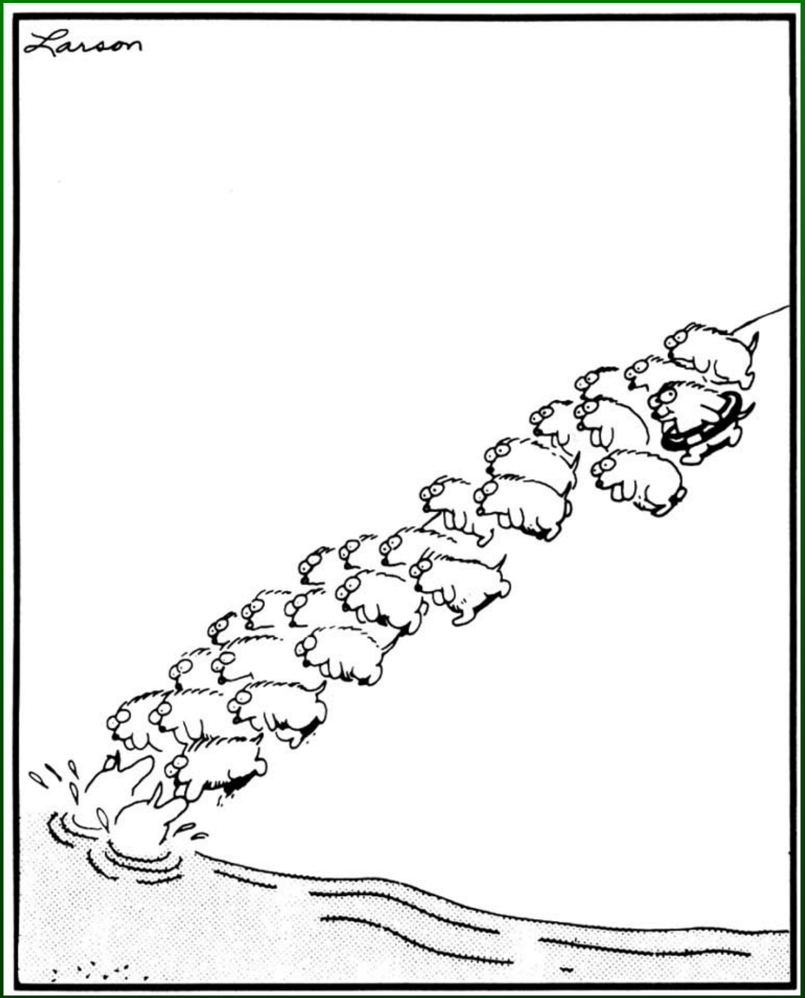
Selection & Adaptation

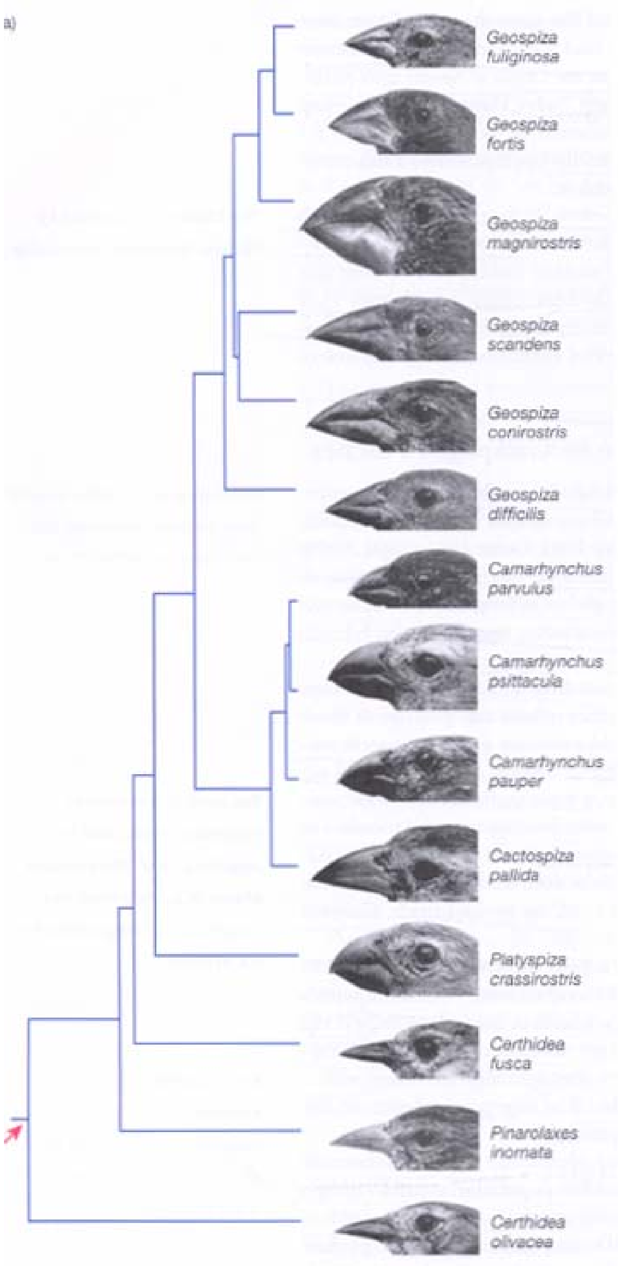


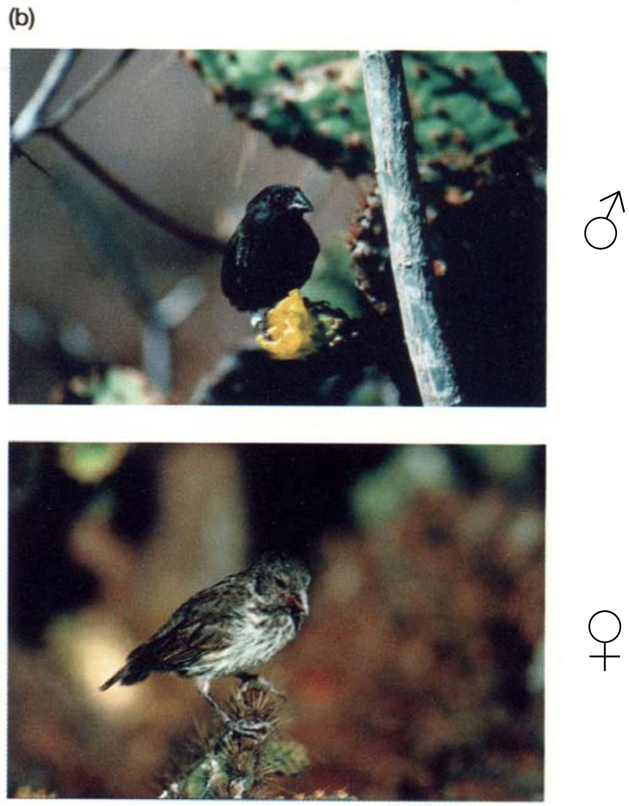
Natural Selection as “the” mechanism that produces *descent with modification from a common ancestor* aka evolution.

Darwin’s Four Postulates:

1. Individuals within a spp. are variable.
