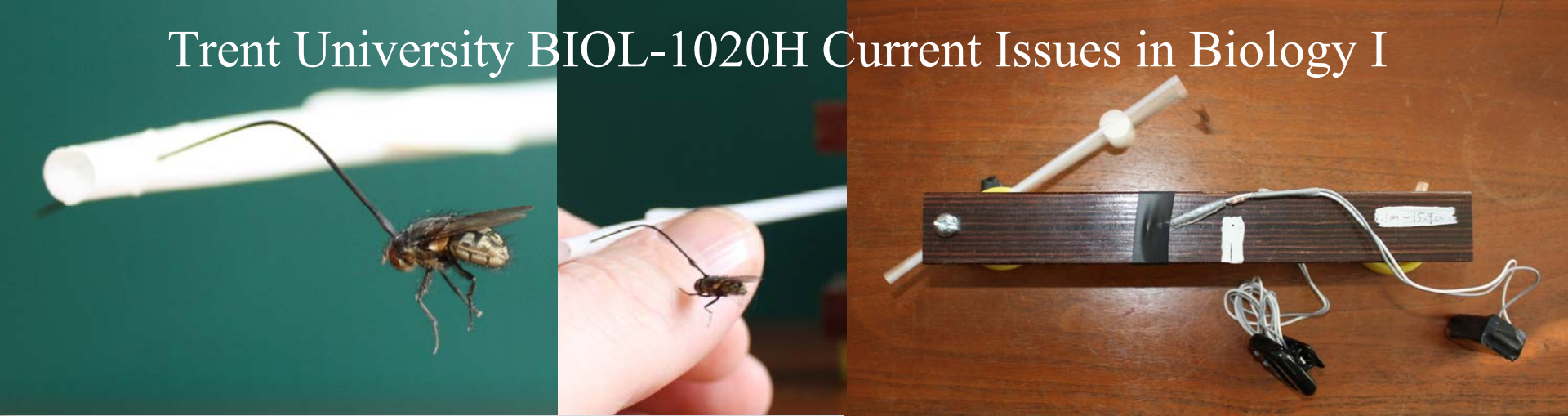


# Trent University BIOL-1020H Current Issues in Biology I



review lecture for final exam: first part of the course  
Monday Dec 9 Trent BIOL1020H-A 9AM  
last name starts with A or B, room SC215  
last name starts with C to Z, exam in the Gym



Why understand biology?

Biological thinking is needed in many aspects of decision making



picture of the Douro-Dummer municipal yard

164 species wood borers in eastern N America,

- most are native species

- Asian ash trees resistant to emerald ash borer                      Why?

- Emerald ash borer is invasive,    Why?

- what is going to happen to Ontario's ash tree? Should we be cutting them down? Will the quarantine work?

You can develop hypotheses about these and make predictions based on your understanding of natural selection



# Course objectives

To understand:

- hypothesis testing
- natural selection
- how to do experiments in ecological studies
- how to write a scientific paper

week 1: induction and deduction; syllogisms as the basic unit of reasoning; basic structure of a ecological experiment; complex systems, examples: influenza, cholera, iron and disease, thinking of adaptive peaks as strategies in biology, positive and negative feedback loops

week 2: good and bad hypotheses and predictions, variability in nature, natural selection as tracking and adaptive peak in multivariate space, from the literature examples: apple maggot fly, DDT, mosquitoes and immunity, the niche and novel environments, dynamic vs static systems, natural selection and playing the odds, iterations in nature, DDT and ecological backlashes, new diseases in humans, animal behaviour

week 3: more hypotheses examples, optimality theory and selection, examples of making predictions based on selection pressures, eg whelks and crows, lions, killer bees and habitat shifts, genetic basis of behaviour and selection pressures, so called flaws in nature, novel environments and changes in human responses, evolutionary response of humans, and modern disease ecology, eg what we eat, near vs far sightedness, a recent example of natural selection at work in crickets.

week 4: diversity indices, role of dispersal in selection pressures, Trivers' hypothesis of why sexes differ

week 5: populations and selection, carrying capacity and growth models, K vs r selection strategies, making predictions, evolutionary stable strategies, side blotched lizard example, role of parasites, cow bird/bot flies/wasps examples

## Inductive reasoning: from the particular to the general

examples (a philosophical example):

to learn about swans:

- catalogue swans, see they are all white
- conclude that swans must be white
- problem, a black swan is a possibility - not all swans have been observed

produces new information but cannot provide certainty



## deductive reasoning: from premises or general principles to particular

examples

example: all triangles have three sides,

this is a triangle, it must have three sides

returns certainty, BUT no new information

the scientific method (s)

Baconian method, observation and verification  
observe and discover new facts and relationships,  
not trustworthy

hypothetico-deductive method (Karl Popper)  
falsify hypothesis using experiments

multiple hypothesis method  
falsify several alternative hypotheses using experiments

## Hypotheses and the hypothetico-deductive method

**We try to falsify or reject the hypothesis**

**if we cannot, then we conclude we cannot reject it, which lends support for it**

**Note that an experiment does not support a hypothesis directly, an experiment allows us to reject a hypothesis or not.**

biological systems

systems approach

keeps relationships, stops us thinking of isolated phenomenon

keeps dynamic nature of relationships

individuals within the system affect the system itself

2 types of feedback in systems

positive destabilizing, eg Allee effect

and negative, stabilizing, eg density  dependent cannibalism in dragonfly larvae

## Scientific Reasoning

Sir Ronald Fisher (statistician who invented the F-test, and ANOVA) describes our approach to as that of a gambler:

- what are the odds that we are right?
- we are content if the odds are good
- we want to know about each of our explanations "does it work?"



**Ronald Fisher: Australian biologist and statistician:**

- was right about evolution
- was wrong about smoking

observation

↓ *inductive reasoning*

research hypothesis

↓ *deductive reasoning*

prediction

↓

experiment

- gather data
- examine data with a **statistical test**
  - **null hypothesis** results due to chance
  - **alternative hypothesis**: results not due to chance

↓

assess results

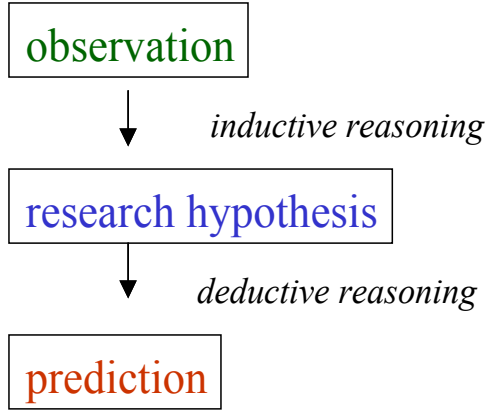
- reject **null**? then something other than chance is at work  
hence the prediction is correct, supports **research hypothesis**
- accept the **null**? then chance alone can explain results  
the prediction is wrong, no support for **research hypothesis**

↓ *inductive reasoning*

revise/form new research hypothesis

outline of biological experiments (Hilborn and Mangel, 1997):

# How to communicate this in a report or paper!



## INTRODUCTION

- present the question
- give examples from the literature of other people's work
- state the hypothesis and the deduced prediction

## MATERIALS AND METHODS

- say what you did, give details of experiment

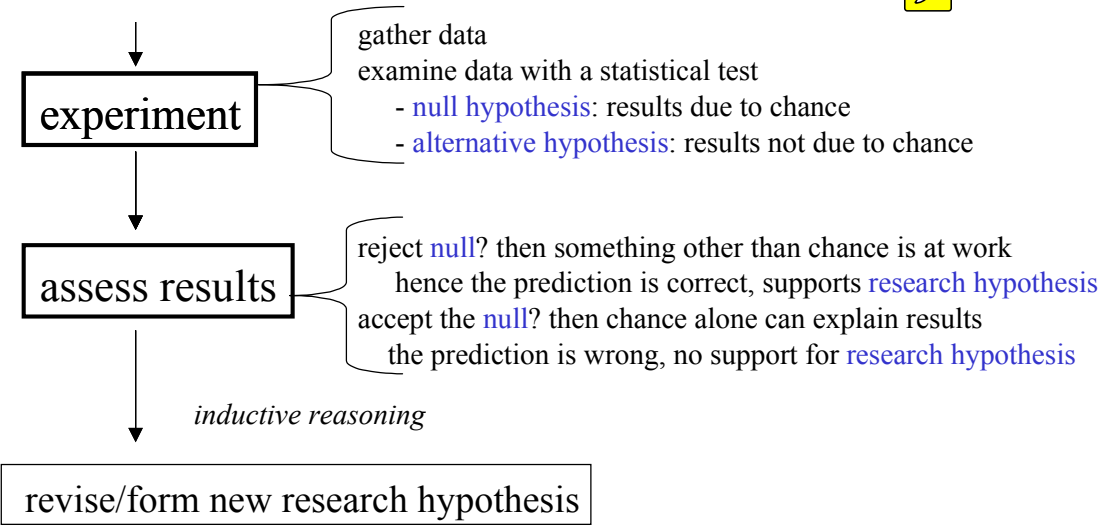
## RESULTS

- tell what you found in text, graphs, and tables



## DISCUSSION

- was prediction right or wrong? So, was the hypothesis rejected? If not, it was supported.
- is there any information in the scientific literature on this?
- explain your results and suggested new follow-up work
- the next step.



what works will continue

what doesn't work will not continue

more accurately, what continues is that which can

often called survival of the fittest

Dobzhanski renames this as survival of any fit enough to survive **and**  
**reproduce**

(eg fit squirrels run from foxes, brave irrels are not fit, they are food)

natural selection

tracking multivariate space

effect measured as fitness

fitness is ability to track the hypervolume through time

individuals that fall outside of the hypervolume do not reproduce

fitness is reproductive fitness 

example Apple Maggot Fly (*Rhagoletis pomonella*)



Male apple maggot fly. Photo courtesy Agriculture & Agri-Food Canada



Apple maggot larvae in apple. Photo courtesy Agriculture & Agri-Food Canada

adaptive peak example: role of environment: *Apis mellifera* honey bees

two major races in the species

European honey bee (*Apis mellifera*) and African honey bees, (*A. m. scutellata*, so-called killer bees)

genetics:	African dominant genes	European recessive genes
habitat:	tropical	temperate
flowers:	always in bloom	bloom in cohorts
store food?	no, always food	yes
predators:	common	rare



## behavioral differences

Africanized: evolved for a tropical life with tropical agriculture

European: evolved for a temperate life with agriculture

recent natural experiment in adaptation:

stopped by climate, cannot overwinter!

each sub-group occupies separate adaptive peak N America they

sort out to occupy their niche

**with no advantage to prior**

**occupancy**



## new development: crickets and flies

see: Zuk, M., Rotenberry, J. T., and Tinghitella, R. M. (2006). Silent night: adaptive disappearance of a sexual signal in a parasitized population of field crickets. *Biology Letters*.

