RESEARCH IN EVOLUTIONARY ECOLOGY

WHERE?

1) LAB




advantages?

- replicates, controls, controlled environment, genotypes, generation times..

drawbacks?

-info on particular environmental factors, dismiss interplay with any other ecological variable

WHERE?

1) NATURE (real environments and real populations)

advantages?

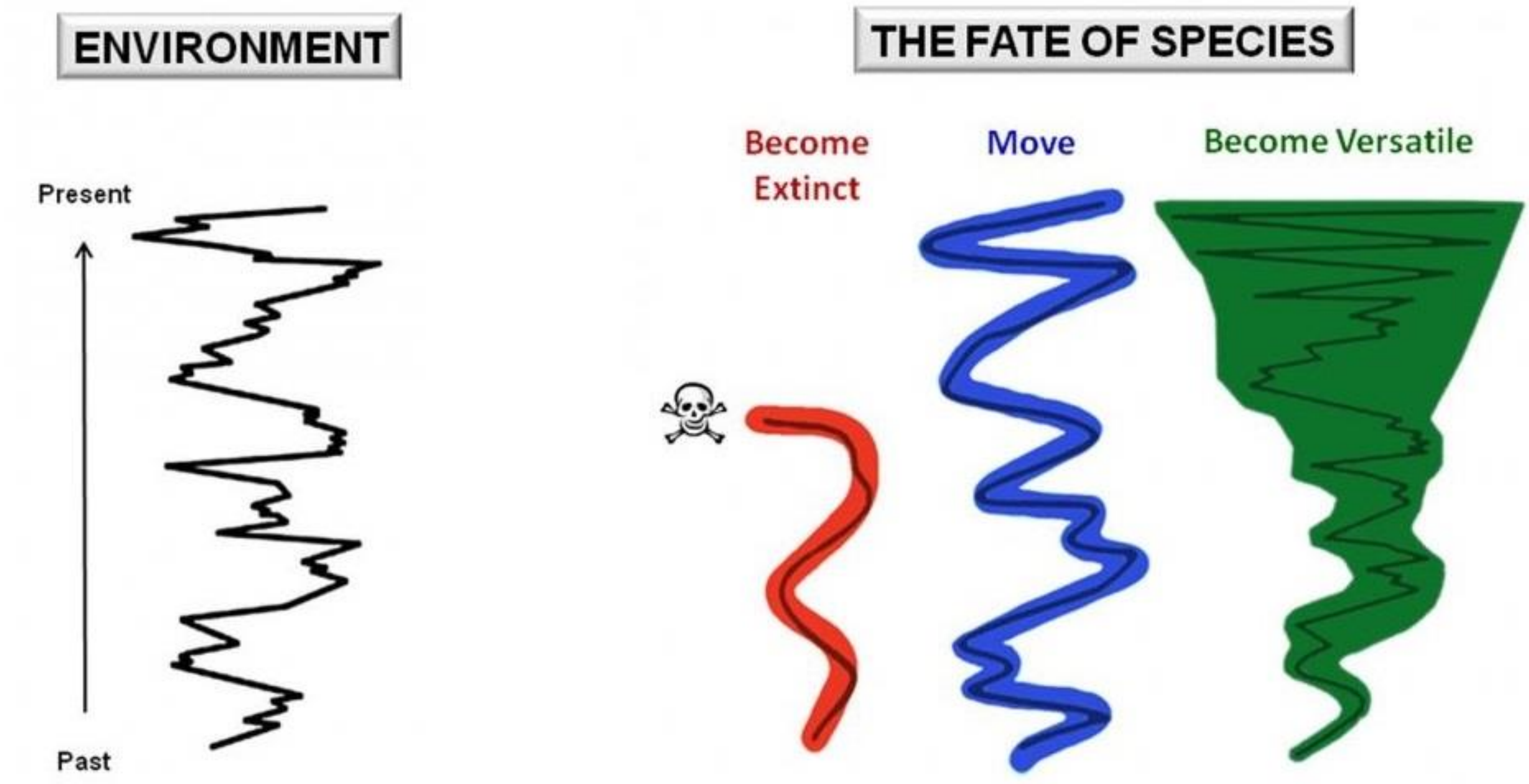
- takes in account interplay among all ecological and evolutionary effects

drawbacks?

-difficult to isolate particular ecological variable or evolutionary effect, harder to include controls and replicates

ADAPTIVE EVOLUTION

Change of environment (temporal or spatial)



The Smithsonian Institution, https://humanorigins.si.edu/research/climate-and-human-evolution/climate-effects-human-evolution

Adaptation

1) Phenotypic plasticity

-change of individual phenotype during the life

2) **Genetic adaptation**

- heritable change of phenotype within population and across generations

ECO –EVO

- adaptation of populations to changing environment

EVO- ECO

- trait change in a focal population alters its population dynamics, influence the structure of its community or alters the ecosystem processes (contemporary evolution leading to ecological change)

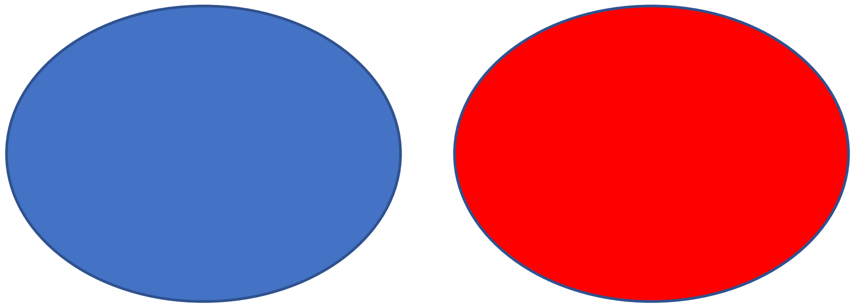
- feedback ECO → EVO →ECO

Adaptive evolution

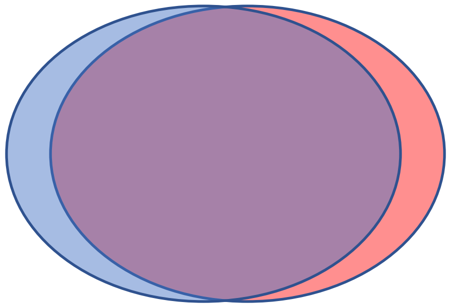
- NOT ECO-EVO?

1) evolutionary changes not under direct effect of ecological change (e.g genetic drift- often leads to allopatric speciation)

allopatric



sympatric



- **EVOLUTIONARY FORCES:**
- Selection
- Gene flow
- Genetic drift
- Mutation
- Recombination

SELECTION

- The preferential survival and reproduction or preferential elimination of individuals with certain genotypes (genetic compositions), by means of natural or artificial controlling factors (*Encyclopedia Britanica*)
- Natural selection occurs whenever there is consistent, average difference in fitness (reproductive success) among sets of individuals that differ in some respect that we may refer to as phenotype (*Losos, 2014*)

- can act on **different levels of biological organisation** (genes, DNA, cells, individuals, populations, species.. (e.g. number of linages of herbivorous insects increases faster than other insects)

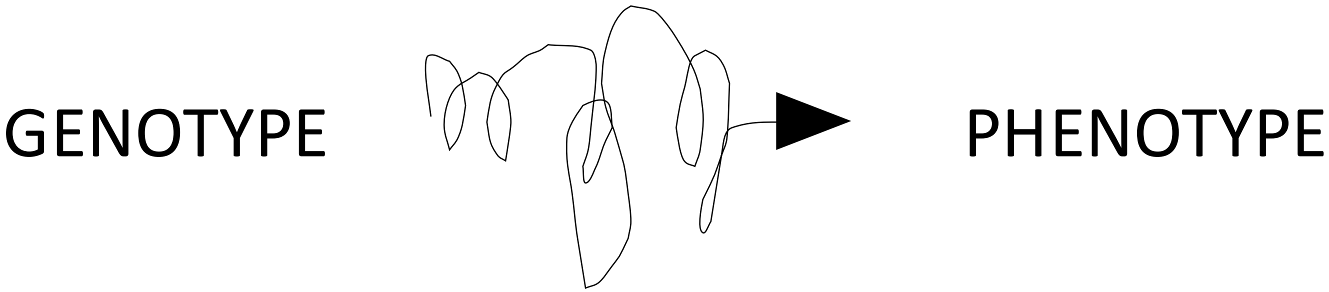
PHENOTYPE OR GENOTYPE?