2. Some variations are passed on to offspring.
3. More offspring produced than survive.
4. Survival and reproduction are NOT random.

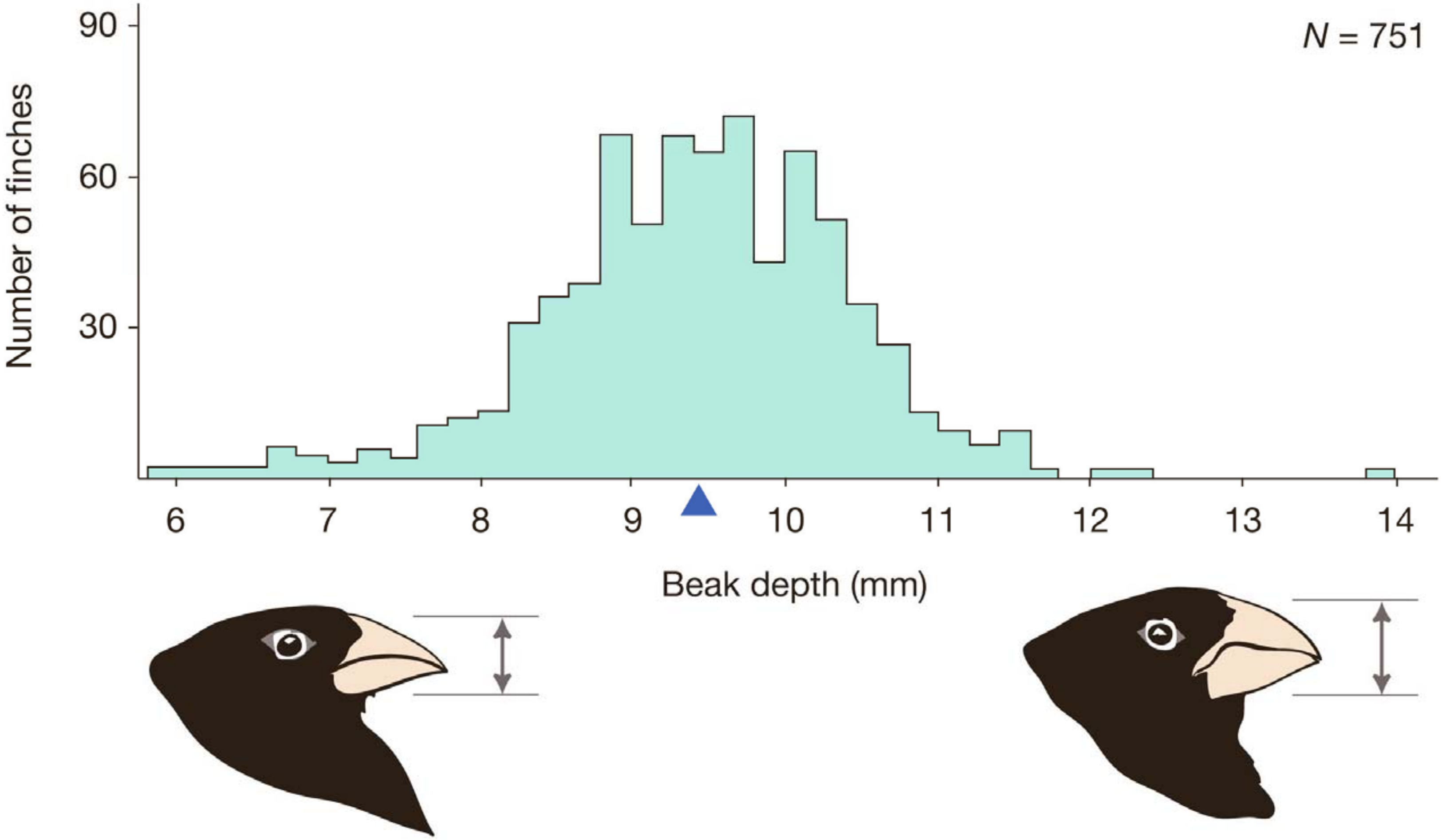
Fitness = Winners @ survival and reproduction
Adaptation = modified traits or characteristics
Galapagos Finches on hypothesis testing, winners by a beak!