Hawaii--island of Kauai:

### selection pressure for loud calling

new introduction of parasitic fly, *Ormia ochracea*, hunts crickets by sound

lays eggs on cricket, maggots consume live cricket

### selection pressure against calling



examples of potential future speciation

**sympatric speciation:** apple maggot fly on apples and hawthorns

**allopatric speciation:** cricket example on Hawaiian island



Male apple maggot fly. Photo courtesy Agriculture & Agri-Food Canada



Apple maggot larvae in apple. Photo courtesy Agriculture & Agri-Food Canada



## mimicry hypotheses

possible reason why predators learn one pattern faster than two, less mistakes made  
mistakes mean prey is mauled  
if so, we expect different species use same colours and patterns for warning

*formally stated:*

Hypoth. selection favours similar warning colours among prey species **in the same region**

assuming same predators

Pred. if so, then we will find same warning patterns where prey species co-exist, but different patterns where prey species do not coexist

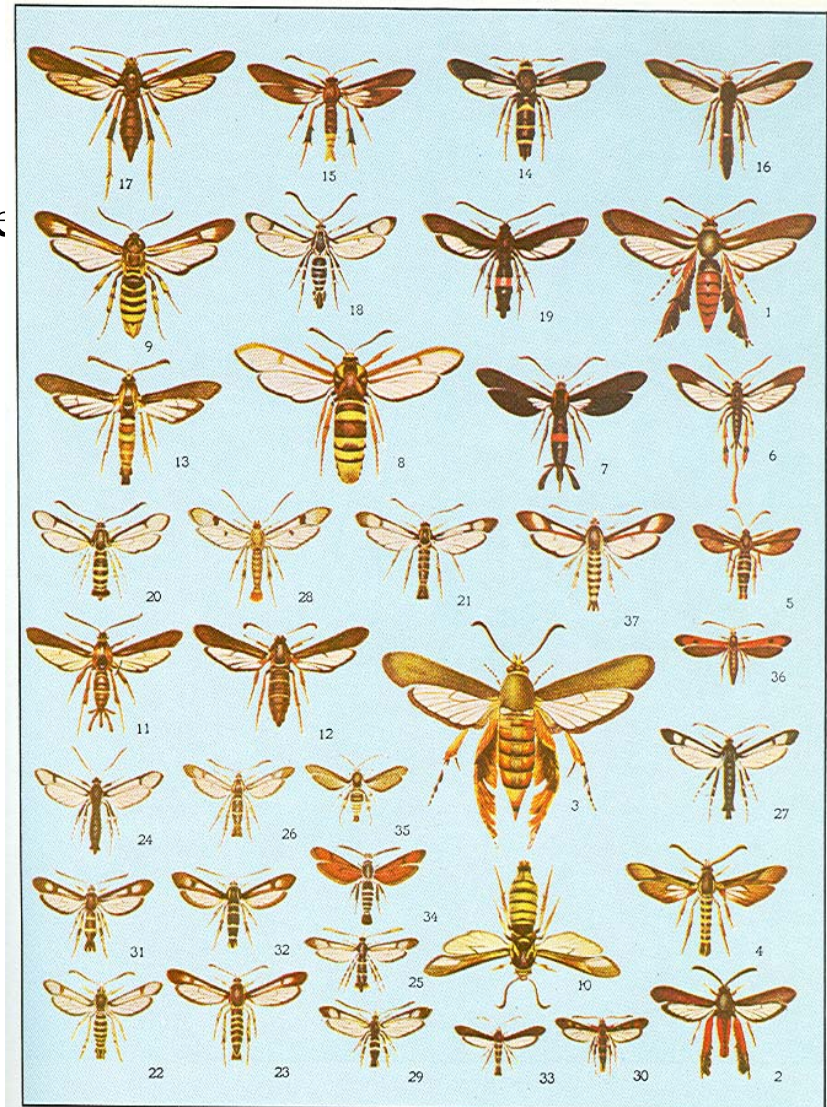


Figure of wasp mimicry in different moth species, from W J Holland, 1903

results:

different prey species of specific set of predators tend to be similar when they co-exist in the same region

but, some prey species are similar yet are prevalent at different times or in different regions

the prediction "if H is true, then we will find same warning patterns where prey species co-exist, but different patterns where prey species do not coexist" is wrong!

→ hypothesis is wrong!

why? further observations ...

bot flies found in summer mimic bees that occur in spring further south

main predator is migratory birds

- birds learn to avoid bees

- bot flies take advantage of that!



New Hypothesis: selection favours similar warning colours among prey species **in the same ecological space** - assuming same predators

Prediction: if so, then we will find same warning patterns where prey species co-exist, but different patterns where prey species do not coexist in ecological space

The fundamental paradigm of modern biology:

Natural selection

... and *cause* in biology

two types of causal explanations in biology:

*proximate cause*; the *how* questions:

genetic, developmental, physiological, environmental, learned e.g.  
cultural

*ultimate cause*; the *why* questions:

evolutionary, why did this plant or animal evolve that mechanism?

Novel environments (meaning a new situation or change in environment):

1. reveal the adaptive space to us

adaptive space is dynamic, changing

phenotypes (what an individual actually is) are always one generation out of step!

the phenotypic makeup of a population is the result of the last generation's reproduction under selection

2. seemingly outside, far-reaching events are important contributors to selection pressures



Novel ecology (crowding and short life expectancy) in WW1 changed influenza virus. Similar conditions push virus to similar changes in modern agriculture



## Novel environment: DDT immunity selected for in mosquitoes

behavioural immunity

DDT was used to control *Anopheles gambiae* mosquitoes in parts of Africa where malaria is endemic.

mosquitoes bite human hosts

land on the walls of the house to rest before flying out doors

paint with DDT applied to walls of bedrooms

mosquitoes that landed all killed 

non-landers did not die, all extant mosquitoes are now "immune" to DDT on bedroom walls, all are descendants of non-lander

→ NB the mosquitoes did not learn, did not change their behaviour, the non-landers always existed, just in lower numbers

# Novel human environments near sightedness or myopia

excessive growth of the eye  
too far from lens to retina

cure

glasses refocus light to retina

growth controlled by genes as we grow from child to  
adult, eyes coordinate growth as eyeballs get larger

<1% error will affect the focal point

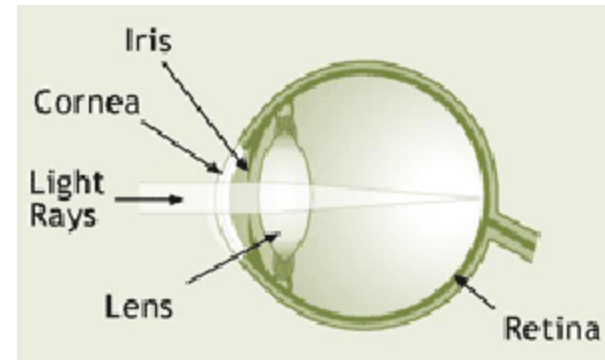
25% of humans:



reading books (or television, computer monitors)  
with close attention causes brain to keep sending  
the growth signal (not known why)

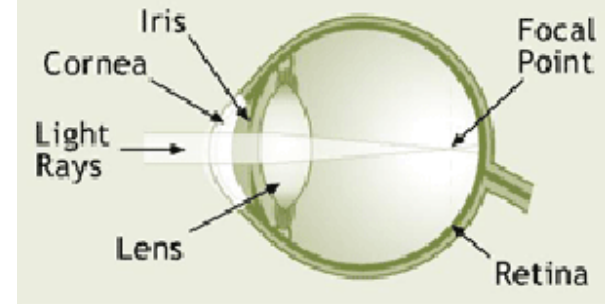
historically, not found, no historic adaptive pressure  
against this

currently, not a defect, a quirk of the combination of  
new environment and old genetics, and **no adaptive  
pressure against this trait**

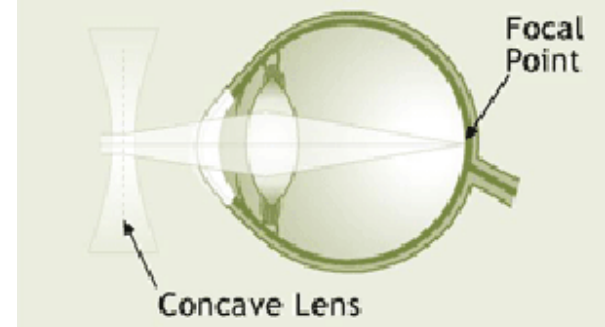


## Myopia (short-sightedness)

The shape of the cornea is too convex



## Traditional Correction of Myopia through the use of spectacles



## populations

*made up of individuals*

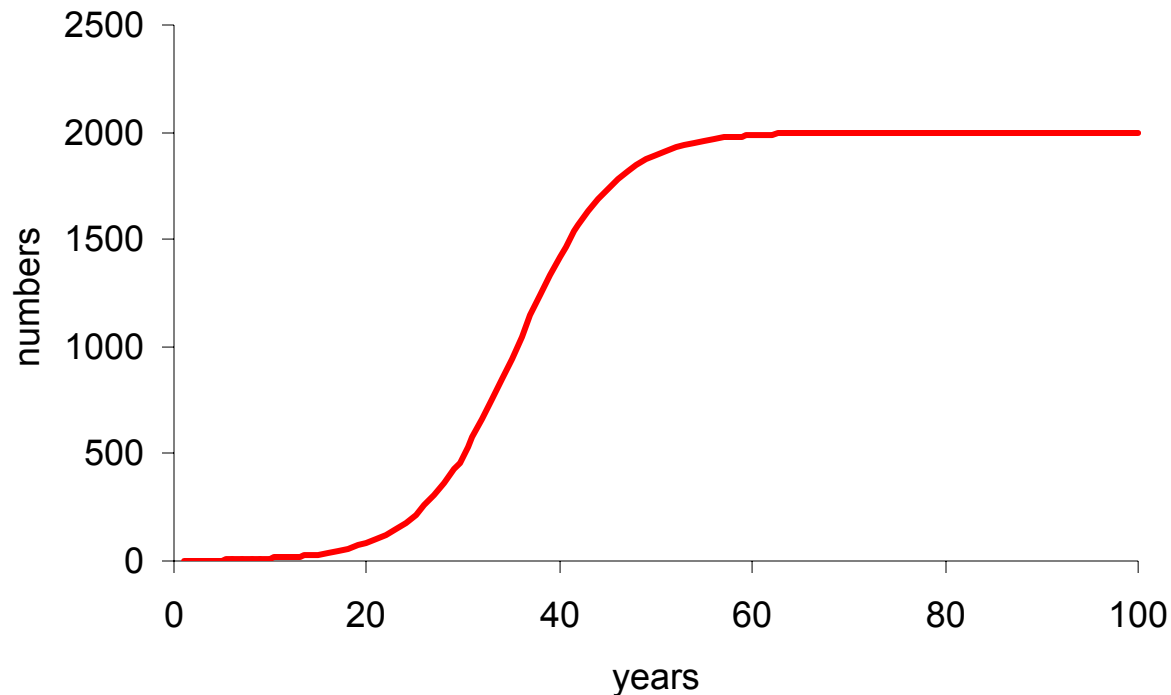
*can be understood as a unit of measurement*

