allendorf & Luikart 2012

Host's adaptive genetic diversity: Major Histocompatibility Complex (MHC)

Key function in the immune system

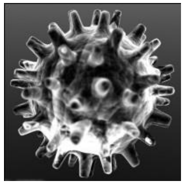


MHC-Glycoprotein

MHC Class I:

- present intracellular antigens

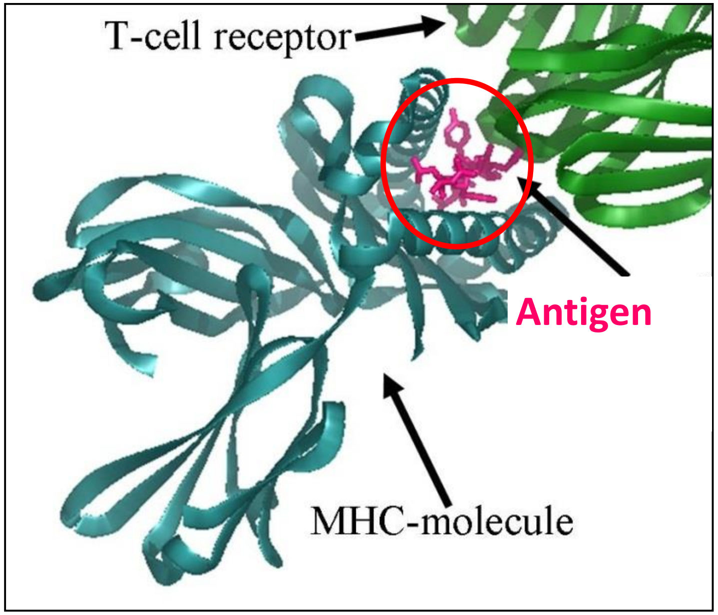
(e.g. virus-, cancer-infected cells)



MHC Class II:

- present extracellular antigens

(e.g. bacteria, nematodes, cestodes)



➡ **important role in population health, ecology, behaviour & conservation**

MHC Heterozygote Advantage

In clinical studies in humans or under laboratory conditions

- slower progression to AIDS after HIV infection in humans
  (Carrington et al. 1999)
- more effective clearance of hepatitis B viral infections in humans
  (Thursz et al. 1997)
- reduced pathogenicity during bacterial infection in lab mice
  (streptococcus-induced lesions: Chen et al. 1992; *Salmonella* and *Listeria*: Penn et al. 2002, McClelland et al. 2003)
- faster clearance rate of parasitic worms in lab mice
  (*Heligmosomoides polygyrus*, Behnke & Wahid 1991; *Schistosoma mansoni*, Sher et al. 1984)
- lower tumor incidence and faster regression in virus-infected captive chicken
  (rous sarcoma virus (RSV), Senseney et al. 2000)
- increased survival rate in virus-infected captive Chinook salmon
  (haematopoietic necrosis virus (HNV), Arkush et al. 2002)

Advantage / disadvantage of specific alleles

In clinical studies in humans or under laboratory conditions

- malaria, Epstein-Barr-virus, hepatitis B, leprosy, tuberculosis, gastric cancer, cestode infections in humans
  (Hill et al. 1991; Decamposlima et al. 1993; Thursz et al. 1995; Jeffery & Bangham 2000; Li et al. 2005);
  (*Echinococcus multilocularis,* Godot et al. 2000)

- gastrointestinal nematodes in lab mice and in straightbred Scottish Blackface sheep
  (*Trichinella spiralis*; Wassom et al. 1983, 1987; *Nematospiroides dubius*, Enriquez et al. 1988;
  Trichuris muris, Else et al. 1990; *Ostertagia circumcincta*, Schwaiger et al. 1995; Buitkamp et al. 1996)

- Marek's disease (= tumour disease caused by a herpes virus) in chicken
  (Briles et al. 1977)

- bacteria and virus infection in captive Atlantic salmon
  (*Aeromonas salmonicida* , Langefors et al. 2001; Lohm et al. 2002; salmon anaemia virus, Grimholt et al. 2003)

Variety matters? MHC diversity and pathogen load in different phylogenetic radiations

Meyer-Lucht, Otten, Püttker & Sommer (2010) Cons Genet

Meyer-Lucht & Sommer (2009) Evol Ecol Res

Schad et al (2005)