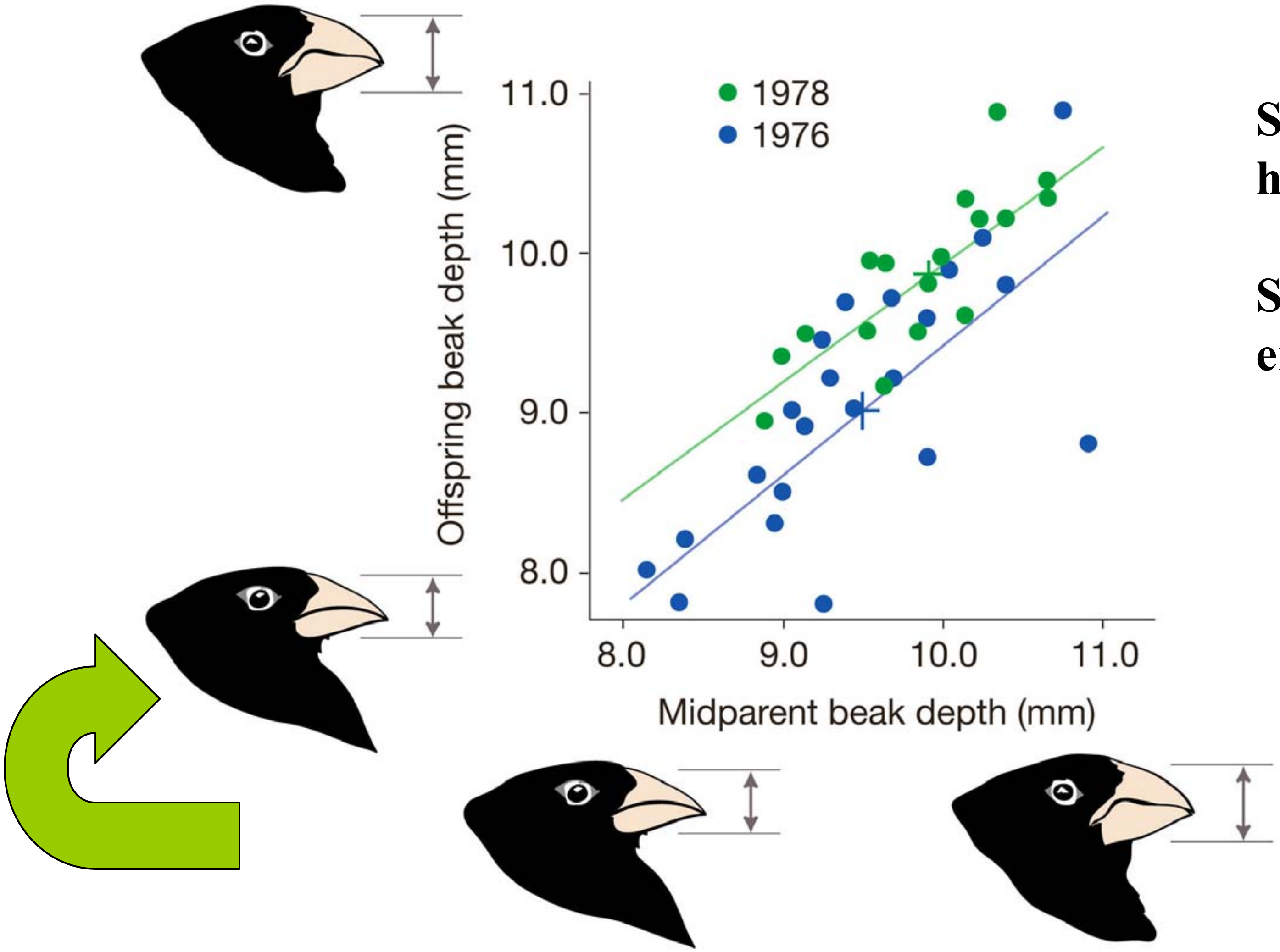


Darwin’s Finches as a Model for Natural Selection

Individuals within a spp. are variable.



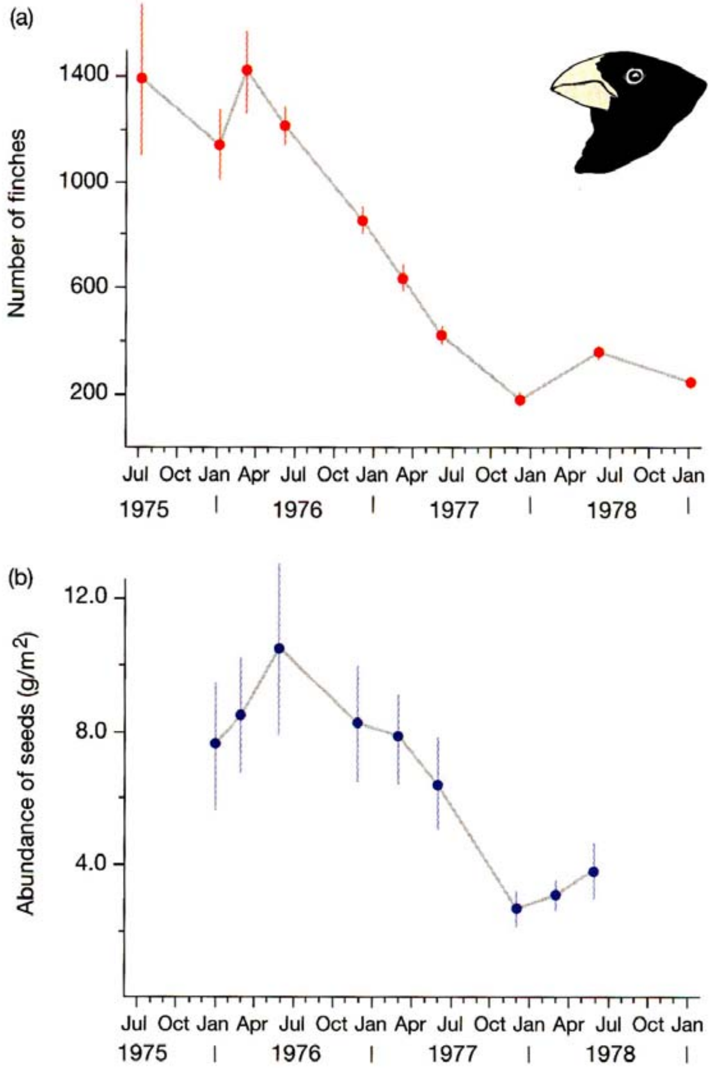
Some variations are passed on to offspring.