*one of the parameters that affect individuals*

general pattern of growth: colonization, growth, levelling off at some peak

*new population established, called **Allee effect***

positi



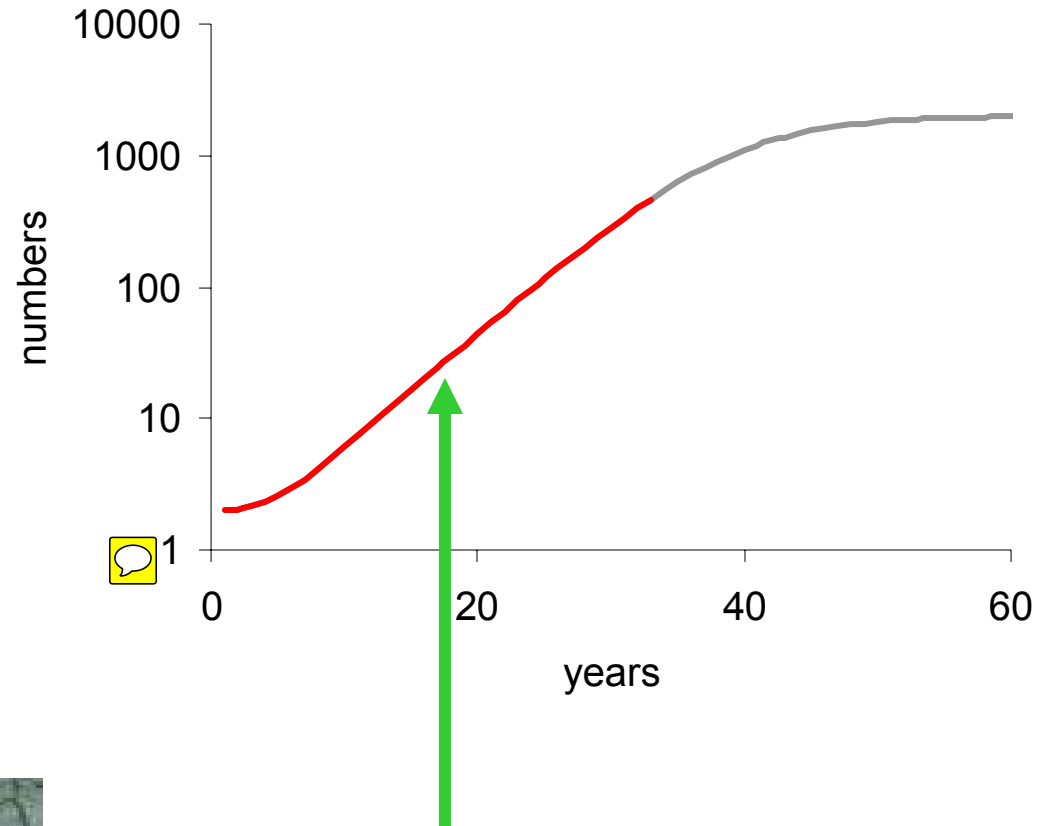
early stage: exponential growth

*exponential population growth continues*

*selection pressure for dispersal, finding new colonies*

eg house flies, manure flies,  
many diseases, weeds  
(except...)

***r-selected reproduction strategy***



late stage: stable population near carrying capacity

carrying capacity "K" is the number that can be sustained in any region

by definition: if numbers go above K, population drops, if below K, numbers rise

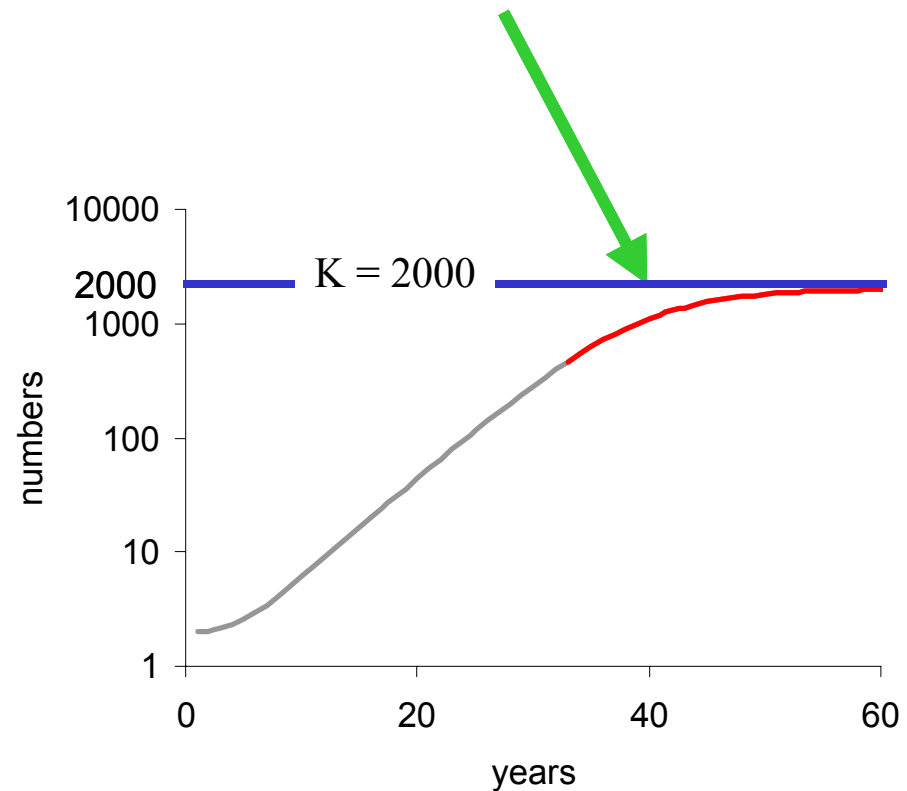
negative feedback loop

called logistic population growth

curve has sigmoidal shape

*these species have K-reproductive strate*

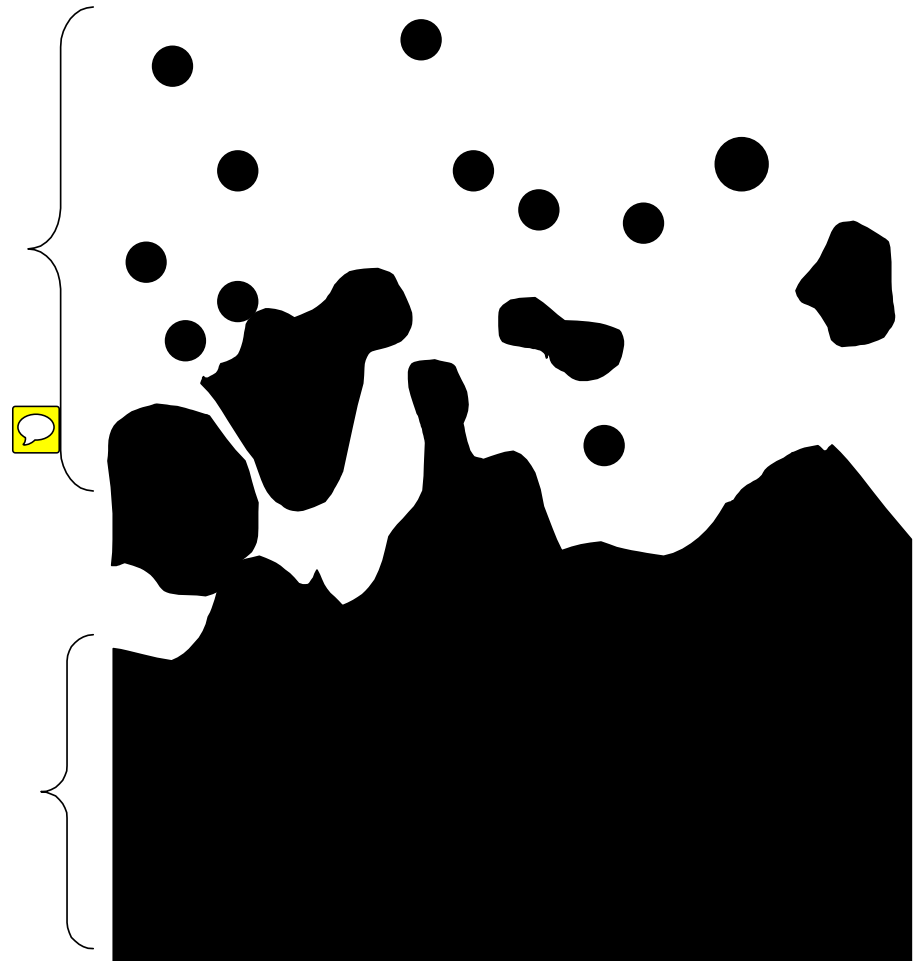
selection pressure at K: stable life in  
for quality offspring