SELECTION ACTS DIRECTLY RATHER ON PHENOTYPES, NOT GENOTPYES

ECOLOGICAL EFFECTS ARE ALSO DRIVEN BY **PHENOTYPES**

GENOTYPE →PHENOTYPE?

- monogenic or polygenic traits, plastic traits

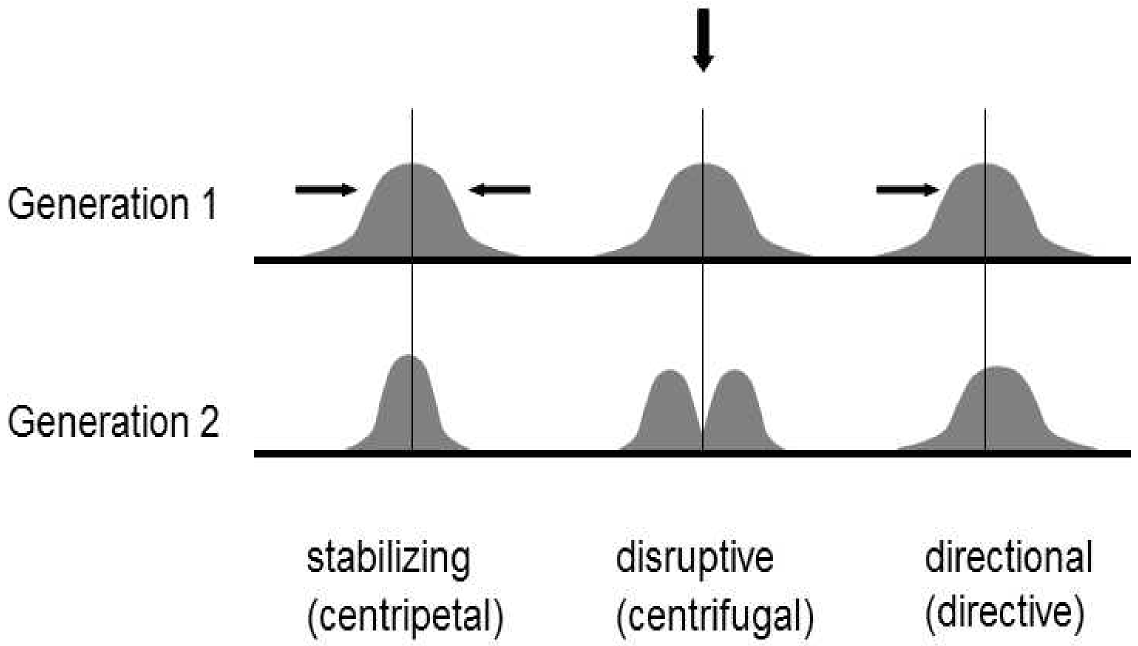


- SELECTION

AA AB BB

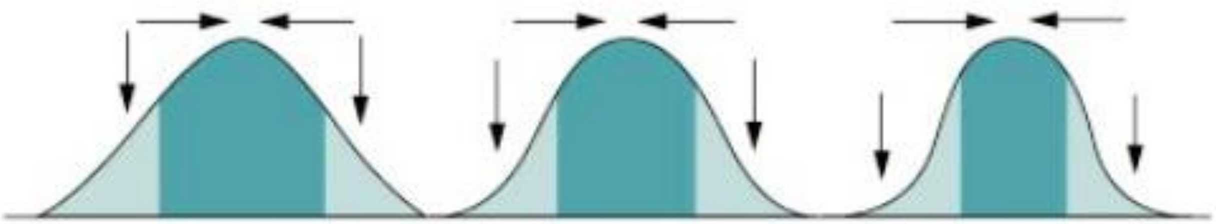
mode of selection depends on the relative fitness of three genotypes

1) directional AA > AB > **BB**, AA < AB < **BB**
2) disruptive **AA** > AB < **BB**
3) stabilizing AA < **AB** > BB



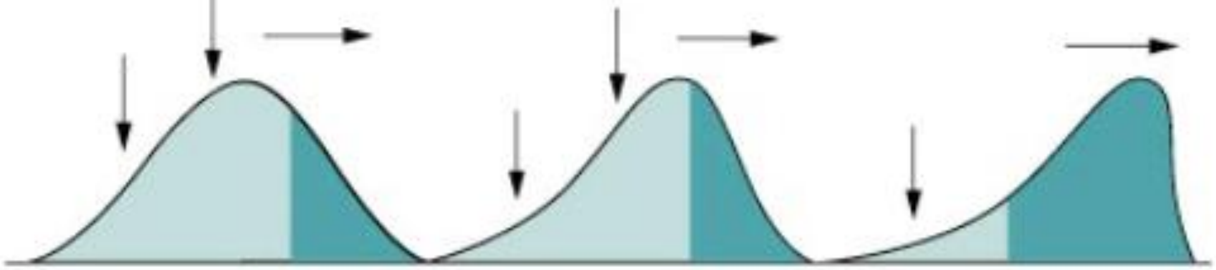
CHANGE IN ALLELIC FREQUENCIES ACROSS GENERATIONS

1) **STABILIZING** AA < **AB** > BB



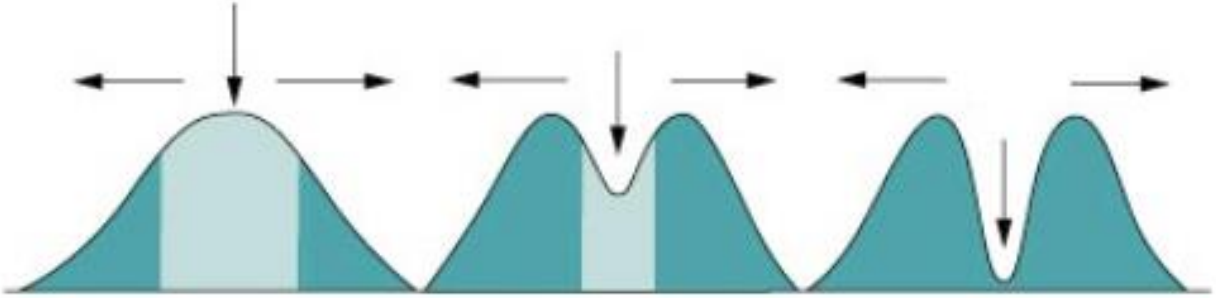
(a) Stabilizing selection

2) **DIRECTIONAL** AA > AB > **BB**, AA < AB < **BB**



(b) Directional selection

3) **DISRUPTIVE** **AA** > AB < **BB**



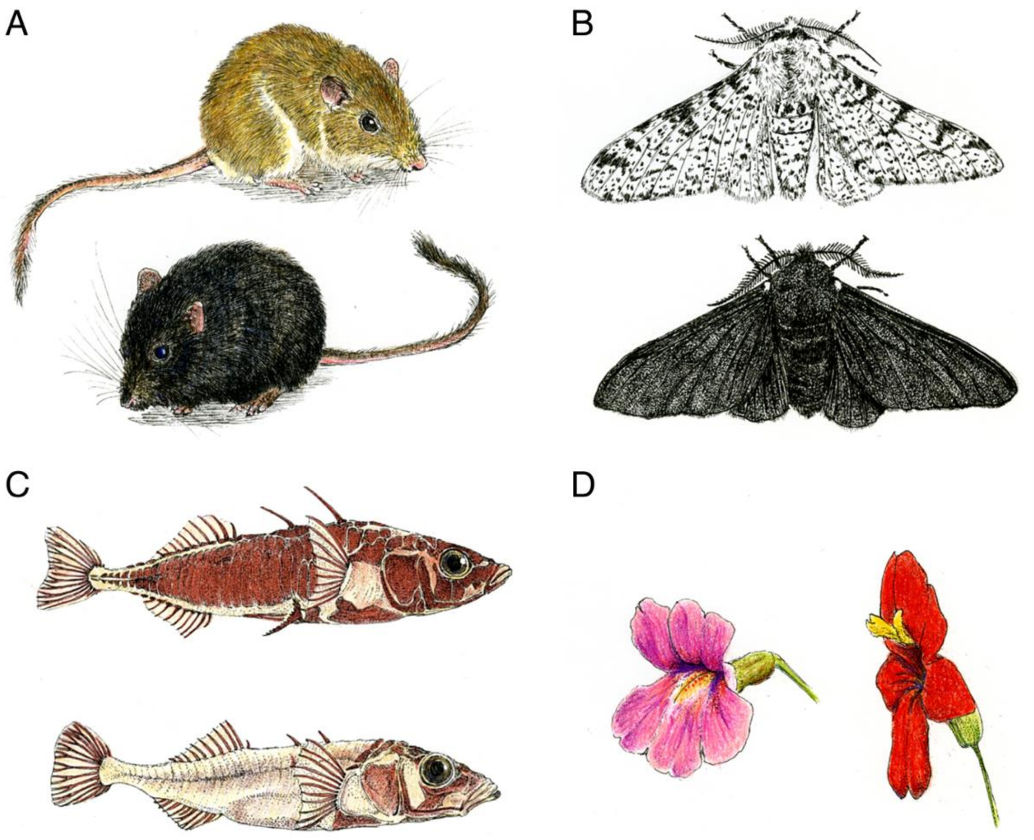
(c) Disruptive selection

CHANGE IN ALLELIC FREQUENCIES ACROSS GENERATIONS

- **GENETIC VARIABILITY IS CRUCIAL FOR THE NATURAL SELECTION !!**
- e.g. if all individuals in a population have the same genotype (eg. AA), there will be no difference in the fitness between genotypes, or change in allelic frequencies across generations, all individuals in next generation will again be all AA