Slope of 1 indicates heritability.

Slope of 0 indicates environment.

More offspring produced than survive.



Decline of finch population and available seeds, during the 1977 drought.

Over 20 months 84% of the finches disappeared.

Thought to be due to the availability of seeds.

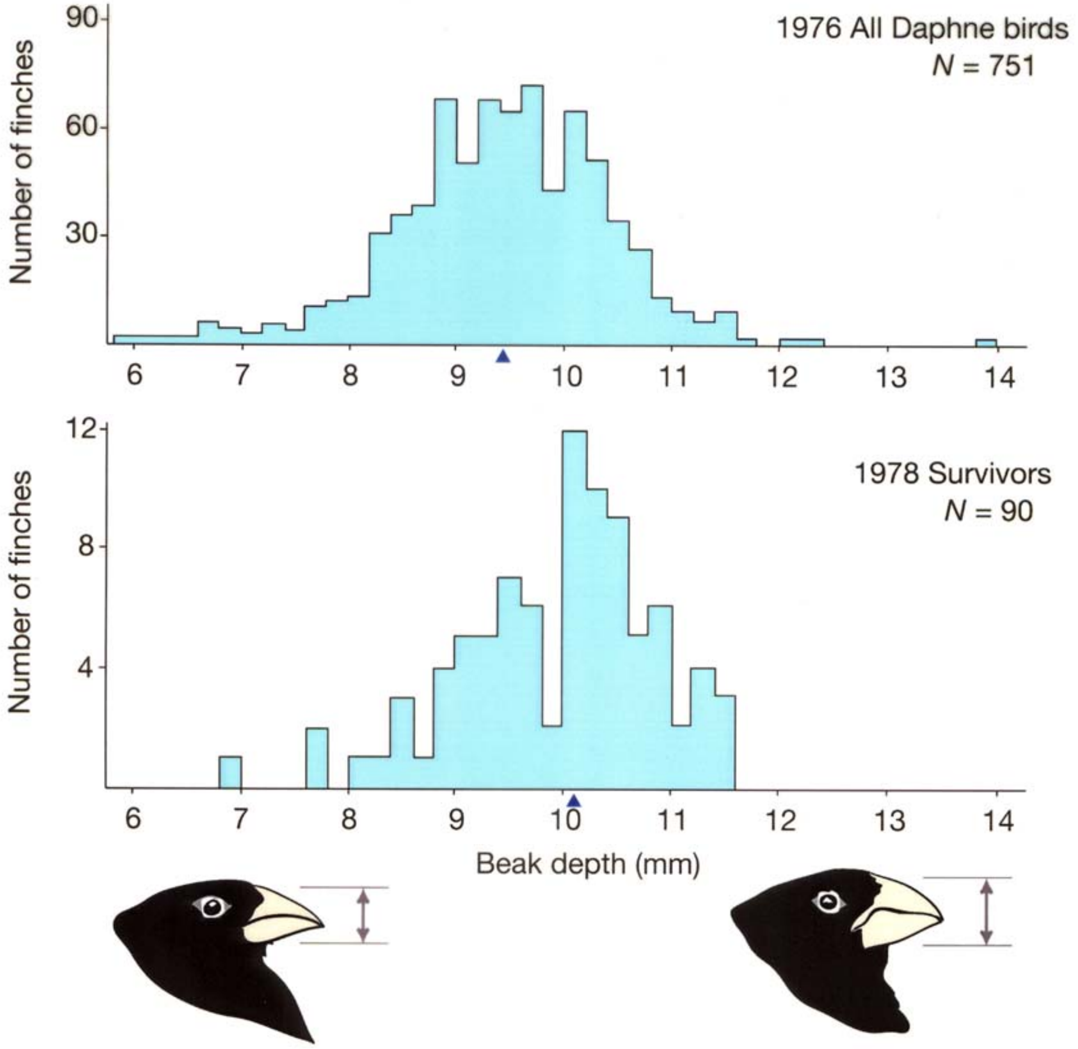
Reproductive potential

This table gives the number of offspring that a single individual (or pair of individuals, for sexual species) can produce under optimal conditions, assuming that all progeny survive to breed, over various time intervals. Darwin picked the elephant for his calculations because it was the slowest breeder then known among animals.