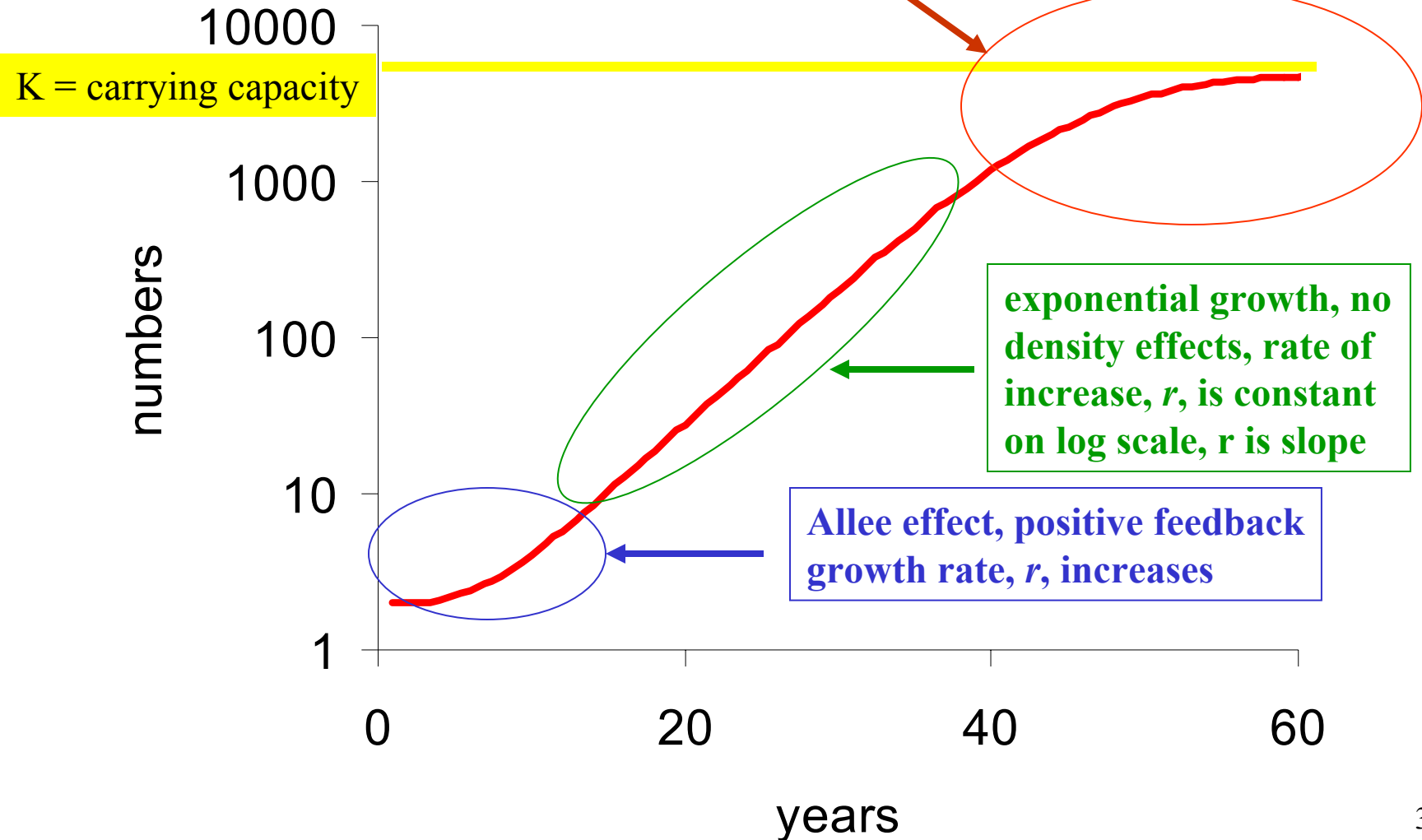
## along a spatial scale

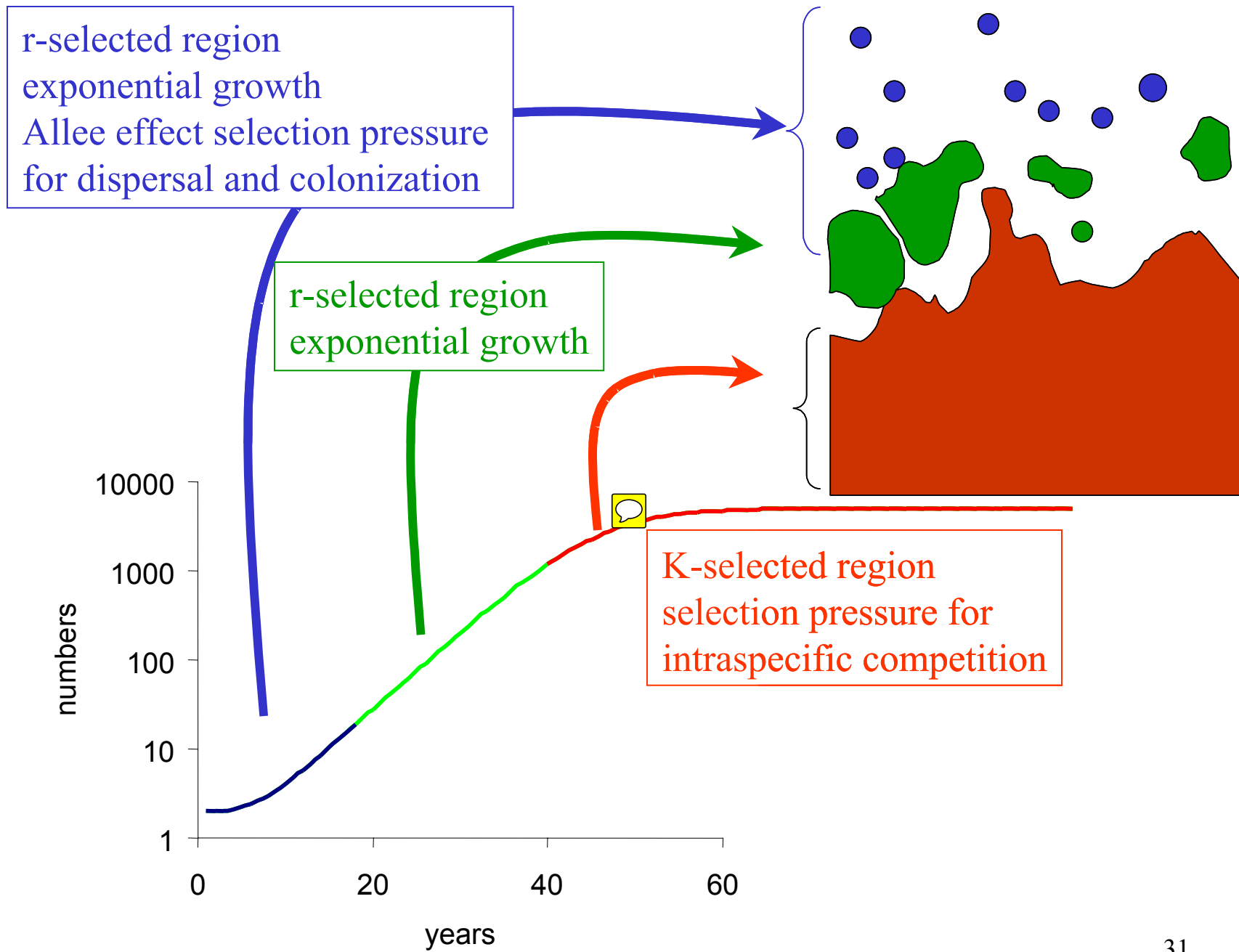
temporary habitats: extinctions and  
colonization  
selection pressure for high colonizing  
ability, high dispersal  
selects for an **r-reproductive strategy**

permanent habitats:  
selection pressure for geneflow,  
intraspecific competition, populations  
remain at K  
selects for a **K-reproductive strategy**



summary of last  
lecture



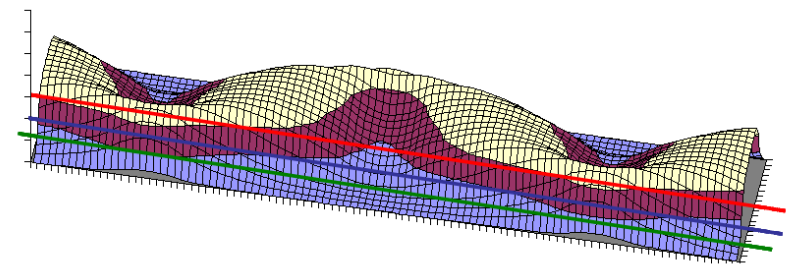


# Carrying Capacity lecture

changing spatial patterns in carrying capacity

**Possible essay question:** explain what carrying capacity is, what stochasticity is, and how changes in the spatial and temporal scale can affect patterns based on sampling over time at the same place, and result in mistaken conclusions.