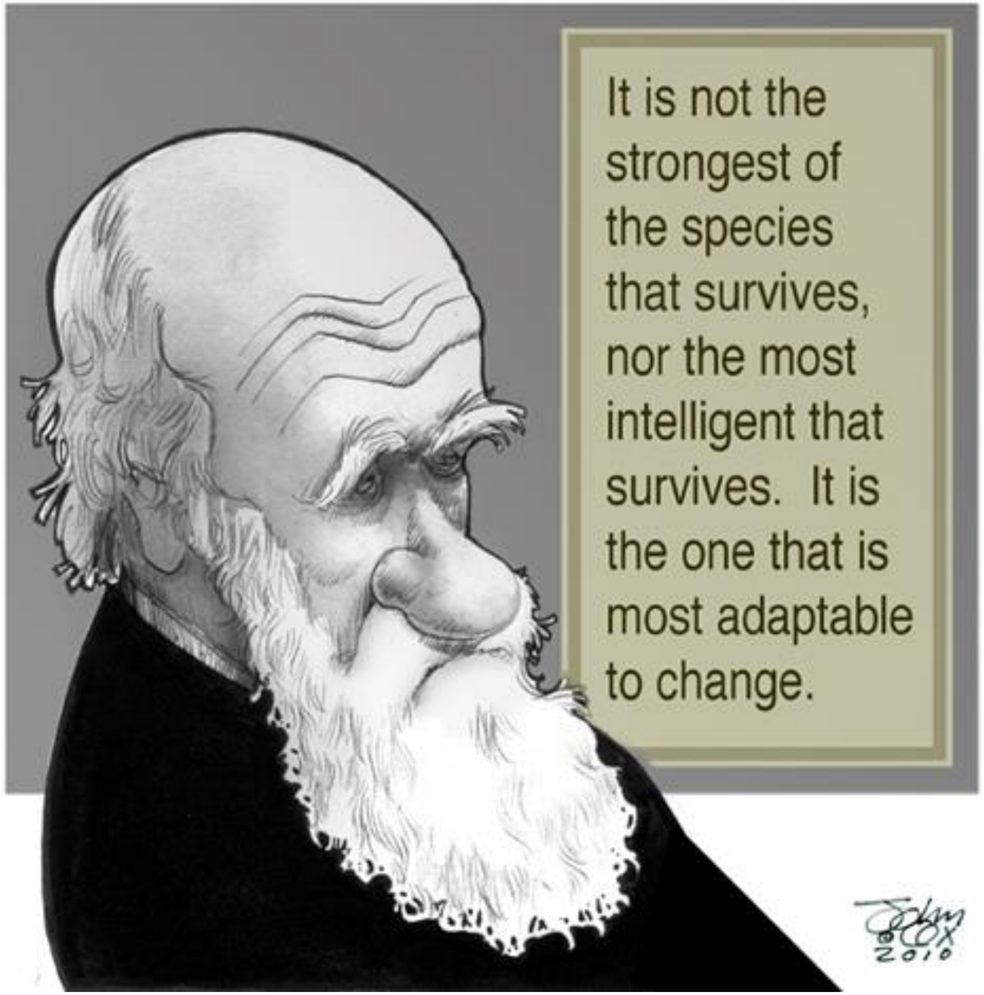
AA=AA

Process of natural selection leads to genetic adaptation – better survival and fitness of individuals with the genotype conferring higher fitness



Examples of systems used to study the genetics of adaptation. (A) Pocket mice (Chaetodipus intermedius); (B) peppered moths (Biston betularia); (C) threespine sticklebacks (Gasterosteus aculeatus), with red marking bony structures; (D) monkeyflowers (Mimulus lewisii and Mimulus cardinalis; note: these species are now in the genus Erythranthe). See text for references. Drawings by K.B.

https://www.pnas.org/doi/10.1073/pnas.2122152119

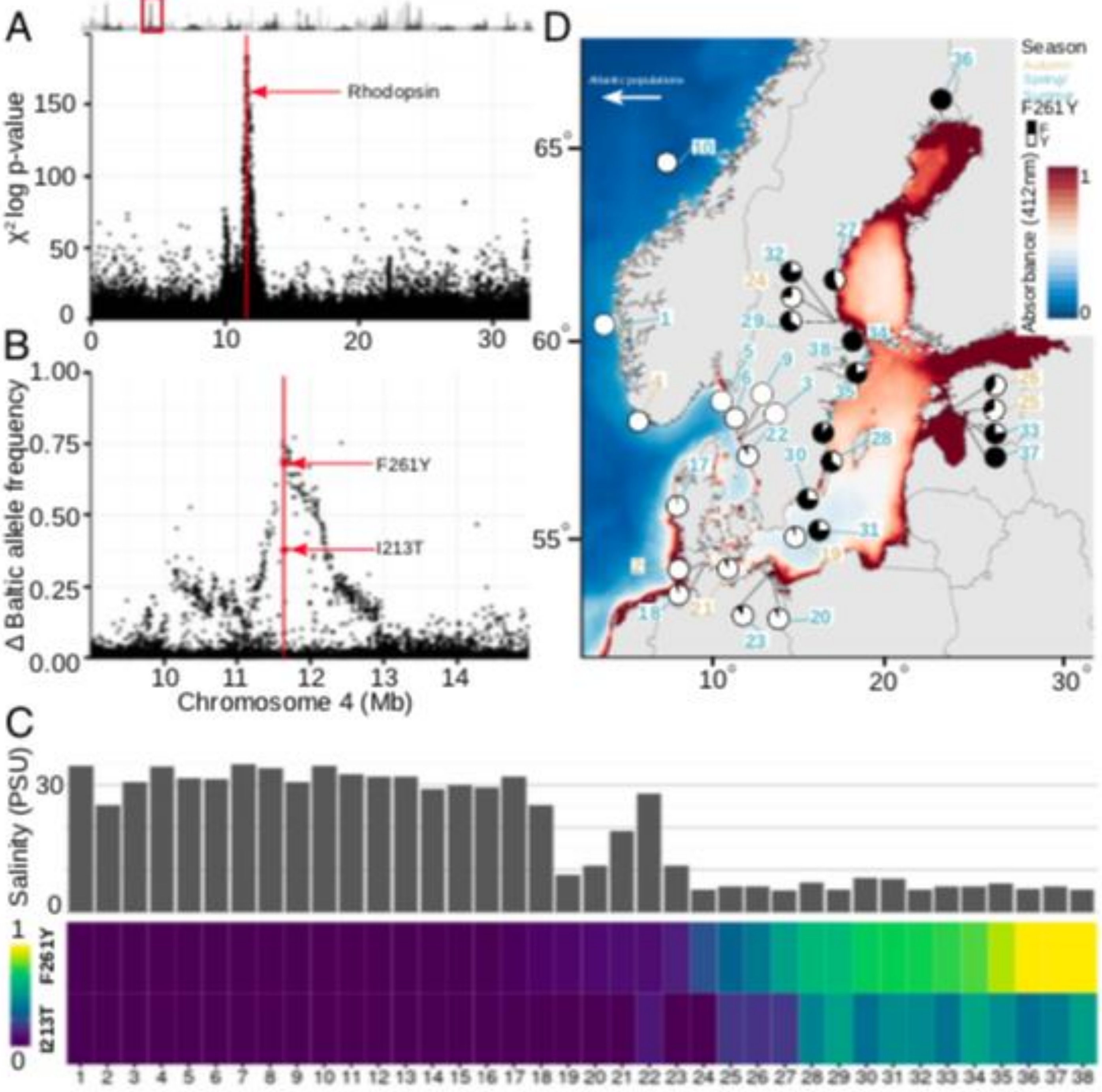

It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is most adaptable to change.
John Cox 2010