Organism	**Reproductive potential**	**Citation**
Aphis fabae (an aphid)	524 billion in one year	Gould 1977
Elephant	19 million in 750 years	Darwin 1859
Housefly	191×10^{18} in 5 months	Keeton 1972
Mycophila speyeri (a fly that feeds on mushrooms)	20,000/square foot, in 35 days	Gould 1977
Staphylococcus aureus (a bacterium)	cells would cover the Earth 7 ft deep in 48 hours	Audesirk and Audesirk 1993
Starfish	$>10^{79}$ in 16 years*	Dodson 1960

*10^{79} is the estimated number of electrons in the visible universe.

Survival and reproduction are NOT random.



After 1977 drought, 89% do not reach puberty.

Shift in average beak depth too.

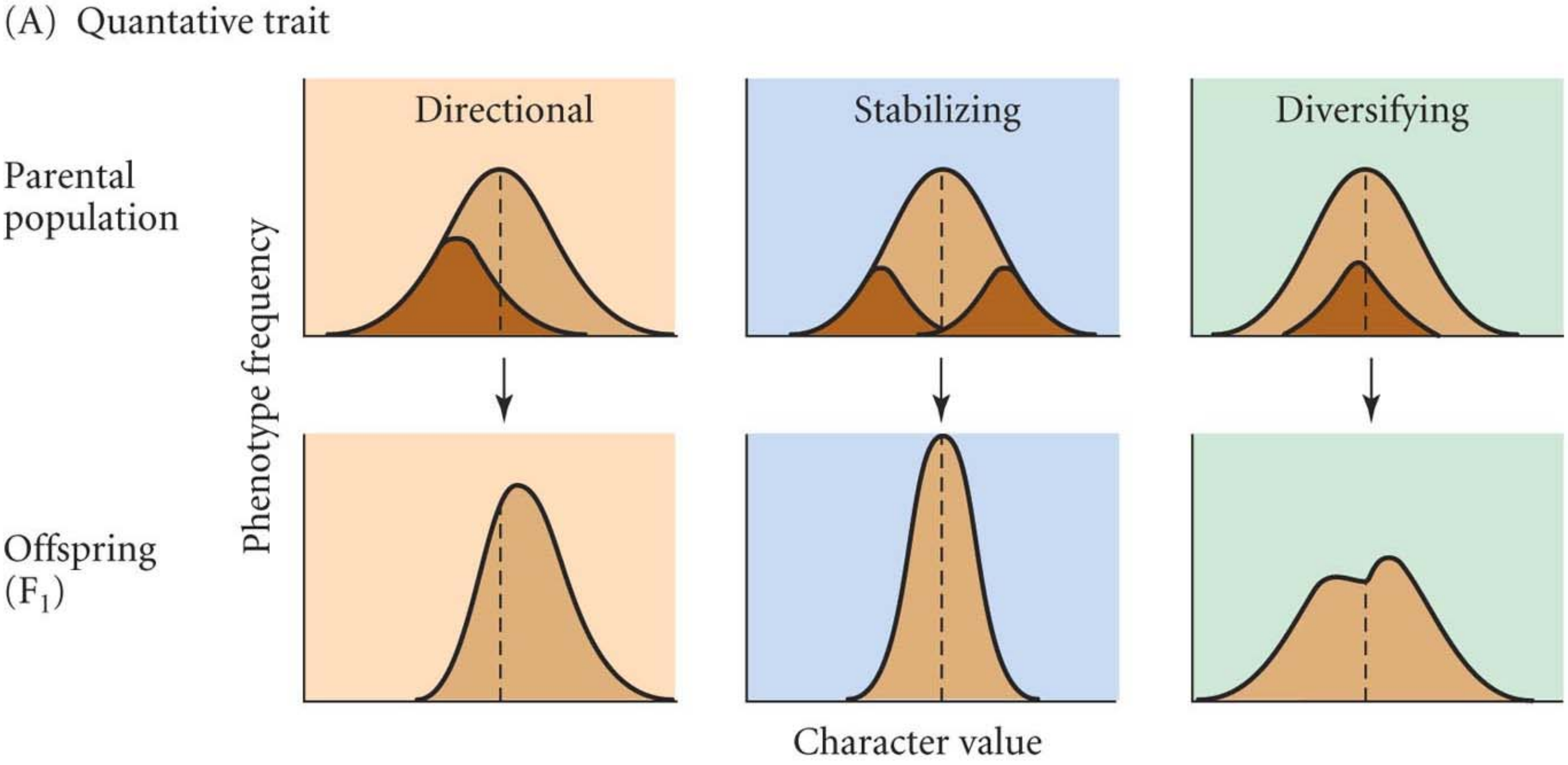
Natural Selection

- NS does NOT change the characters of individuals.
- NS does change the character distribution of populations.
- NS acts only on existing phenotypes.
- NS does NOT result in perfection (Not forward looking nor progressive).
- NS occurs within generations whereas evolution occurs across generations.

NeoDarwinism – Includes the mechanism(s) for **natural selection**.