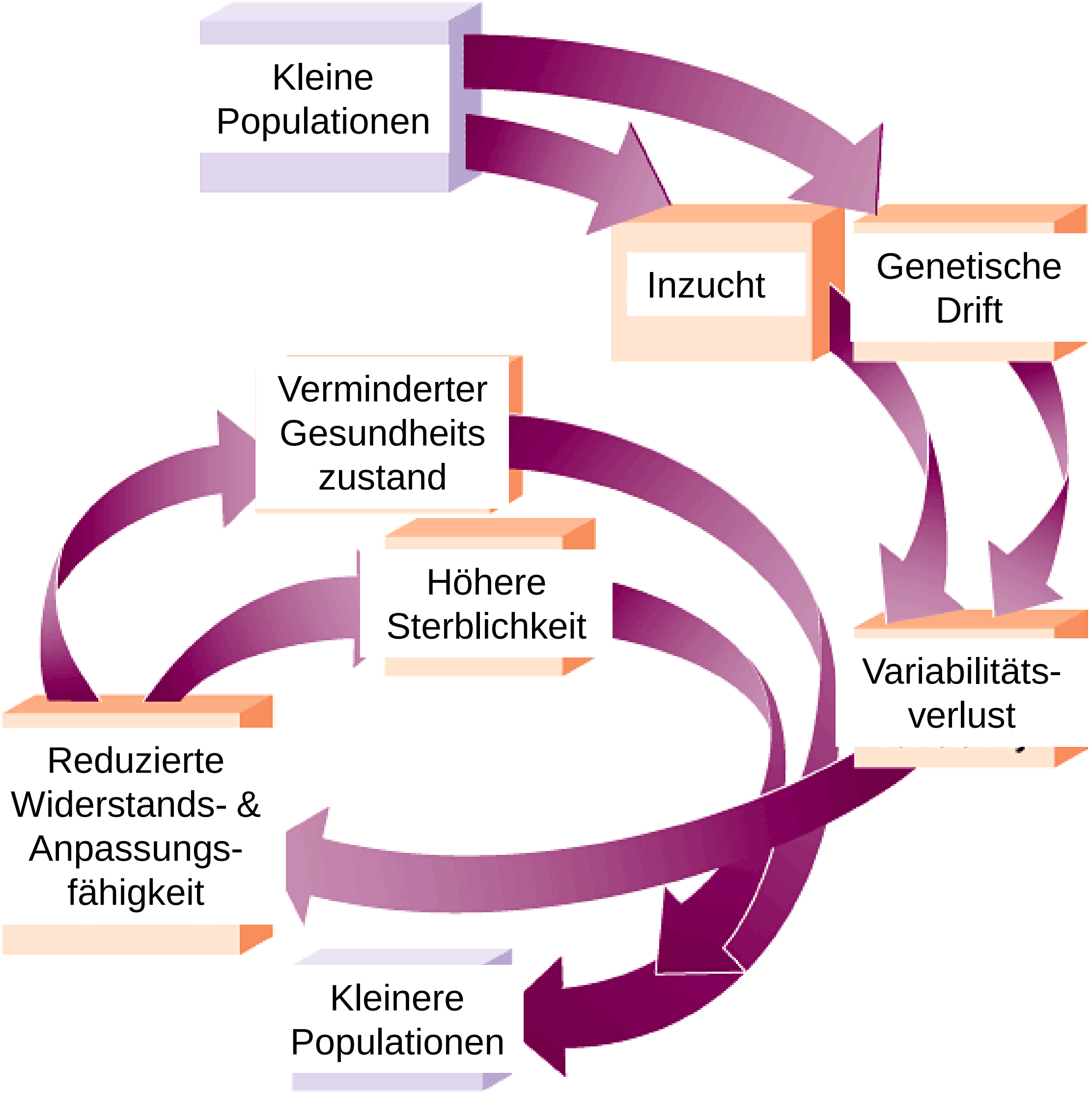
Schwensow et al (2007; 2008, 2010)

Schad et al (2012) PLoS One

Very low MHC diversity → **Normal: very high MHC diversity**

High pathogen load ← **Lower pathogen load**

Wie beeinflussen Umweltveränderungen die Gesundheit von Wildtieren?