Adaptation of the Baltic cod to light conditions

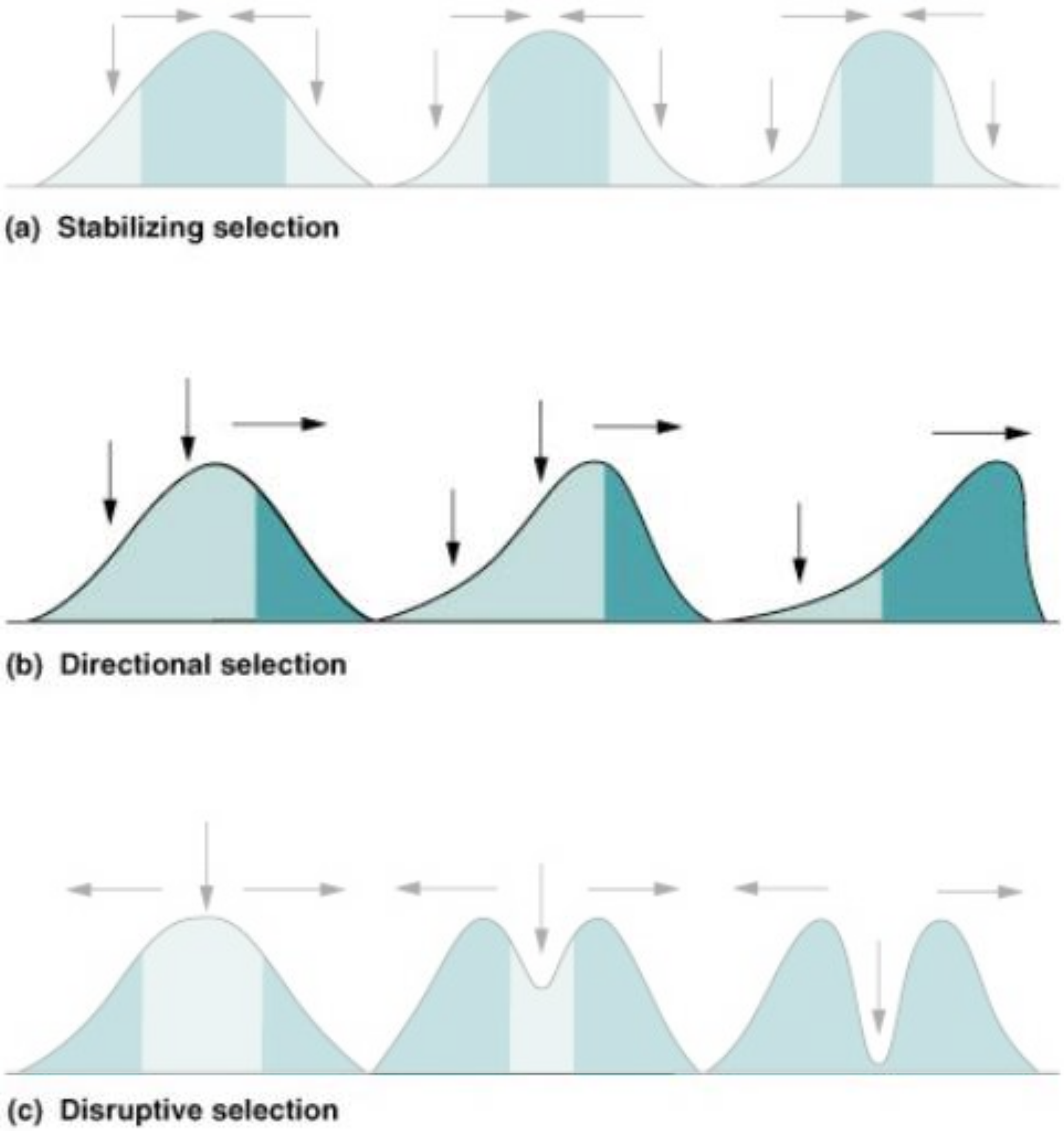
Adaptation of the Baltic cod to light conditions

- **Baltic cod** immigrated from **Atlantic** 10,000 years ago
- Baltic Sea has lower salinity, more organic matter, and different light absorbance
- in the Baltic population there is frequent change of one amino acid in pigment **rhodopsin** (Phe -> Tyr). This variant increased in frequency in the last few hundred years
- same mutation occurred over **20 times independently** in different fish groups- convergent evolution

Jason Hill et al. **Recurrent convergent evolution at amino acid residue 261 in fish rhodopsin**. *PNAS*, 2019



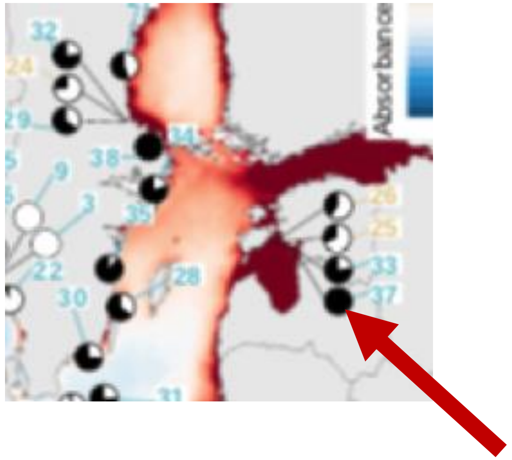
Signal of selection and frequencies of rhodopsin alleles in Atlantic and Baltic herring. *(A) Genome-wide scan of* ***allele frequency differences in the contrast*** *between Atlantic and Baltic herring populations revealed a highly significant signal on chromosome 4. The genome-wide plot at the top of the panel highlights the signal containing* ***rhodopsin****; the remainder of the panel shows the signal in the context of chromosome 4. (B) Delta allele frequency of SNPs that are* ***fixed in Atlantic populations and polymorphic in Baltic populations****, and therefore novel to the Baltic populations. The location of rhodopsin is highlighted with a red line in both A and B. (C) The correlation between salinity (Upper), as a proxy for visual environment, and allele frequencies of* ***Tyr261*** *and* ***Thr213*** *(Lower), is shown for each population numbered on the x axis. (D) Location of herring populations in the East Atlantic and Baltic Sea used in this study (Dataset S1). Pie charts are the frequency of the* ***Phe261Tyr*** *mutation in each population, and label colors denote autumn- or spring-spawning populations. Absorbance values at 412 nm are derived from MODIS-Aqua satellite data (30); higher values correspond to more absorbance at 412 nm and, as a consequence, a red-shifted visual environmen*