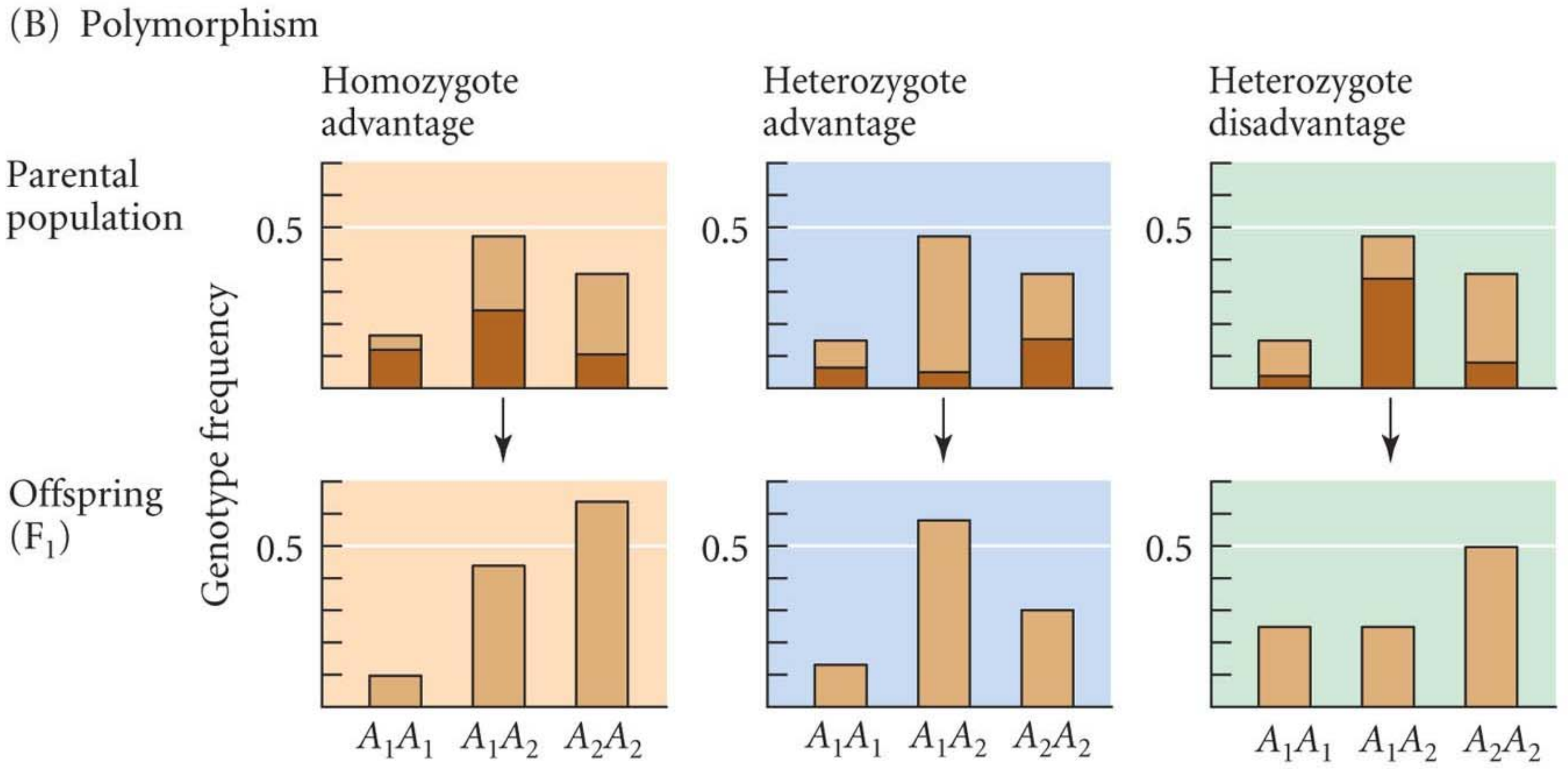
1. **Mutation** – generates variability within a population.
2. **Genetics** – Heritability or passing of traits to the next generation.
3. **Age of Earth is known** – Thermonuclear decay gets factored in!
4. **DNA structure is known** – The double helix with semi-conservative replication.

Modes of selection on a heritable quantitative character.



