Organismal reproductive diversity

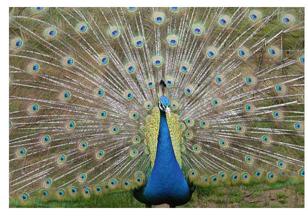
E. coli

Chimpanzee

Hydra

Passion flower

Fungi



Peacock

1

Lecture 8
Sex, reproductive systems and evolution

1. Why did sex evolve?

2. How do we explain the diversity of reproductive systems?

3. What are the costs and benefits of inbreeding & outbreeding?

Required readings: Coyne Chapter 6

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Reproductive Modes

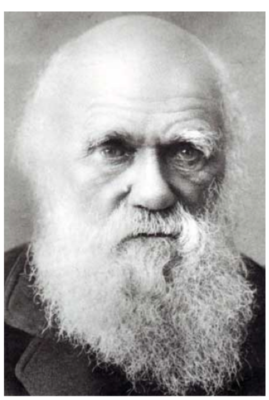
Reproductive system: asexual | sexual

Sexual system (sexual): dioecious | hermaphrodite

Mating system (hermaphrodite): cross-fertilization | self-fertilization

3

Darwin on sex



"We do not even in the least know the final cause of sexuality ... why new beings should be produced by the union of the two sexual elements, instead of by a process of parthenogenesis… The whole subject is as yet hidden in darkness"

Darwin 1862

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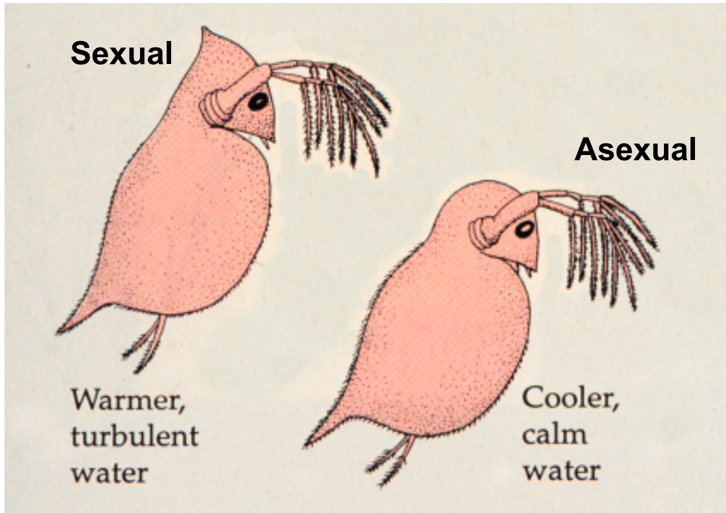
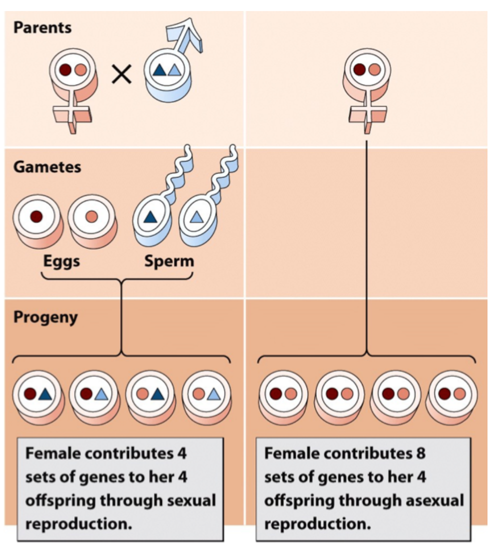


In water fleas (*Daphnia*) different reproductive systems occur in different environments

5

Transmission bias



A sexual female contributes only 50% of her genes to the next generation compared with an asexual female

This is know as a **transmission bias** favouring asexuals

From Ricklefs Chapter 8

6

Costs of sex

- 50% less genetic transmission
- time and energy to find and attract mates
- increased energetic costs
- risk of predation & infection
- cost of producing males
- break up of adaptive genes combinations

So what are the benefits? – this is the big question – known as 'the paradox of sex'