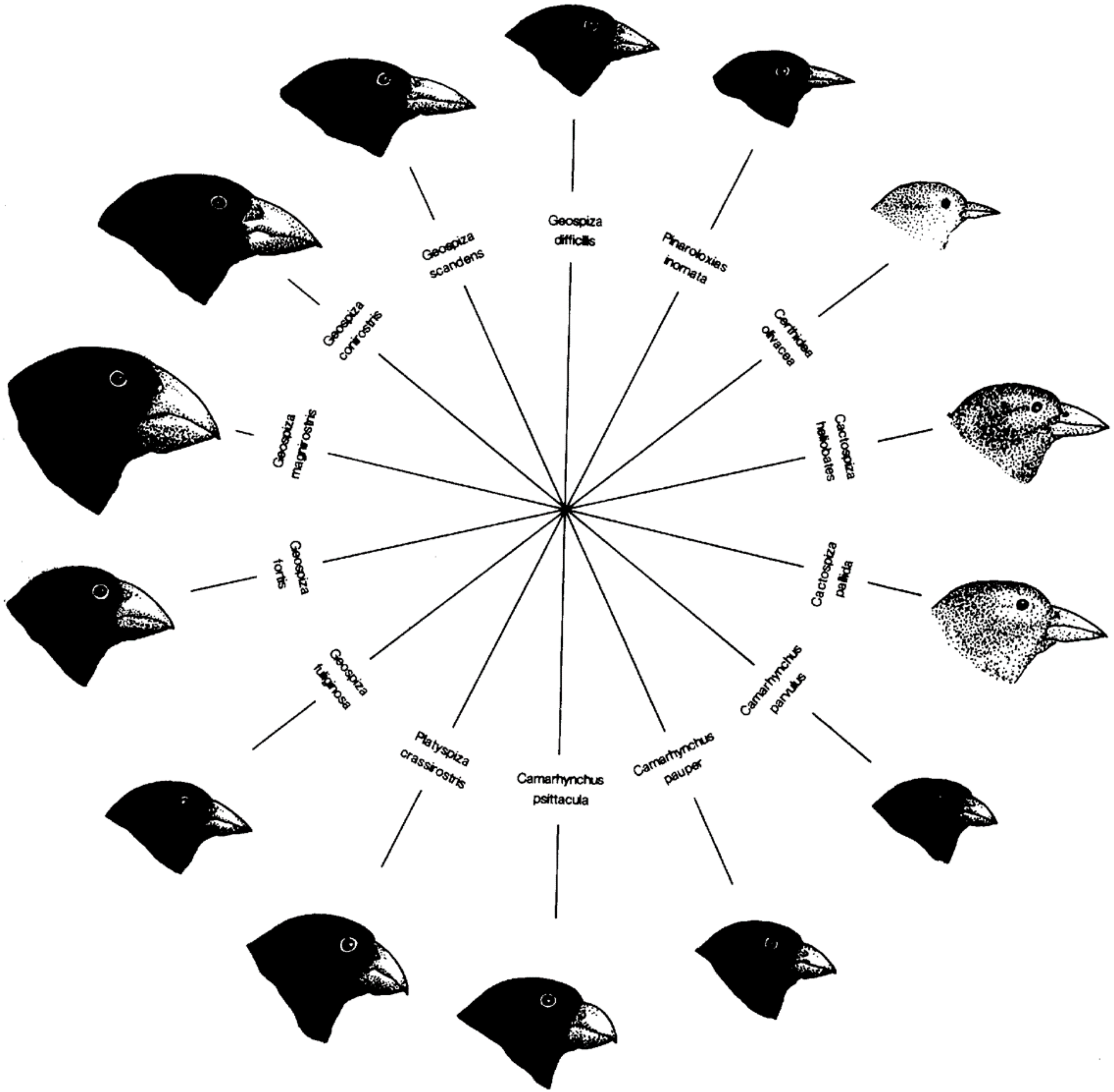


More individuals with Phe261Tyr mutation

DIRECTIONAL SELECTION!

In some Baltic populations this mutation is FIXED- it is present in all individuals, there is no more genetic diversity





Geospiza difficilis
Pinaroloxias inornata
Certhidea olivacea
Cactospiza heliobates
Cactospiza pallida
Camarhynchus parvulus
Camarhynchus pauper
Camarhynchus psittacula
Platyspiza crassirostris
Geospiza fuliginosa
Geospiza fortis
Geospiza magnirostris
Geospiza conirostris
Geospiza scandens

REPORTS

Intense Natural Selection in a Population of Darwin's Finches (Geospizinae) in the Galápagos

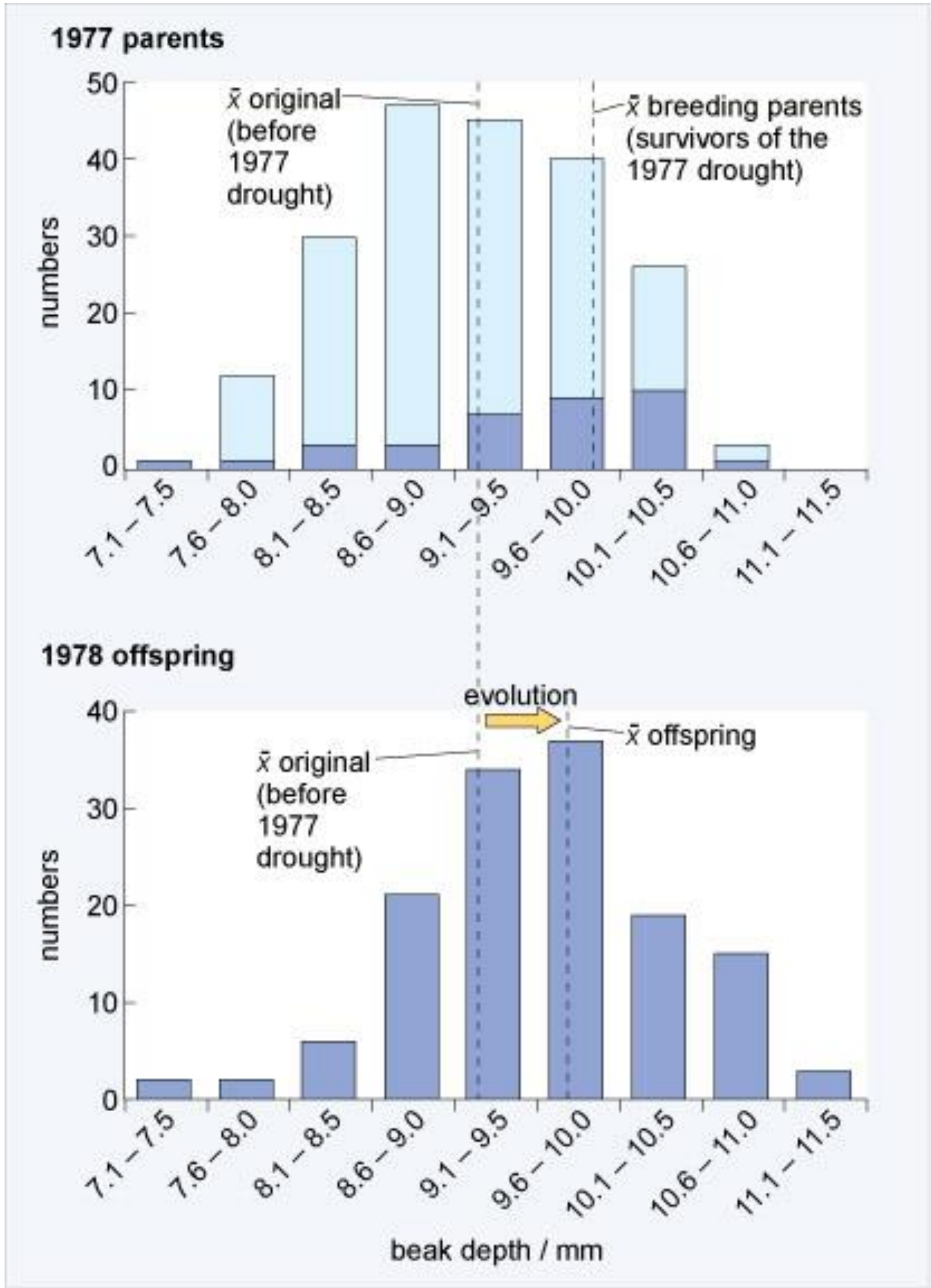
PETER T. BOAG[1], PETER R. GRANT[1]
+ See all authors and affiliations

Science 02 Oct 1981:
Vol. 214, Issue 4516, pp. 82-85
DOI: 10.1126/science.214.4516.82

Abstract

Survival of Darwin's finches through a drought on Daphne Major Island was nonrandom. Large birds, especially males with large beaks, survived best because they were able to crack the large and hard seeds that predominated in the drought. Selection intensities, calculated by O'Donald's method, are the highest yet recorded for a vertebrate population.