Umweltzerstörung gefährdet unsere Biodiversität, aber auch die Gesundheit von Tier und Mensch

→ Veränderung und Abnahme des Lebensraumes
→ Veränderungen der Artengemeinschaft
→ Veränderung der Artenhäufigkeiten
→ Verlust des Verdünnungseffektes & Zunahme von Randeffekten

→ **Veränderung der Kontaktwahrscheinlichkeit von Wildtier, Nutztier und Mensch**

Generalisten

- Zunahme der Populationsgröße
- Zunahme der Dichte
- Zunahme des Pathogenreservoirs
- Zunahme der Ansteckung (z.B. Kontaktwahrscheinlichkeit, aggressives Verhalten)

→ Zunahme infizierter Tiere
→ Steigerung des Zoonosepotentials

Spezialisten

- Reduktion der Populationsgröße
- Verlust genetischer Diversität, insbes. Immungendiversität
- Verlust der Immunkompetenz
- Verlust der Abwehrmöglichkeiten gegen Pathogene

→ Zunahme infizierter Tiere
→ Steigerung des Zoonosepotentials

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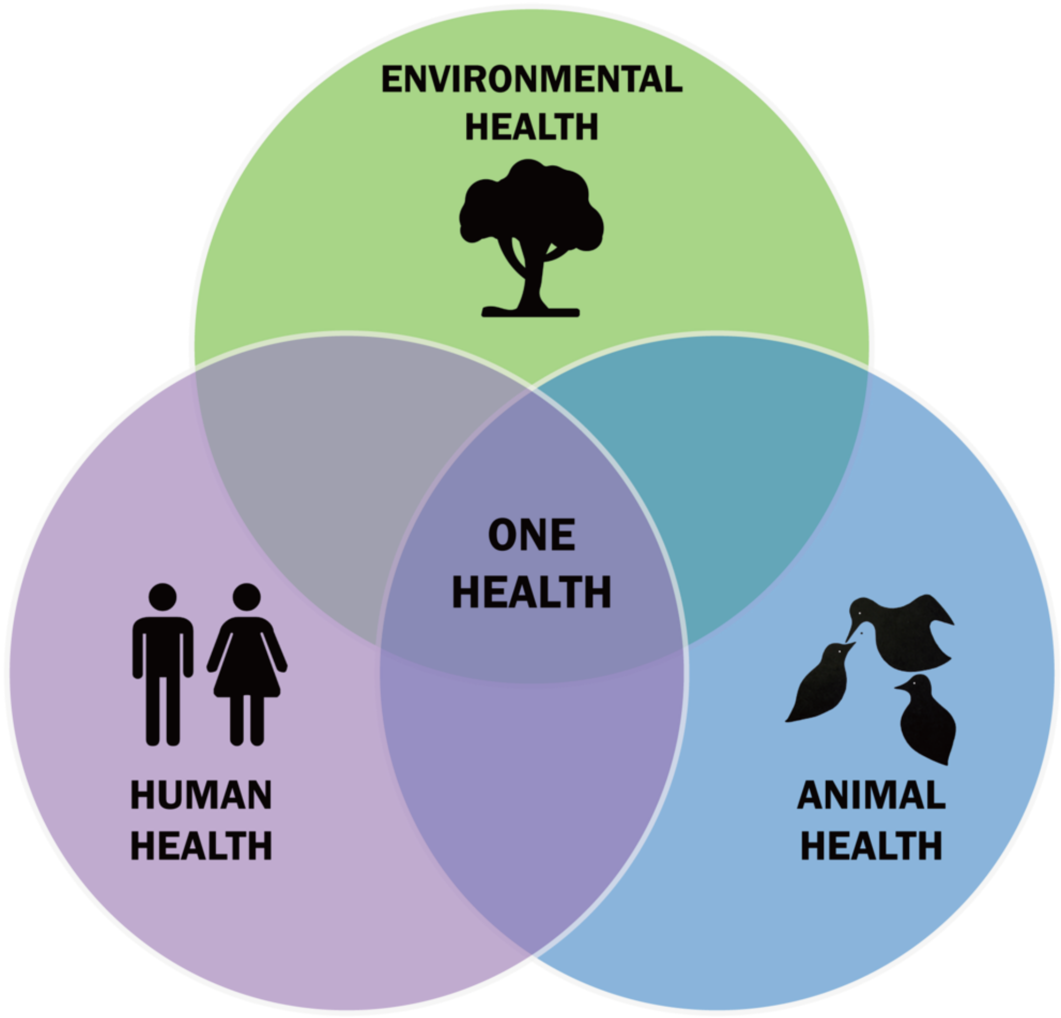

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