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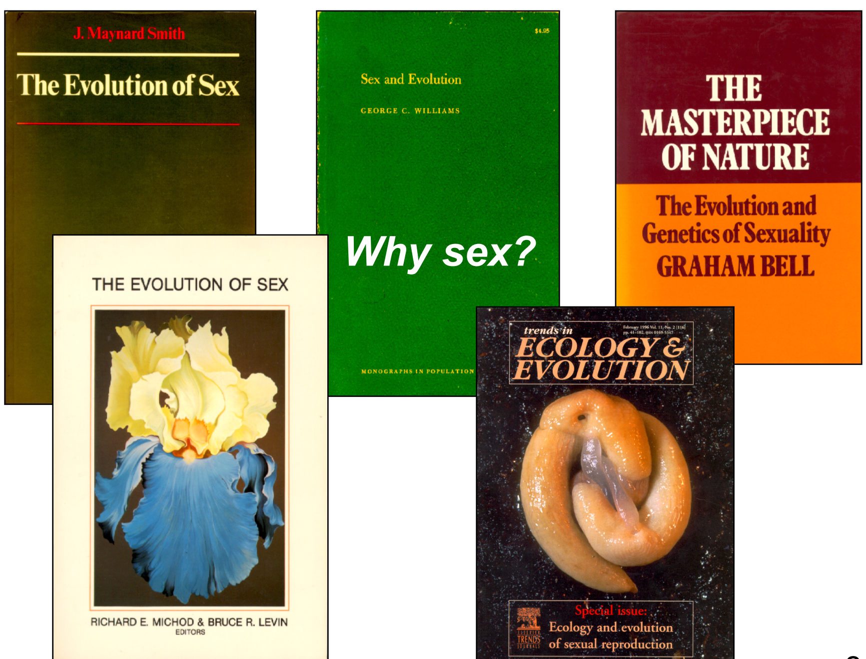

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Canadian researchers working on the evolution of sex

Sarah Otto - UBC

Aneil Agrawal - EEB, Toronto

Graham Bell - McGill

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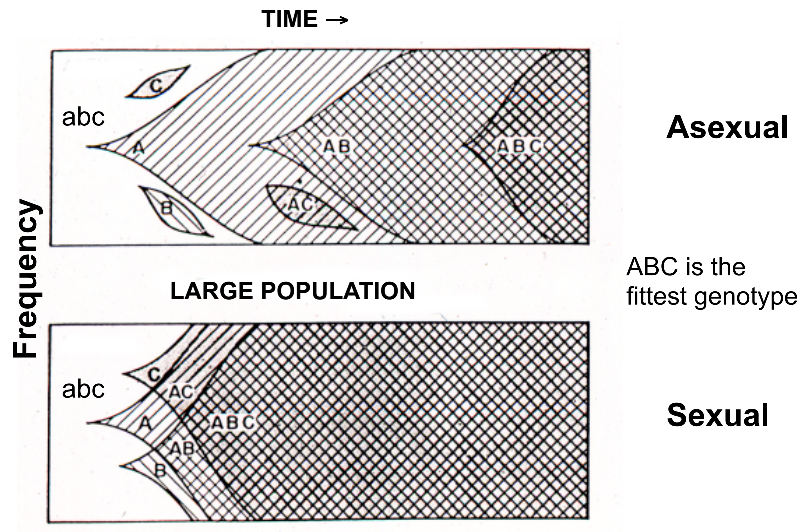
Hypotheses for the advantages of sex

- bringing together favourable mutations – long term benefit

10

*Favourable combinations of mutations brought together more rapidly by sex**



Similar arguments can be made for eliminating deleterious mutations 11

Thought experiment:

Which is best way to win a lottery?