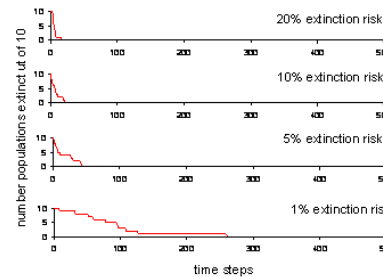
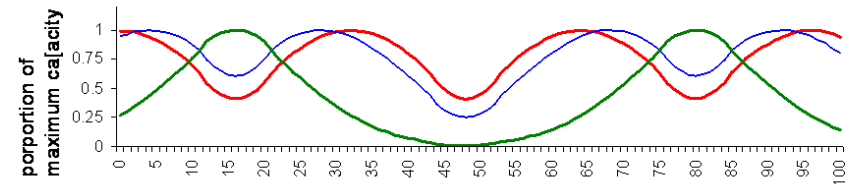
Explain the rescue effect and how connectivity can affect persistence of a species in a metapopulation



sampled in centre

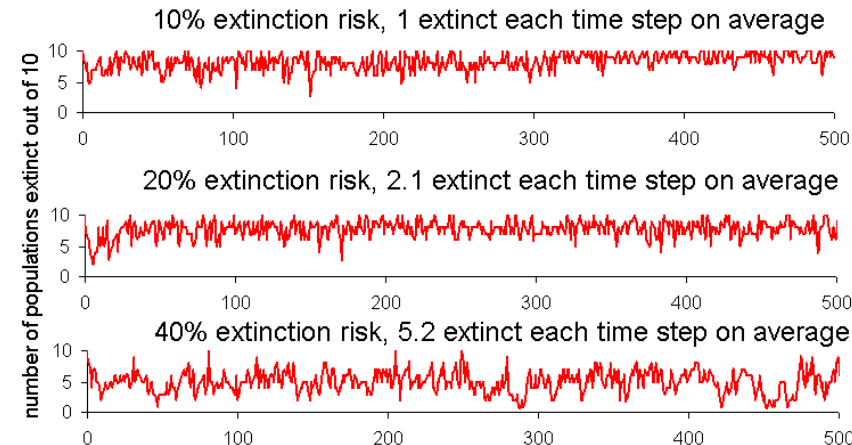
sampled midway to edge

sampled along bottom edge



no rescue

with dispersal and rescue



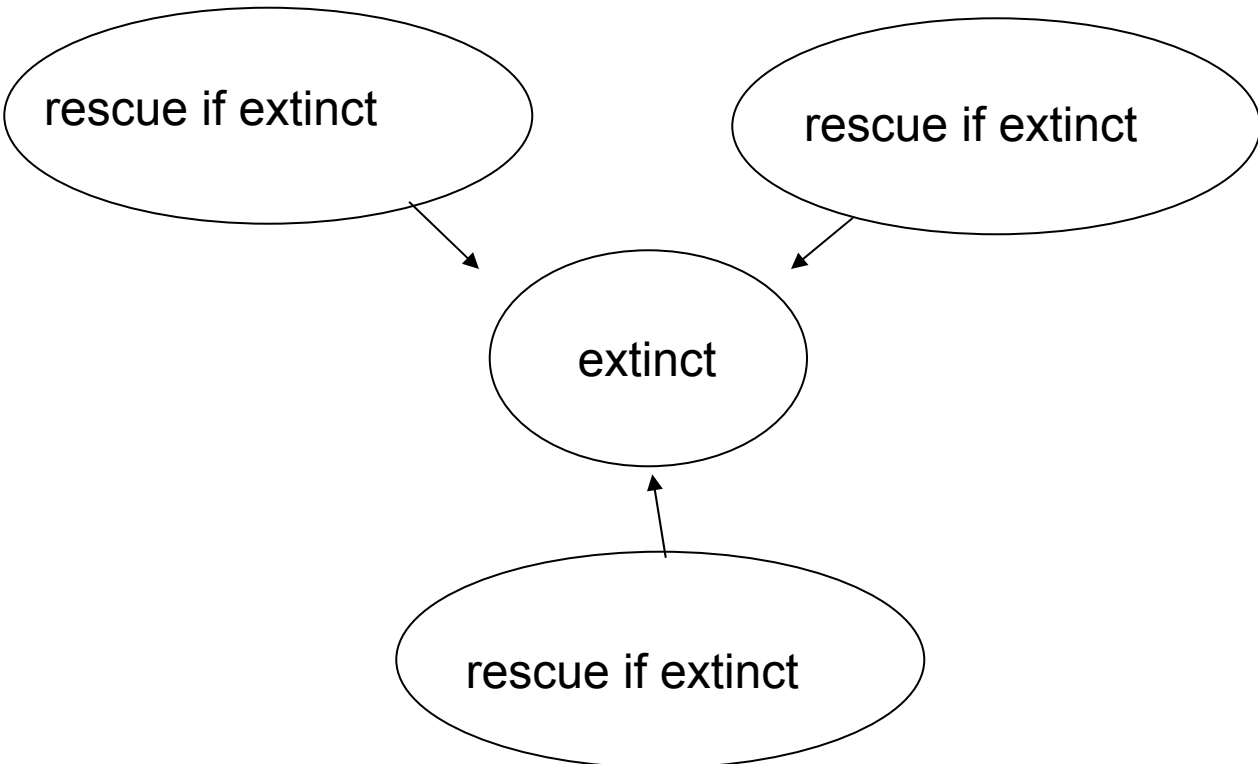
# metapopulation effect: populations rescue neighbouring populations without dispersal

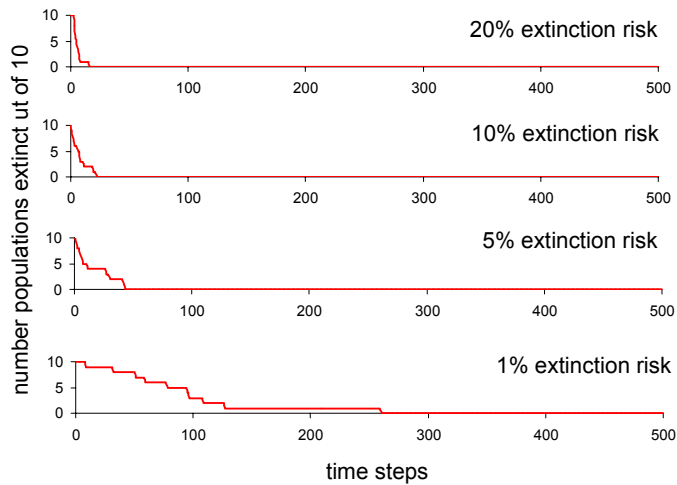
**% chance of stochastic extinction 10**

time step	10 populations, not connected, typical island populations with modeled chance of extinction									
	1	2	3	4	5	6	7	8	9	10
0	1	1	1	1	1	1	1	1	1	1
1	1	1	1		1	1	1	1	1	1
2	1	1	1		1	1	1	1	1	1
3	1	1	1		1	1	1	1	1	1
4	1	1	1		1	1	1	1	1	1
5		1	1		1	1		1	1	1
6		1	1		1	1		1	1	1
7		1	1		1	1		1	1	1
8		1	1		1	1		1	1	1
9		1	1		1			1	1	1
10		1	1		1			1	1	1
11		1	1		1			1	1	1
12		1	1		1			1	1	1
13		1	1		1			1	1	1
14		1	1		1			1	1	1
15		1	1		1			1	1	1
16		1	1		1			1	1	1
17			1		1			1	1	1
18			1		1			1	1	1
19			1		1			1	1	1
20			1		1			1	1	1
21			1		1			1	1	1
22			1		1			1	1	1
23			1		1			1	1	1
24			1		1			1	1	1
25			1		1			1	1	1
26					1			1	1	1
27					1			1	1	1
28					1			1	1	1
29					1			1	1	1
30					1			1	1	1
31					1			1	1	1
32					1			1	1	1
33					1			1	1	1
34					1			1	1	1

all extinct by year 33

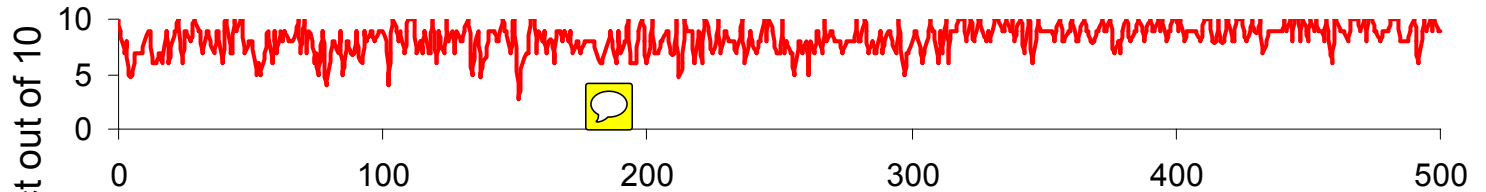
# extinction risk, with rescue by dispersal from 3 neighbouring populations



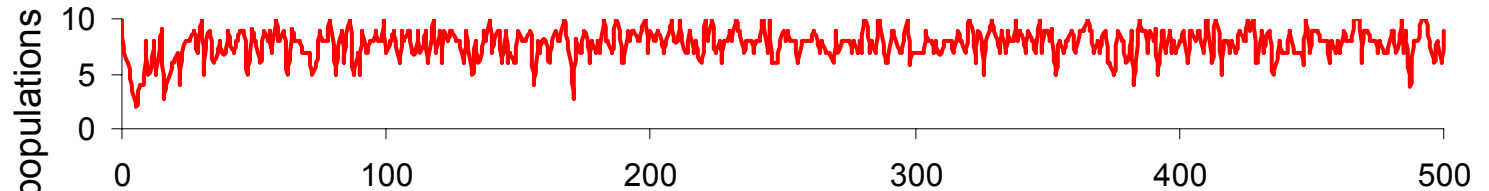


no rescue

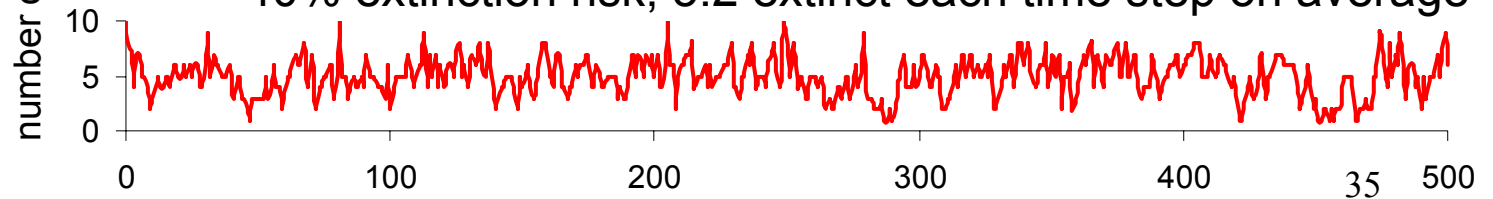
10% extinction risk, 1 extinct each time step on average