aka disruptive

Modes of selection on a polymorphism consisting of two alleles at one locus

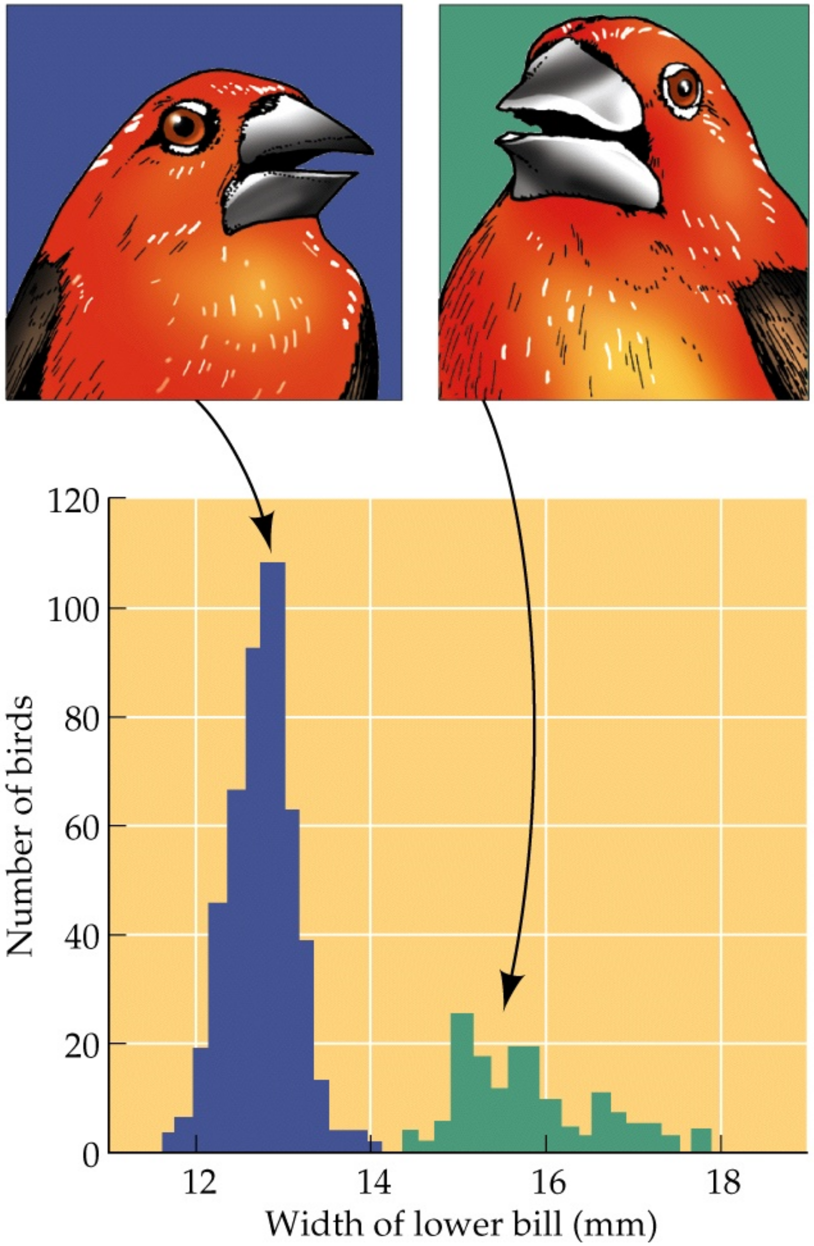


Directional selection increases the proportion of genotypes with a more extreme value of the trait.

Stabilizing selection does not alter the mean, but may reduce the variance.

Diversifying selection is unlikely to be exactly symmetrical, and thus usually shifts the mean.

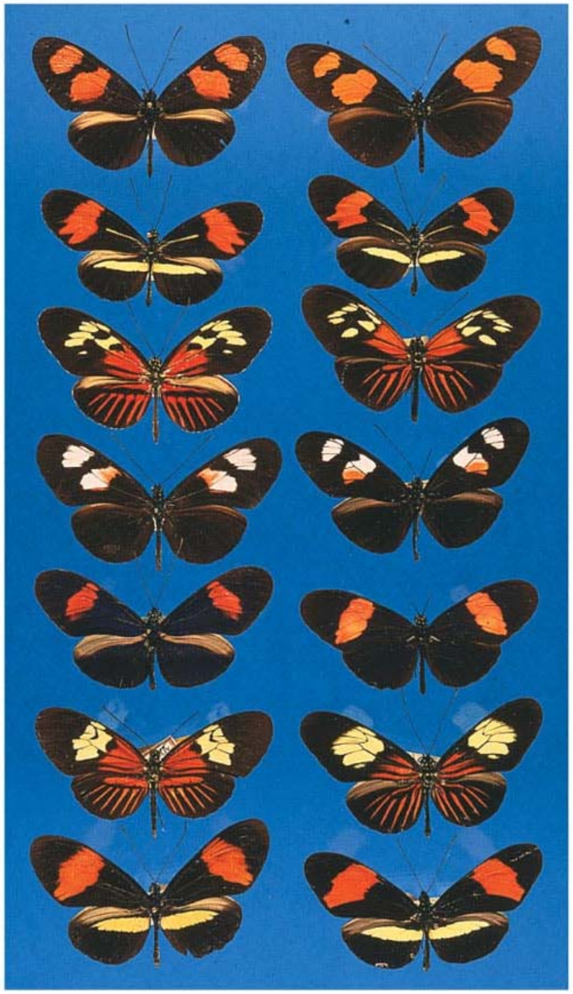
The decline and fall of the dark melanic form of the peppered moth due to less air pollution.



Black-bellied Seedcrackers (*Pyrenestes*)

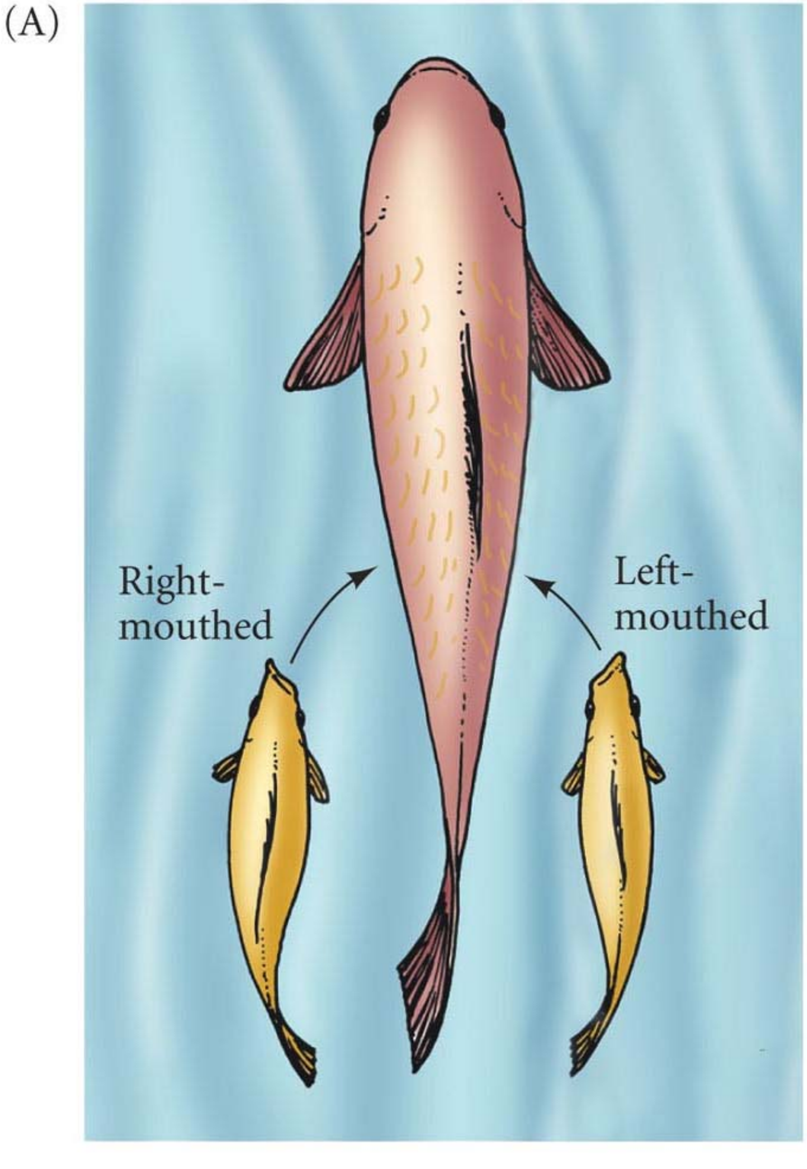
- Live in marshes in W. Africa
- Eat seeds, primarily of two plant species
- One seed type is small, the other type is large
- Bill dimorphism reflects the effects of **disruptive selection**