1. buy 1 ticket and copy it 1000 times, OR
2. buy 1000 tickets

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Hypotheses for the advantages of sex

• bringing together favourable mutations – long term benefit

• benefits of genetic variation in variable environments – short term benefit – "lottery model"

- spatially heterogeneous environments 'Tangled Bank hypothesis'

- temporally heterogeneous environments 'Red Queen hypothesis'

Numerous theoretical models but a paucity of experimental evidence

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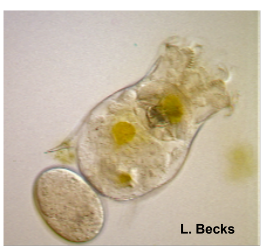
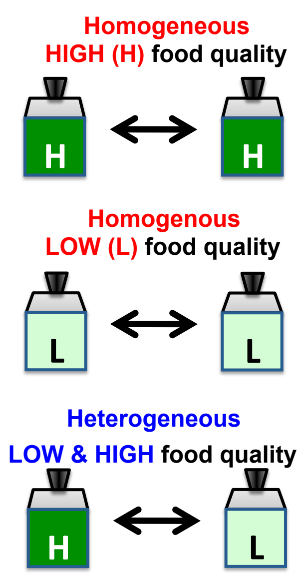
Testing the "Tangled Bank" hypothesis



The rotifer *Brachionus calyciflorus,* a planktonic freshwater animal

Facultatively sexual with genetic variation for the propensity to reproduce sexually or asexually



Lutz Becks

Aneil Agrawal

Each population consisted of two subpopulations, with migration performed manually between them

10 replicate populations evolved under each of these conditions for ~70 generations

Nature **(2010)**

14

How do you predict environmental heterogeneity will affect the incidence of sexual reproduction?

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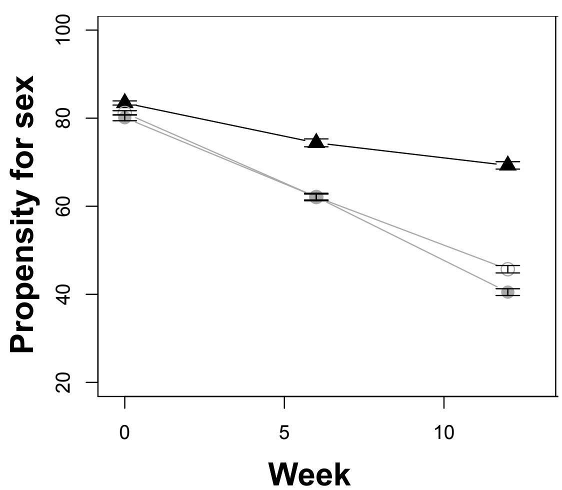

Over 12 weeks (~70 generations), sex declined rapidly in homogenous environments but persisted at a much higher level with spatial heterogeneity

Nature (2010)

16

Testing the "Red Queen" hypothesis

Potamopyrgus antipodarum

- most populations have 2 kinds of female: sexual and parthenogenetic
- host to many species of parasitic trematode

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Testing the Red Queen hypothesis

- proportion of sexual vs sexual females varies between populations
- the frequency of trematode infection
- **How could you test the Red Queen hypothesis in this system?**

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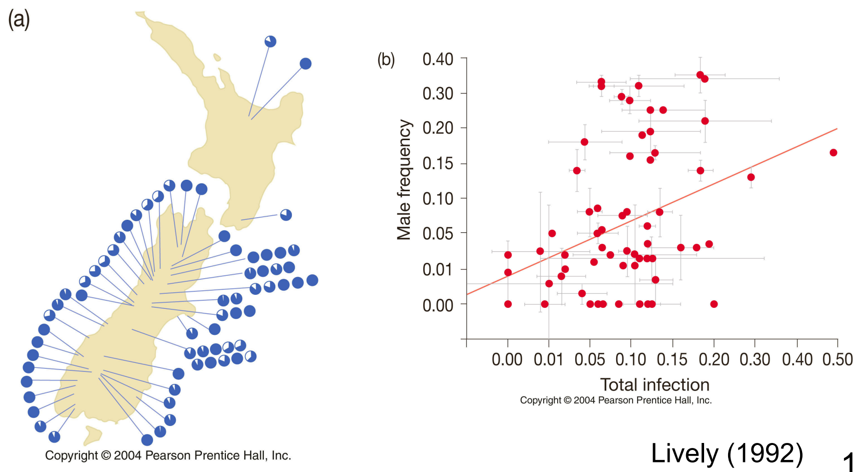