20% extinction risk, 2.1 extinct each time step on average



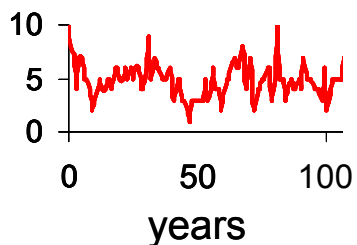
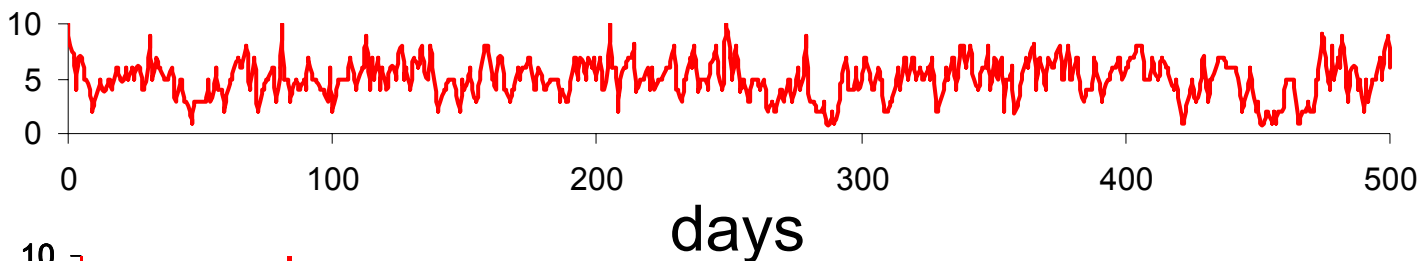
40% extinction risk, 5.2 extinct each time step on average



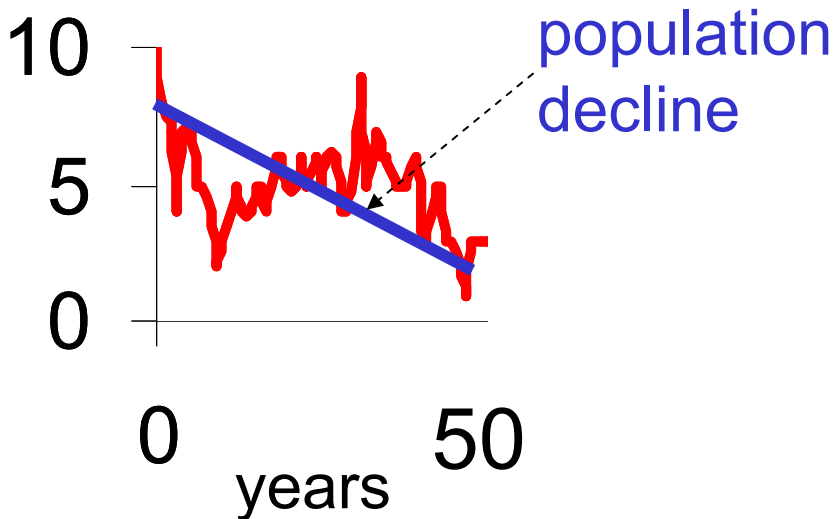
with  
dispersal  
and  
rescue

time scale of the rescue effect can produce spurious conclusions

if extinction, rescue occurs as one year events, local extinctions will be identified as part of the metapopulation in a three year study.



if extinction, rescue occurs at decadal or century scales, local extinctions can be misidentified as problematic rather than as a normal set of events of the system even with long term studies.



# evolutionary stable strategies

## single ESS

example, blackheaded gulls remove egg shells from their nests

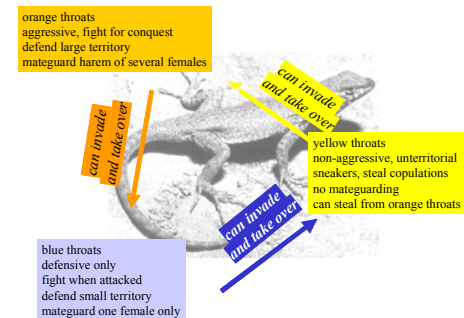
always the best thing to do

**mixed ESS**, catching food for yourself or steal food from another

lots of catchers → steal

lots of thieves → catch your own

both strategies fluctuate around a balance



example: male side-blotched lizards have 3 reproductive strategies based on throat colour:

**orange throats** are very aggressive, keep a harem and territory

**yellow throats** non-aggressive and unterritorial, sneakers

**blue throats** who defend territory and one female only against

why is there sex?

the problem (perhaps paradox?)

**sexual reproduction is costly**, requires two individuals

if reproductive output is the only measure of selective pressure

would predict reproduction always be asexual

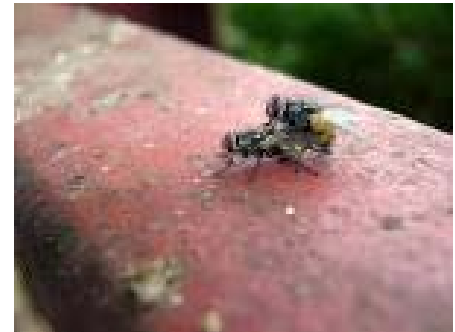
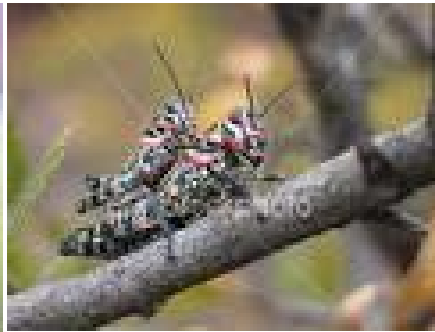
assume parthenogenic (asexual) mutant arises in a female

all offspring females

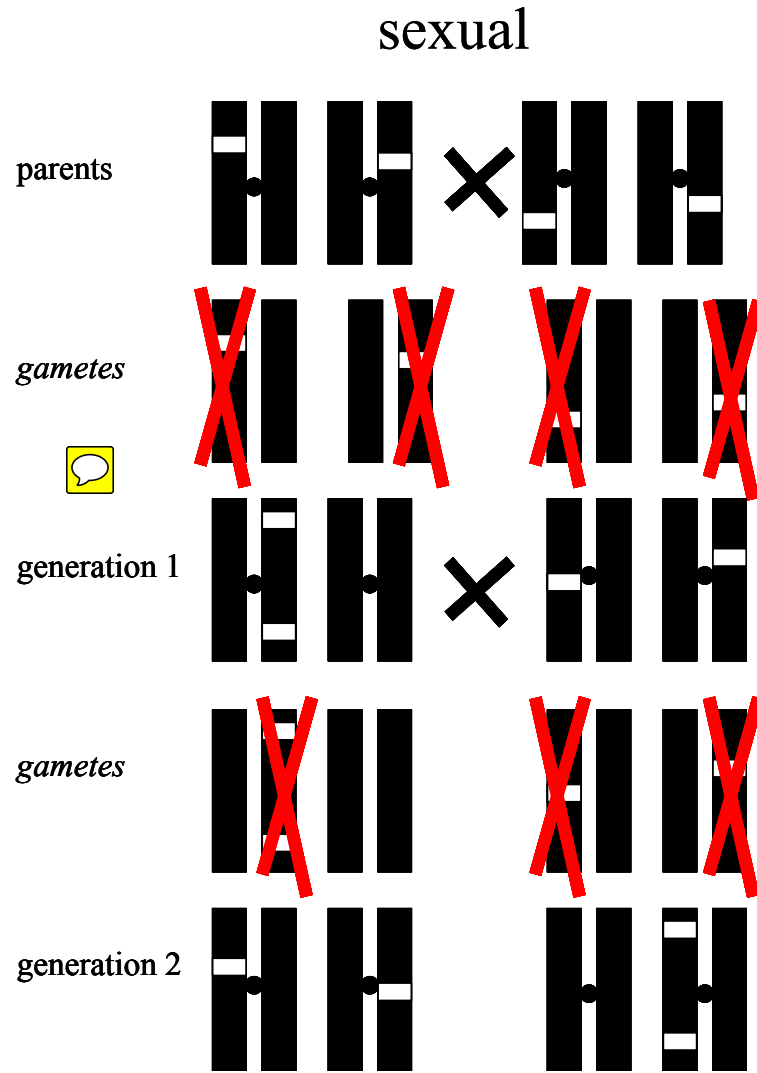
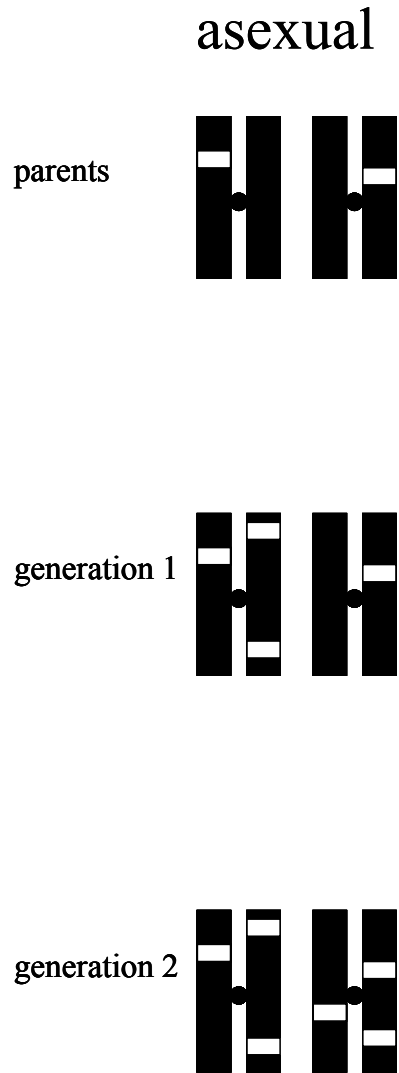
these produce females



**reproductive output is 2 times the sexual female output each generation**



reason for sexual reproduction: Muller's ratchet, harmful mutations accumulate during the lifetime of an organism--- asexual reproduction carries these into next generation---in sexual reproduction, flawed gametes die---meiosis *cleans out* harmful mutations non-deleterious mutations live



sexual reproduction best in unpredictable habitats

habitat predictability (or low variability) favours standardized strategy of asexual reproduction

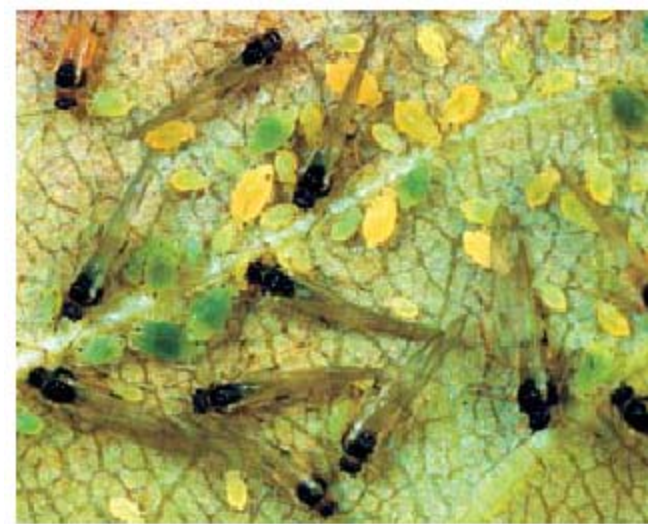
soybean aphids (*Aphis glycines*) alternate between sexual and asexual

asexual reproducers on a leaf, give live birth to pregnant females, 3 to 8 each day, populations double every 3 days.