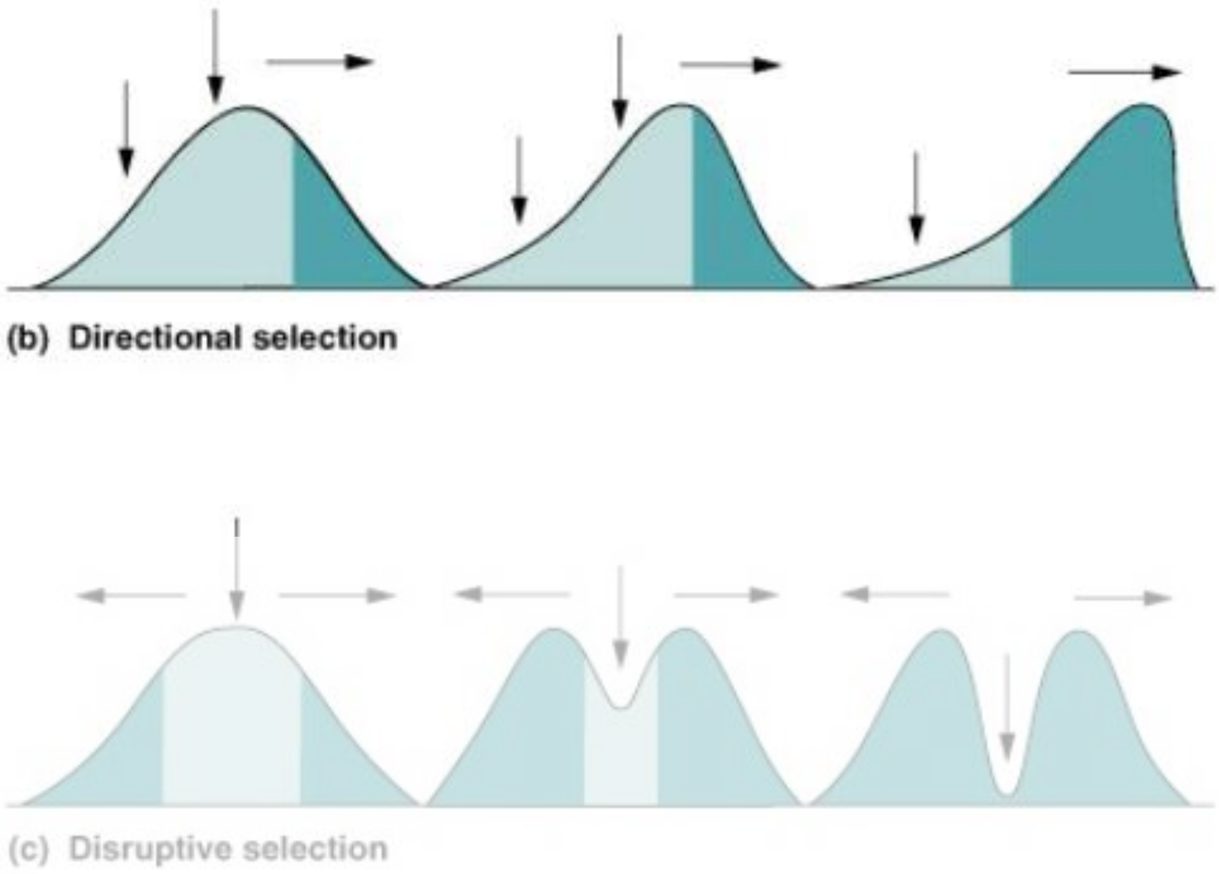
1976-1977 **– draught**… prevented reproduction by most plants. The resident population of *Geospiza fortis* rapidly depleted available seeds, many individuals starved to death and population declined by 85%. The **depletion of seeds was non-random** (only finches with large beaks can consume large seeds). As the draught persisted, the birds with larger beaks were more likely to survive **– DIRECTIONAL SELECTION TOWARD LARGER BEAKS**
When the draught ceased, the finches that breed were mostly the ones with larger beaks (highly heritable trait).



DIRECTIONAL SELECTION !

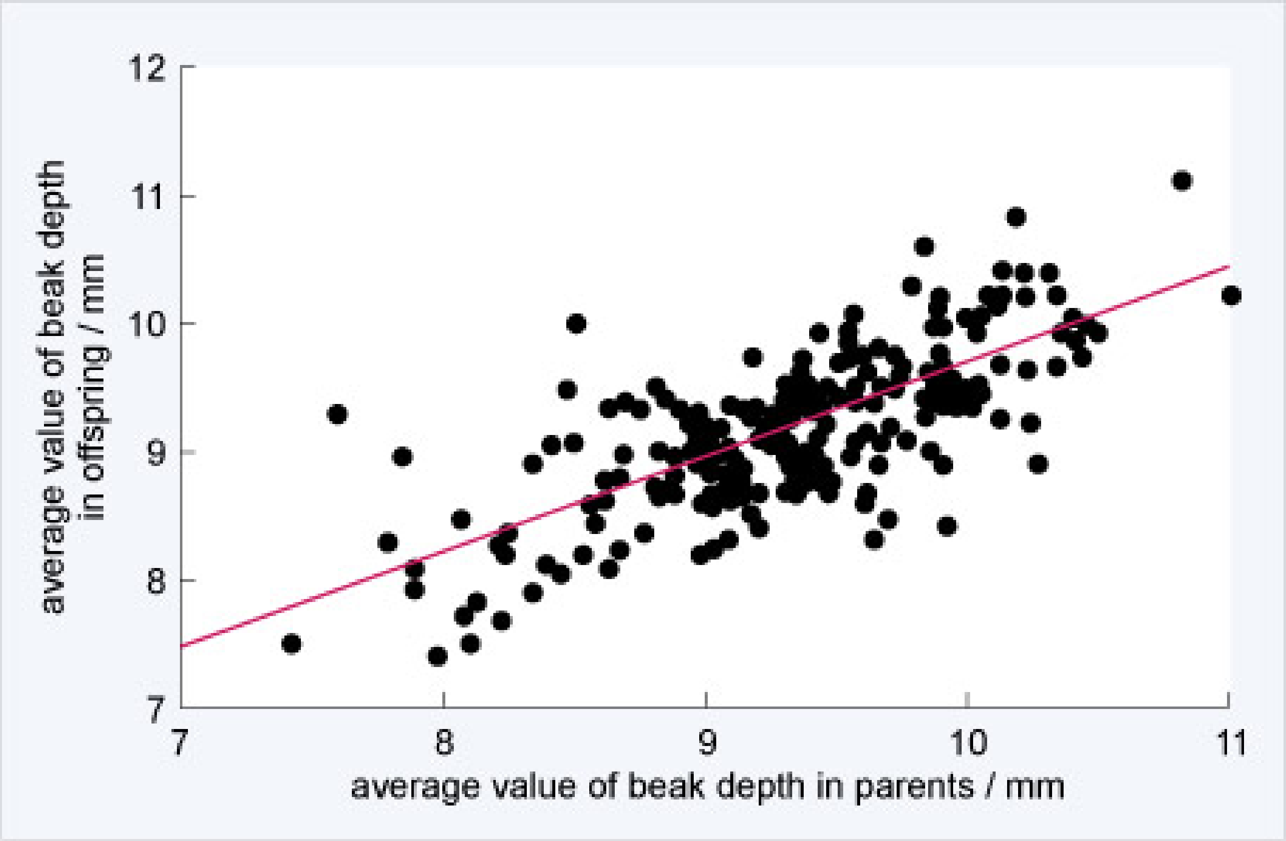
a) **The pale blue bars show the total number of birds on the island with beaks in each size class, before the drought. The blue bars show the number of birds with beaks in each size class that survived the drought and subsequently reproduced.**

b) **The average beak size of offspring produced by adults that survived the drought. The dashed vertical lines show the average beak size from one year to the next. Based on Grant et al. (2003).**