Lively (1992)

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Evolutionary history of asexuality

• asexuality (parthenogenesis) is sporadically distributed across the animal kingdom; more common in invertebrates but rare in vertebrates

• asexuality (clonal propagation) is much more common in plants although few species (if any) are exclusively asexual

• asexual species are usually at the tips of phylogenies; their long term evolutionary potential is probably low due to lack of genetic variation

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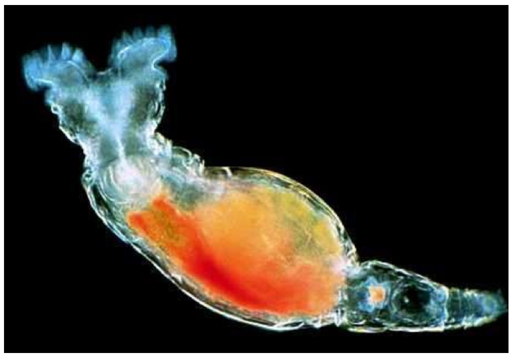
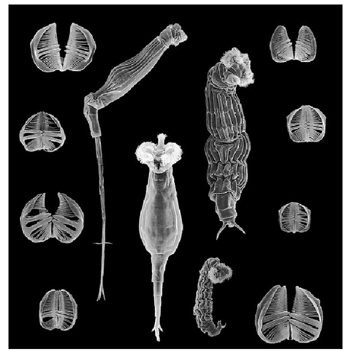
Mystery of the Bdelloid rotifers - no sex for millions of years!





A rare case of ancient asexuality in which males are unknown but diversification has led to > 300 spp.

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Mating patterns – who mates with who and how often?

- Mates less closely related than random
  = Outbreeding
- Mates **more** closely related than random
  = **Inbreeding**

In practice there is a continuum between outbreeding & inbreeding

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The genetic consequences of inbreeding

- Genotypic frequencies changed
- Allele frequencies unchanged
- Heterozygosity reduced by 50% per generation with self-fertilization
- Homozygosity for deleterious recessive alleles results in inbreeding depression

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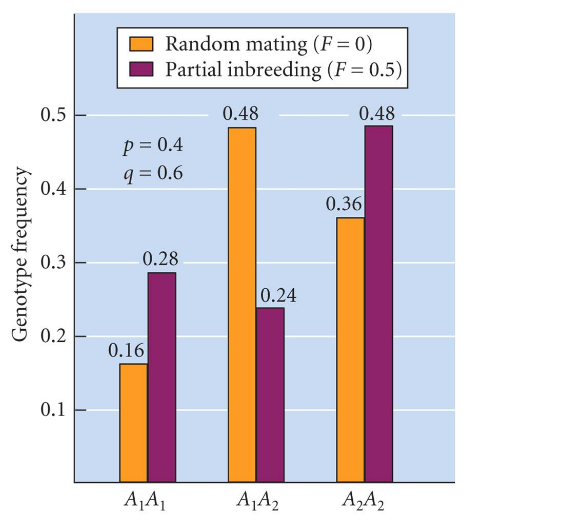
Inbreeding changes genotypic frequencies and increases homozygosity in populations



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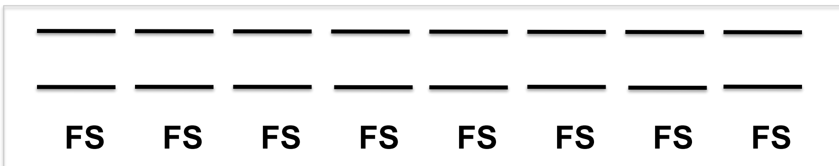
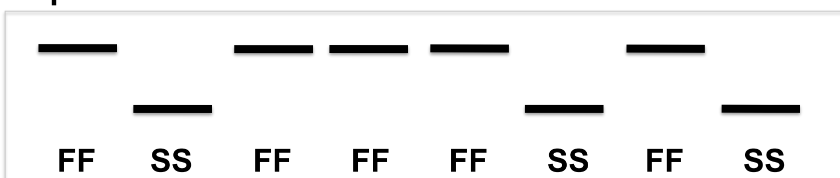
How do these two populations reproduce?