when leaf gets crowded, produce winged individuals of both sexes  
reproduce and find a new host plant

winged individuals produced in fall, migrate from soybeans to Buckthorn host plant for overwintering



Winged and wingless soybean aphids on a soybean leaflet. (David Voegtlin)



Winged soybean aphid. (Marlin E. Rice)

## why the sexes differ: Trivers hypothesis

in species in which females compete for mates then *males should provide the larger amount of parental investment*

evidence from katydids: males provide meal at mating → females eat spermatophore, protein rich package of sperm

years when food abundant male nutritional gift is not important to success

→ females are choosy and males compete for mating opportunities

in years when food is scarce male contribution of protein important for survival of eggs females compete for males

this supports Trivers hypothesis

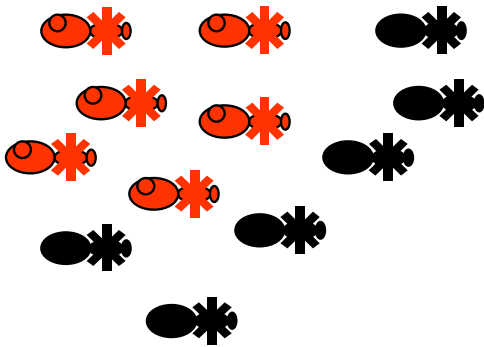


infection selected against due to increased vulnerability to other pressures

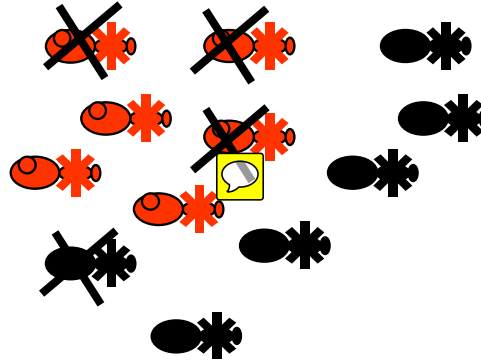
ie predators kill parasitized or diseased individuals

infections selected against, if reproductive ability is reduced

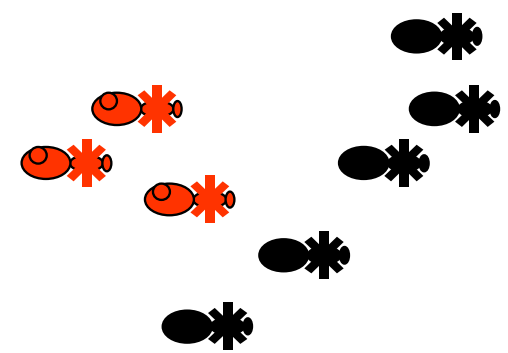
drives an adaptive wedge between predators and prey, predators evolve to catch infected prey



6 healthy, 6 parasitized



attacked un evenly  
by predators, sick  
ones easier to catch  
and kill



5 healthy, 3 parasitized

## parasitic changes in reproductive output: an example

giant cowbirds (*Scaphidura oryzivora*) Central and South America

lay eggs in other species' nests

*S. oryzivora* can be divided into different gentes (singular gens), or lineages which mimic different species eggs

1 gens is not a mimic, called a dumper

the egg is a generalized cowbird egg that is thick shelled for fast dumping into nests

mimic females are shy and sneak eggs to other bird's nests

hide their eggs to look like host eggs

hosts kill cowbird eggs if caught

females dumpers (non-mimics) are aggressive

barge into nests of hosts

lay eggs, no sneaking

hosts do not kill dumper eggs (?)

why?



bot fly (*Philornis sp.*), a horrible fly that lays eggs on skin of young birds

maggots burrow into skin, kill nestlings

cowbird nestlings can catch bot flies and maggots host nestlings by preening

**where bot flies are common cowbirds are dumpers**

**where bot flies are rare cowbirds are mimics**

more wrinkles to the story

bot flies killed by wasps and bees

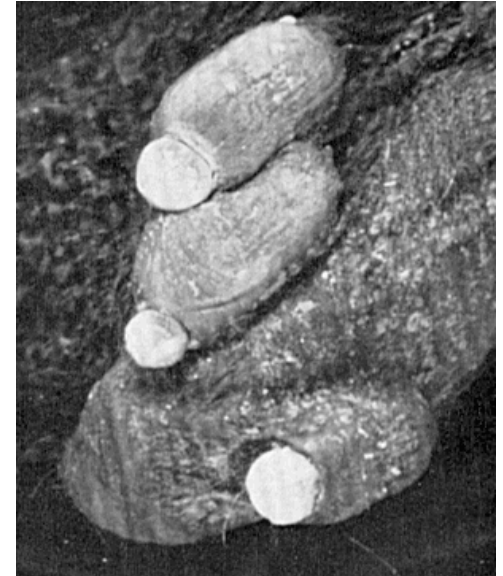
if host birds nest near wasps, cowbirds are mimics

if hosts do not nest near wasps cowbirds are dumpers

the cowbird-host relationship can be either

parasitic — with reproductive costs to the hosts

mutualistic — with reproductive benefits to hosts




## *Exceptions to the benign association rule*

### **parasites manipulate hosts:**

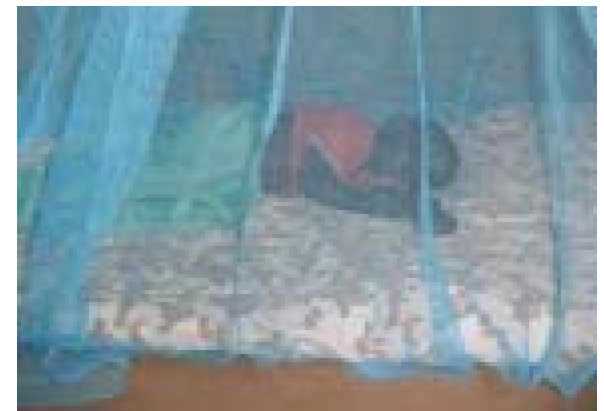
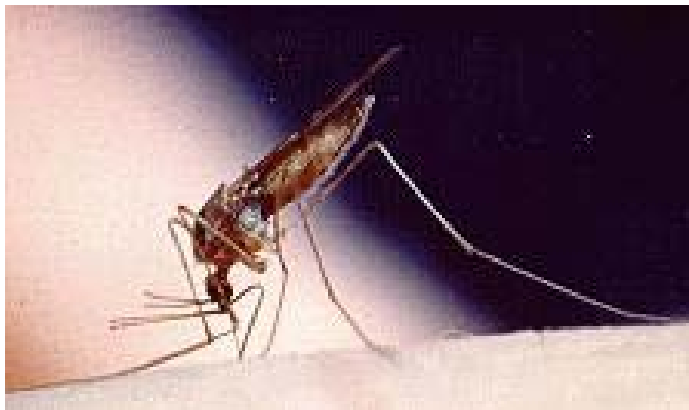
1 eg malarial parasites manipulate humans by making them more easily bitten by mosquitoes

- humans do not slap mosquitoes when bedridden with malaria
- fever increases attraction to human host
- increased CO<sub>2</sub> in breath of human host

mosquito, lives longer with malarial parasite

delays bloodfeeding to coincide with parasite development for re-infection of new human hosts 

adaptive principle: making humans sick increases transmission of parasite, no selective pressure for low virulence in humans



hosts defend against parasites:



eg host suicide

1 pea aphids in dry regions parasitized by brachonid wasps (Nature 328, 797 - 799 (27 August 1987); doi:10.1038/328797b0 Adaptive suicidal behaviour in pea aphids Murdoch K. McAllister & Bernard D. Roitberg)

drop from plants to ground to die, killing parasite and saving other aphids  
aphids in damp regions where they will not die they do not drop



## hosts defend against parasites:

eg host suicide

2 bumble bees infected with conopid flies do not enter hives at night  
bees burrow into the soil where they die, stop transmission of fly  
parasites



<http://tristram.squarespace.com/home/2010/8/19/conopid-fly.html>

the modern bed bug epidemic, *Cimex lectularius* L. (Hemiptera: Cimicidae)

feed on mammals and birds, both sexes produce musty or sweet odour, deposit rusty frass spots

egg to egg generation time is 5 weeks at 75-80% RH, 28-32 C

active at 7 C, and can survive lower (variable reports on this) thermal death at 45 C