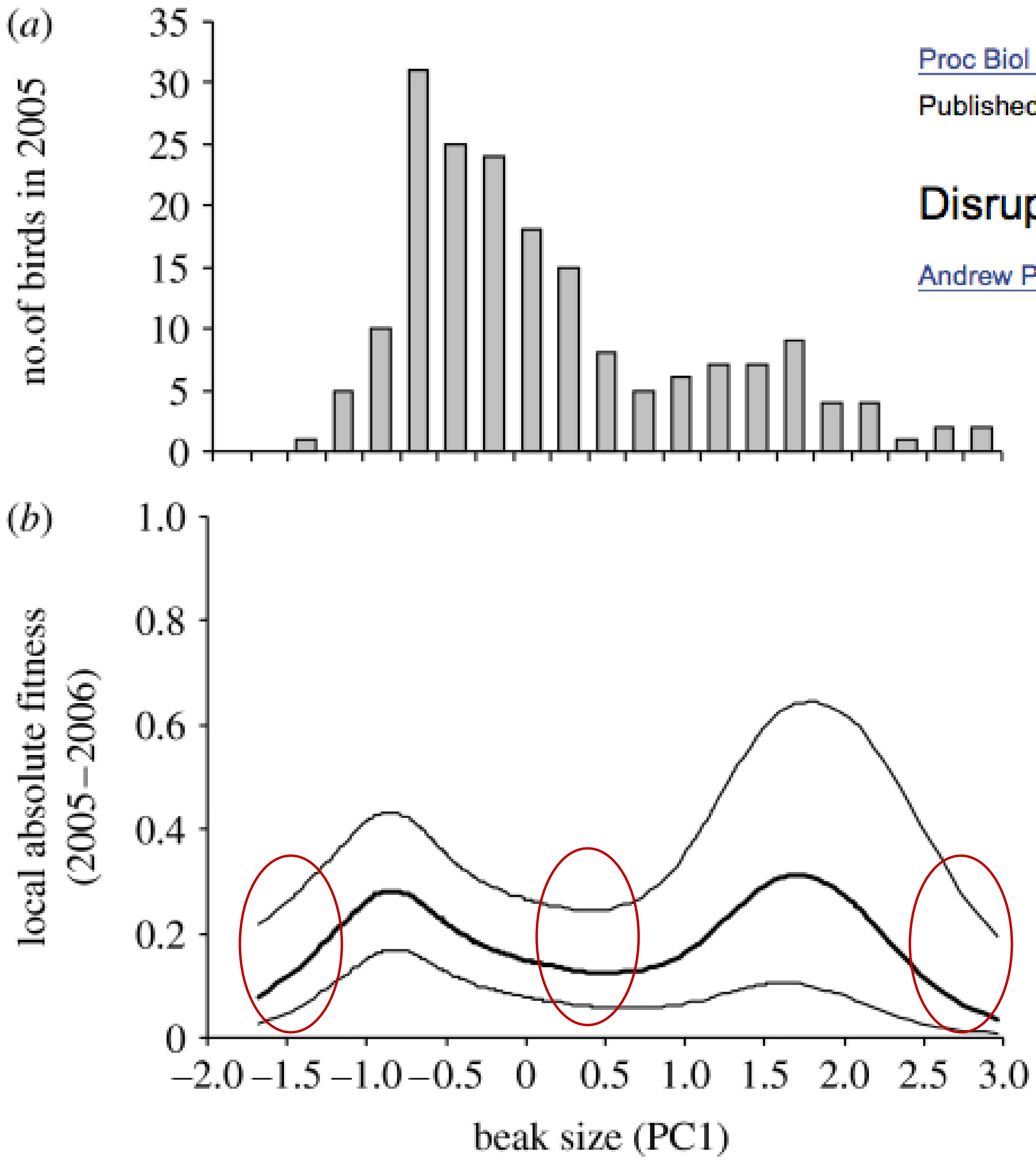


higher frequency of individuals with larger beaks

DIRECTIONAL SELECTION



Heritability is evident in correlation in trait between parental and offspring generation



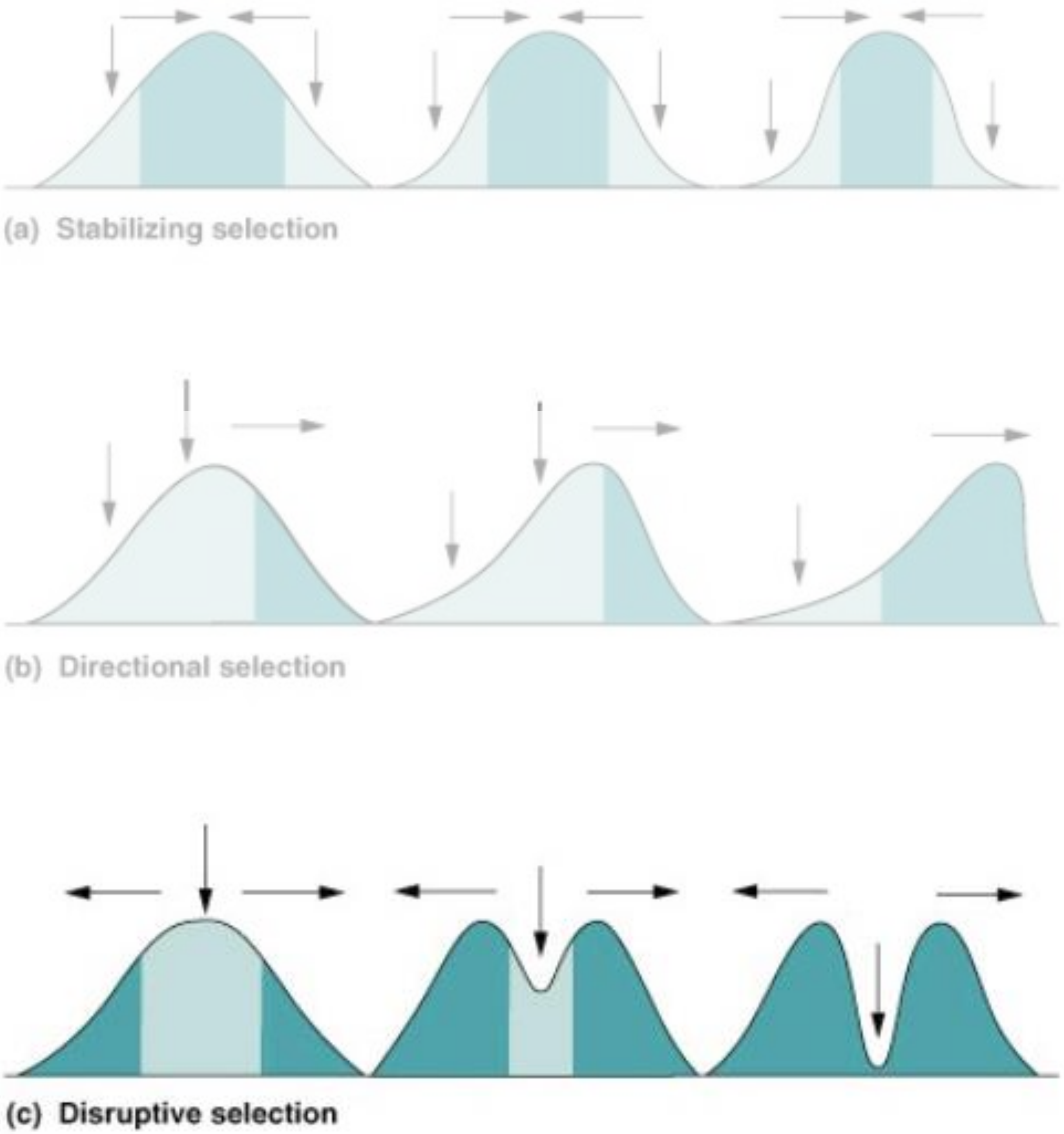
DISRUPTIVE SELECTION !

Proc Biol Sci. 2009 Feb 22; 276(1657): 753–759. PMCID:
Published online 2008 Nov 4. doi: [10.1098/rspb.2008.1321] PM

Disruptive selection in a bimodal population of Darwin's finches

Andrew P. Hendry,[1,*] Sarah K. Huber,[2,3] Luis F. De León,[1] Anthony Herrel,[4] and Jeffrey Podos[2]

- *"The medium ground finch (**Geospiza fortis**) of El Garrapatero, Santa Cruz Island, Galápagos. We examined patterns of selection in this population by relating individual beak sizes to interannual recaptures **during a prolonged drought**. Supporting the theory, disruptive selection was strong between the two beak size modes. We also found some evidence **of selection against individuals with the largest and smallest beak sizes**, perhaps owing to **competition with other species or to gaps in the underlying resource distribution**. Selection may thus simultaneously maintain the **current bimodality while also constraining further divergence**. "*



higher frequency of individuals with larger and with smaller beaks

DISRUPTIVE SELECTION

DISRUPTIVE SELECTION

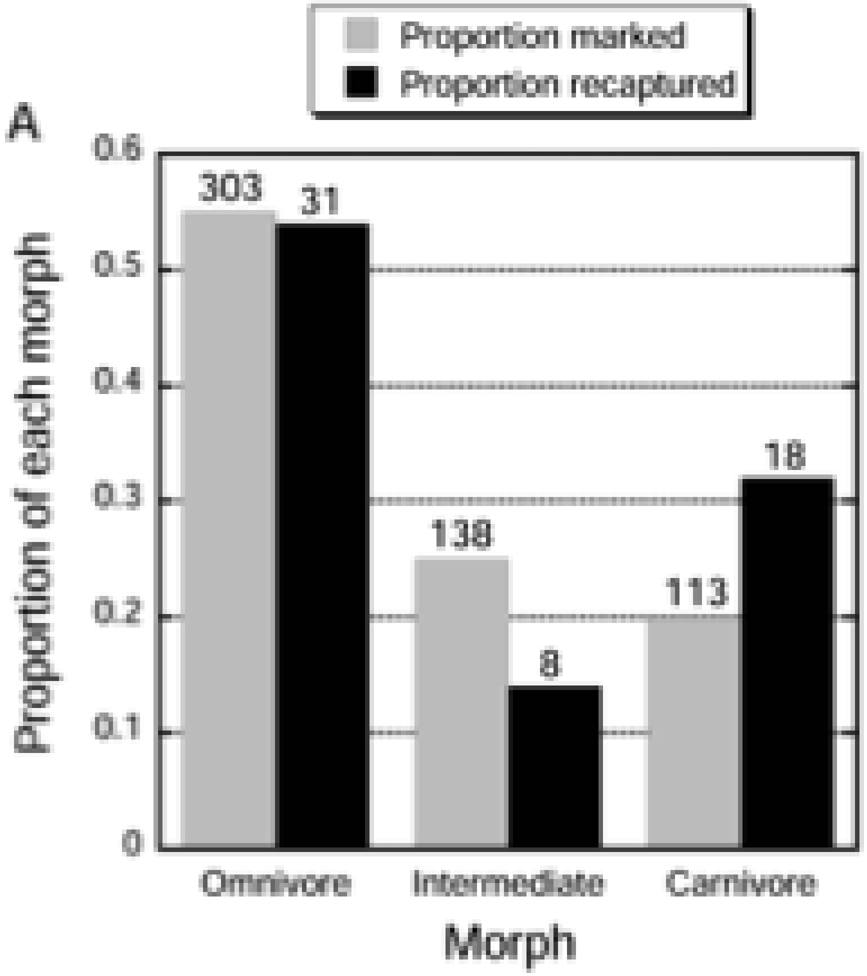
-often in populations experience high competition for resources