Population 1



Population 2



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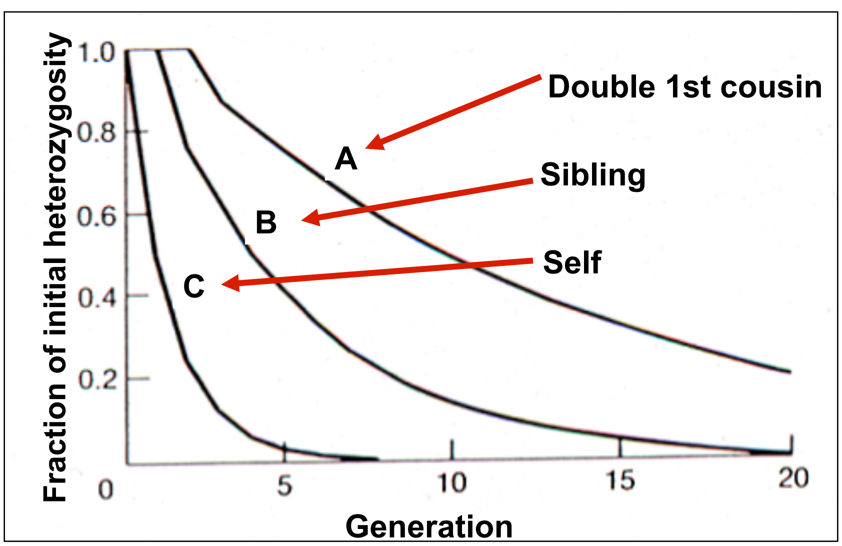
Heterozygosity decreases at different rates depending on mating patterns



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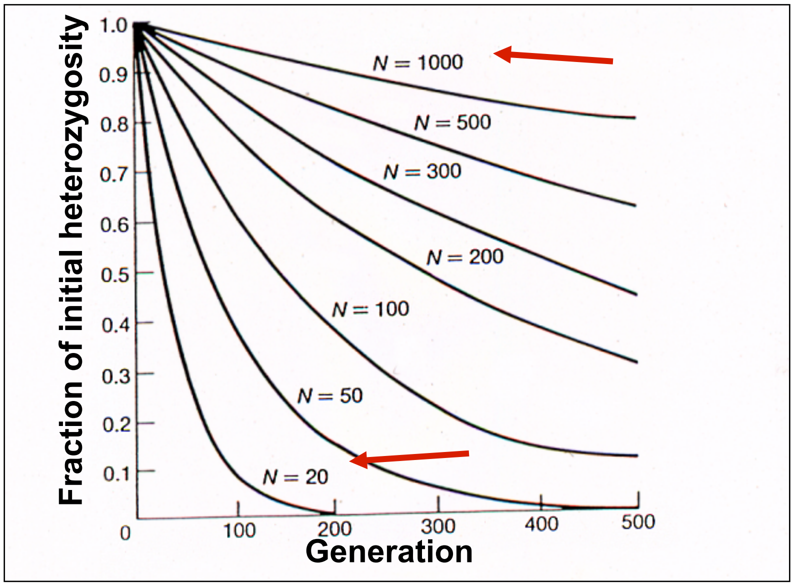
Heterozygosity decreases at different rates depending on population size



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Inbreeding depression

• The reduction in fitness of inbred offspring in comparison with outcrossed offspring

• Manifested by reductions in viability (survival) and fertility (reproductive output)

• Strong inbreeding depression favours survival of outbred offspring thus favouring outcrossed mating systems

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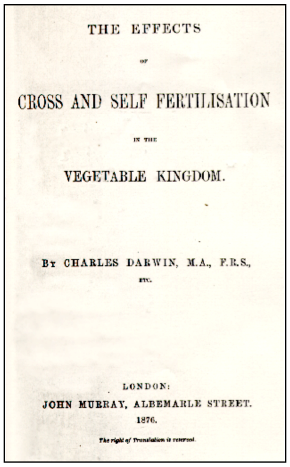


THE EFFECTS

OF

CROSS AND SELF FERTILISATION

IN THE

VEGETABLE KINGDOM.