5 nymphal instars, one blood meal needed to advance



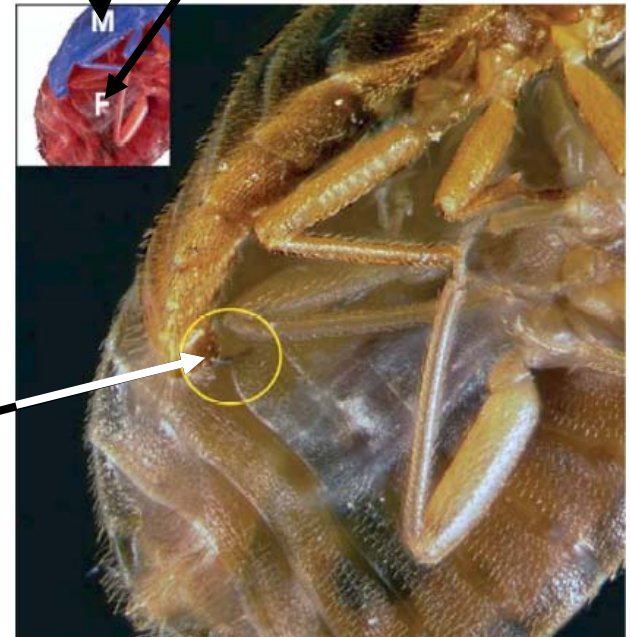
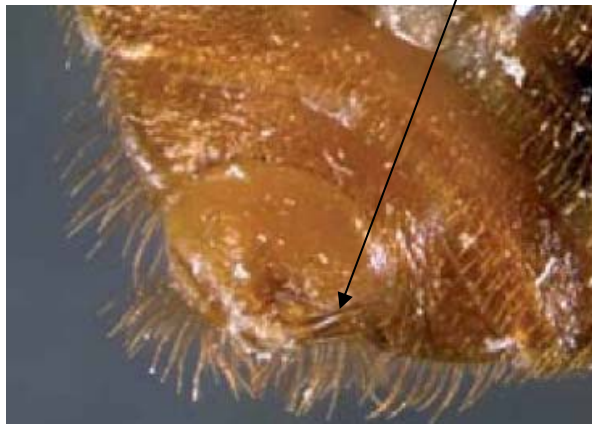
## behavioural characteristics

sexual reproduction, traumatic insemination  
eg, insemination occurs outside of the female  
genital tract

male inserts paramere (spine) and aedeagus  
(penis) through integument of female and  
deposits sperms in abdomen



male (blue) female (red)



site of insemination

ectospermatage of blood filled female (dark region), showing damage where male deposited sperm in a pocket, or mesospermalege



females avoid males, refuse them if they do not have a bloodmeal  
males can overpower a female if she is engorged

females avoid males → females become dispersive and spread population

natural enemies

*Reduvius* (Hemiptera) an assassin bug in houses

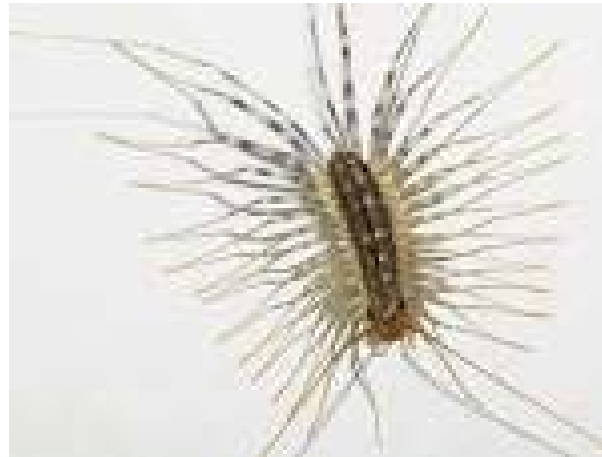
ants can clean an infested house in a day

pseudoscorpions and house centipedes prey upon bed bugs

not known how well

spiders feed on bed bugs

eg. in an Athens refuge camp, 1923-26, spiders eliminated  
a severe infestation




## cross contamination

laundry in hotels, clean and dirty bedding on the same cart

hotel mattresses sold to homeowners

movement of people from summer to winter homes

persistent problems due to control costs,

eg Canada, low income housing administrators use a threshold level as the target rather than elimination → maintaining reservoirs 

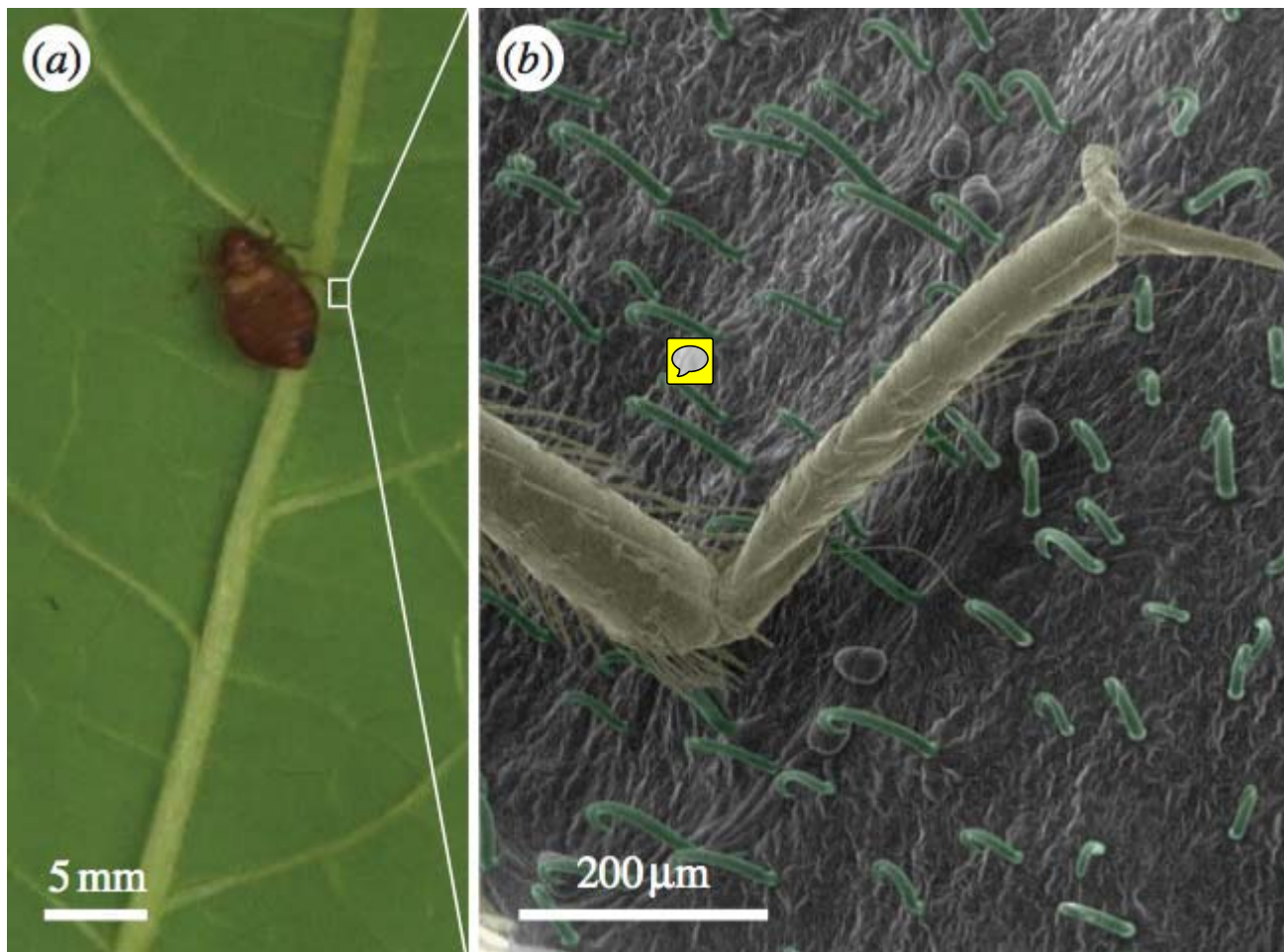
typical case: spread by backpack in public transport

reports that they crawl on ceilings to drop on beds is based on a single literature example

many houses (50% of infested residents) can be infested, **but residents do not know, have no allergic reaction, or in low numbers**



new treatment possibilities  
kidney bean leaves (and other plants)  
small hairs (trichomes) trap bed bugs  
plant defence mechanisms for Hemipterans that suck juice from plants



<http://news.uci.edu/press-releases/bean-leaves-can-trap-bedbugs-researchers-find/>

**delusory parasitosis** (see Hinkle, 2000. American Entomologist 46(1) pp 17-25, source of this information)  
- imagining one is infected with mites, lice, ticks, or some ectoparasite

- feels like something is burrowing, crawling, biting, itching

- delusory, because there are no pests present, yet the feeling is real

typical case history: physician sees a patient with sores or lesions  
- caused by scratching

pest control operators called in, cannot find any pests

→ refuse to apply pesticides

## Glossary

**Delusion:** a false belief that persists despite the facts.

**Dermatitis:** inflammation of the skin.

**Elimite:** a permethrin cream used to treat for scabies and lice.

**Erythema:** abnormal redness of the skin.

**Formication:** the sensation of ants crawling on the skin.

**Idiopathic:** of unknown cause.

**Illusion:** misinterpretation of perception of something objectively existing.

**Kwell:** prescription lindane formulations used in scabies (cream) and lice (shampoo) treatment.

**Paresthesia:** a sensation of pricking, tingling, or creeping on the skin.

**Pruritus:** itching.

**Scarification:** wound or cut marks from scratching.

**Urticaria:** stinging or burning itch.

- seen by for pest control companies and entomologists
- placebos give temporary relief, logic will not work, there is always a ready reason why suggestions are refused by the sufferer



case study, biology used in legal evidence: Steven Truscott case

Steven Murray Truscott (born Jan. 18, 1945  
in Vancouver, British Columbia,  
Canada)

1959, at age 14 found guilty of murder of 12  
year old Lynne Harper

defence depended on the time of death.

If Lynn died after dusk, his alibi is secure

If she died before dusk, he has no alibi

The time of death depends on the **kind of  
flies** that colonized Lynn's corpse, AND  
the assumption that blow flies do not lay  
eggs at night



scenarios:

if maggots are blow flies, and large,  
needs to be lots of large maggots

Truscott guilty

if maggots are small,  
needs to have lots of small maggots

Truscott innocent

if maggots are flesh flies and large, Truscott guilty

if eggs laid during night, then the insect evidence is useless

"The experts all agreed that blow flies will colonize a corpse within minutes of

death, one issue that was raised in the various expert reports was whether blow flies would have laid eggs in the hours between 7:00 p.m. and sunset in the prevailing weather conditions in June."

- VanLaerhoven conducted experiment in June 2006 at Lawson's Bush with animal carcasses under similar weather conditions
- land changed, no longer cattle, and no longer manure piles
- *her experiment demonstrated that blue bottles can and will colonize a corpse after 7:00 p.m. and before sunset*

## Insects exonerate murder suspect after 48 years

By Gordon Shetler

It took nearly 50 years, but bugs brought justice to Steven Truscott.

One of Canada's most notorious murder cases was overturned last month, in part thanks to the testimony of a Michigan State forensic entomologist whose creed is "bugs don't lie."

Entomology professor Richard Merritt testified for seven hours about the incorruptible witnesses that did not testify in the 1959 murder trial of Truscott – common flies.

"The insects were the right size. She was killed after dark. "Truscott could not have done it," according to Merritt.

The timeline created by the investigators was wrong. Truscott could not have killed Lynne Harper because he was at home when she died, Merritt said.

overstated!  
evidence is from  
a notebook  
description to  
identify what  
kind of flies they  
were!