- *Mexican spadefod toads:* ***round bodied*** *(omnivore) or* ***narrow bodied*** *(carnivore).*

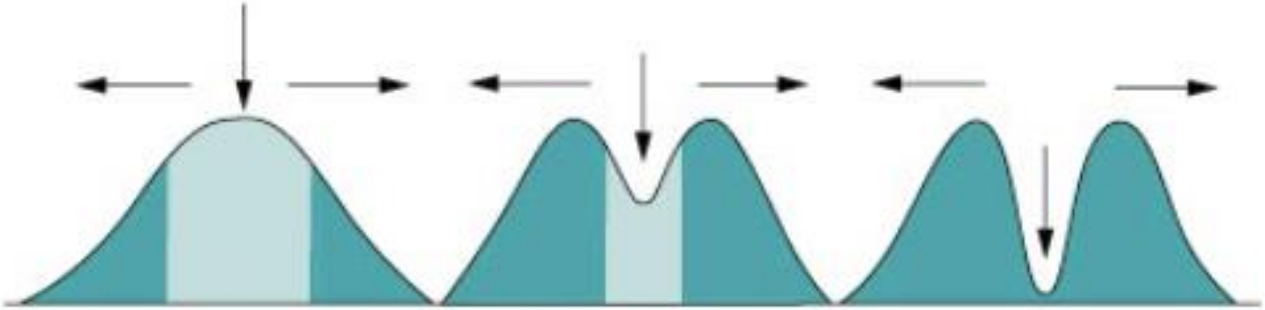
omnivore on the left, carnivore on the right

- tadpoles with intermediate morphology were less likely to survive and had smaller body size than the others.
- *they found that the* individuals that **were the most omnivore-like were the most efficient foragers on detritus**. *They also found that the more* ***omnivore-like tadpoles grew more during the experiment*** *than the more carnivore-like tadpoles. It was also found that most carnivore-like individuals were the most efficient foragers on shrimp*

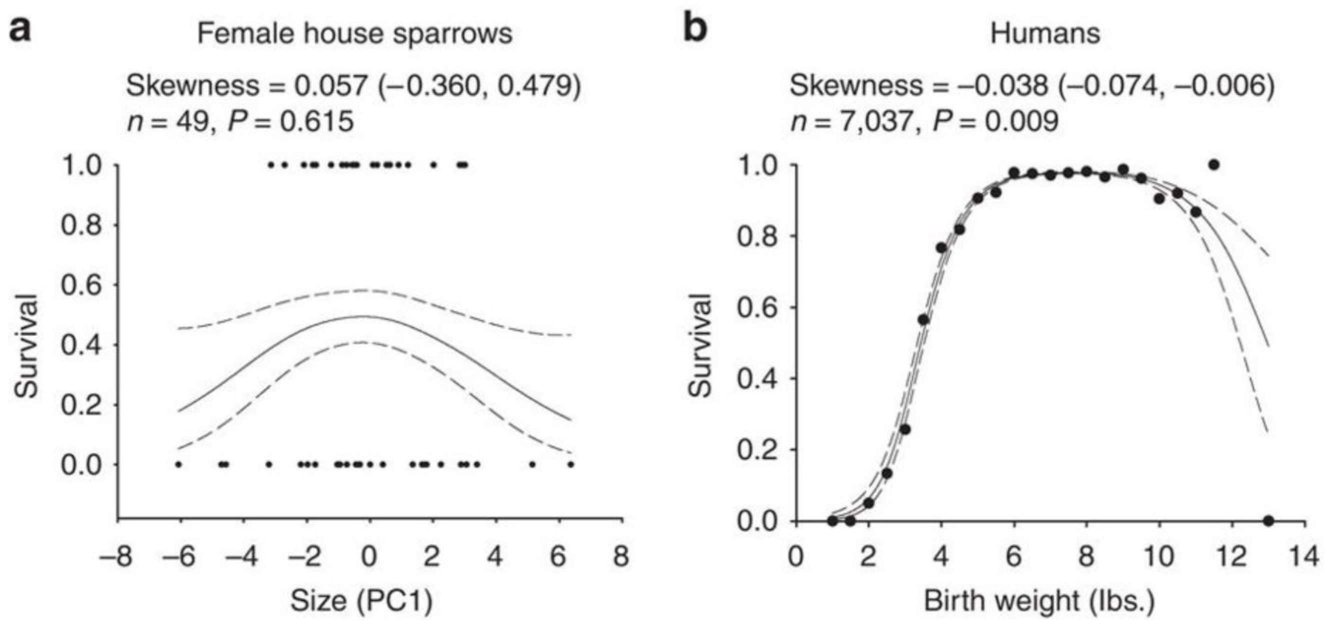
DISRUPTIVE SELECTION !

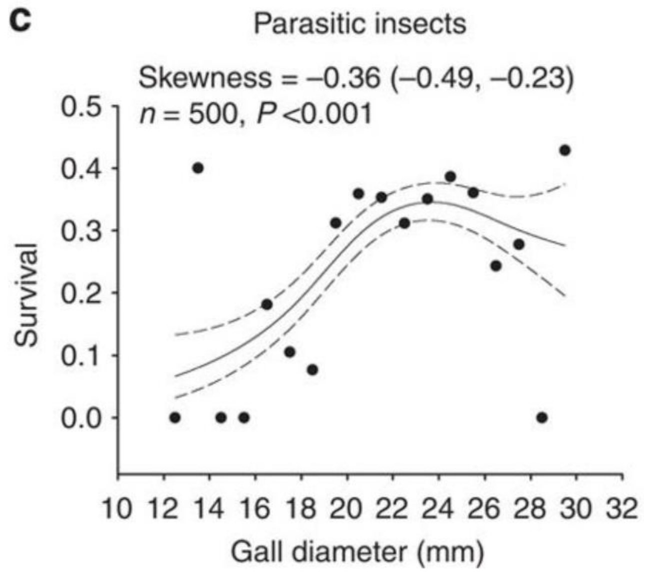


554 tadpoles caught in the pond, marked, and released. Intermediate phenotype was the least represented in the recapture (mark-recapture method) – lower survival in nature.


(c) Disruptive selection

STABILIZING SELECTION !





HIGHEST FITNESS OF INTERMEDIAN FENOTYPE

Female house sparrows, birth weight in humans, gall diameter of parasitic insects

Reproductive isolation in only three generations!!!

Science

REPORTS

Cite as: S. Lamichhaney *et al.*, *Science* 10.1126/science.aao4593 (2017).

Rapid hybrid speciation in Darwin's finches

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Homoploid hybrid speciation in animals has been inferred frequently from patterns of variation, but few examples have withstood critical scrutiny. Here we report a directly documented example from its origin to reproductive isolation. An immigrant Darwin's finch to Daphne Major in the Galápagos archipelago initiated a new genetic lineage by breeding with a resident finch (*Geospiza fortis*). Genome sequencing of the immigrant identified it as a *G. conirostris* male that originated on Española >100 km from Daphne. From the second generation onwards the lineage bred endogamously, and despite intense inbreeding, was ecologically successful and showed transgressive segregation of bill morphology. This example shows that reproductive isolation, which typically develops over hundreds of generations, can be established in only

Geospiza conirostris male arrived at the island Daphne major inhabited by *Geospiza rostrius.* Hybrid offspring became reproductively isolated in only the generations! – different beak morphology