BY CHARLES DARWIN, M.A., F.R.S.,

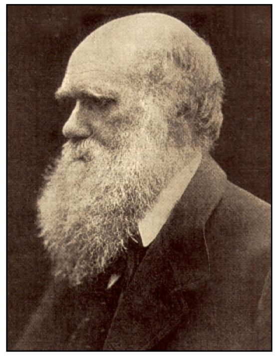
ETC.

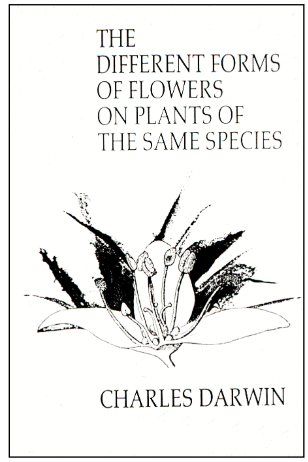
LONDON:

JOHN MURRAY, ALBEMARLE STREET.

1876.

The right of Translation is reserved.





Darwin's fascination with inbreeding & outbreeding in plants

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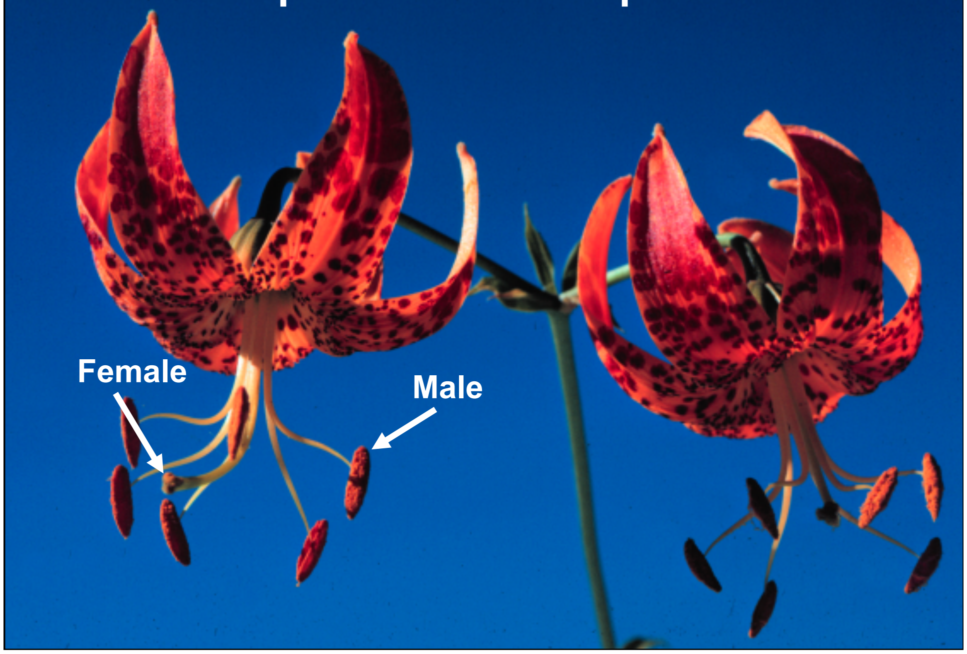
Most plants are hermaphroditic



Dioecy only occurs in 7% of flowering plants

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Evolution of selfing from outcrossing in annual water hyacinth

Brazil **Jamaica**

- populations in Brazil are mostly outcrossing
- Jamaican and Cuban populations are largely selfing

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Automatic selection of a selfing gene
(R.A. Fisher, 1941)

	Outcrosser	Selfer
Seed	1	2
Pollen	1	1
Total Gene Copies	2	3

Selfing form has a transmission advantage

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