Example of heterozygote disadvantage or underdominance in mimetic butterflies

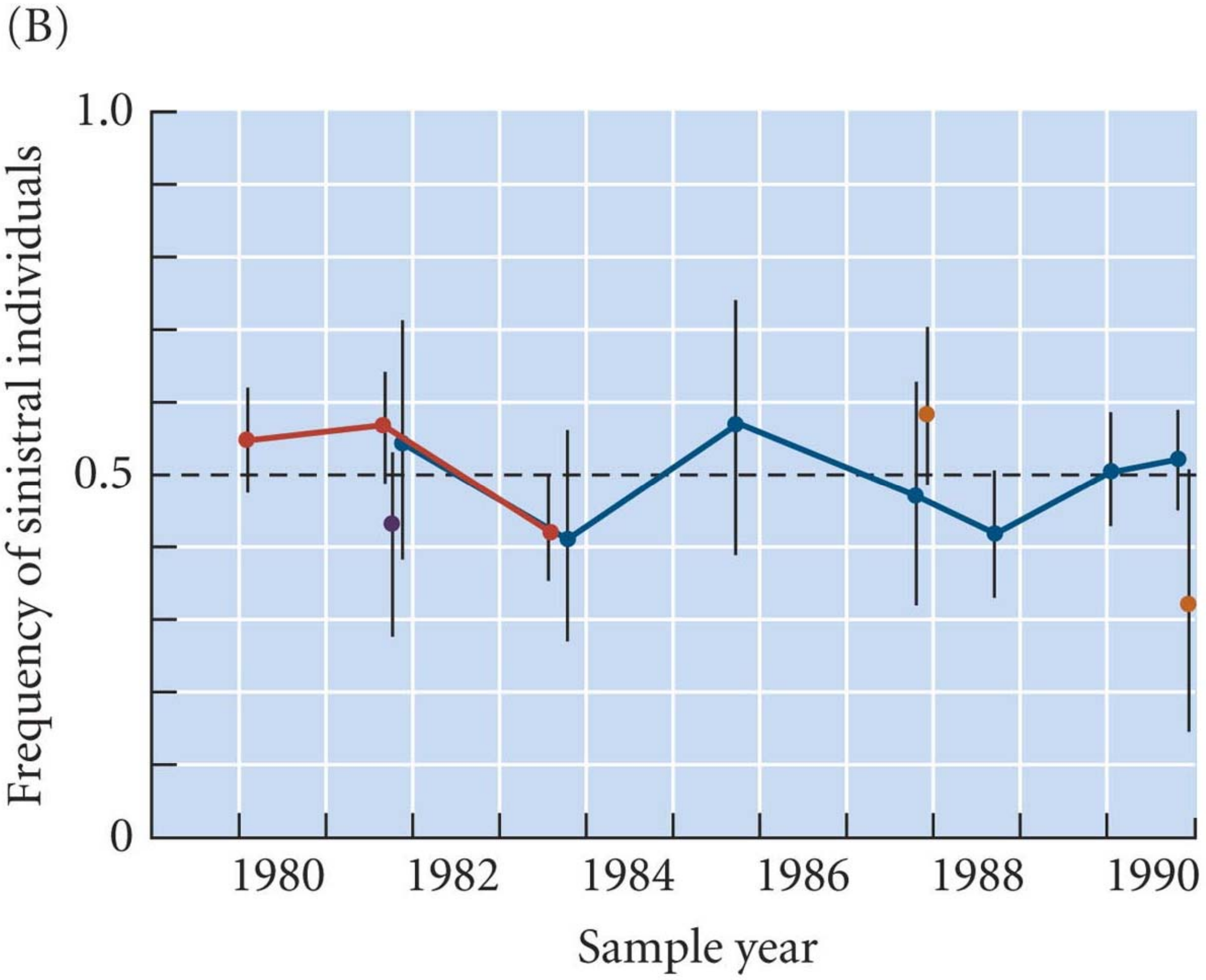


Heliconius melpomene *Heliconius erato*

Frequency-dependent selection



An inverse frequency-dependent polymorphism in the scale-eating cichlid



Components of natural selection that may affect the fitness of a sexually reproducing organism

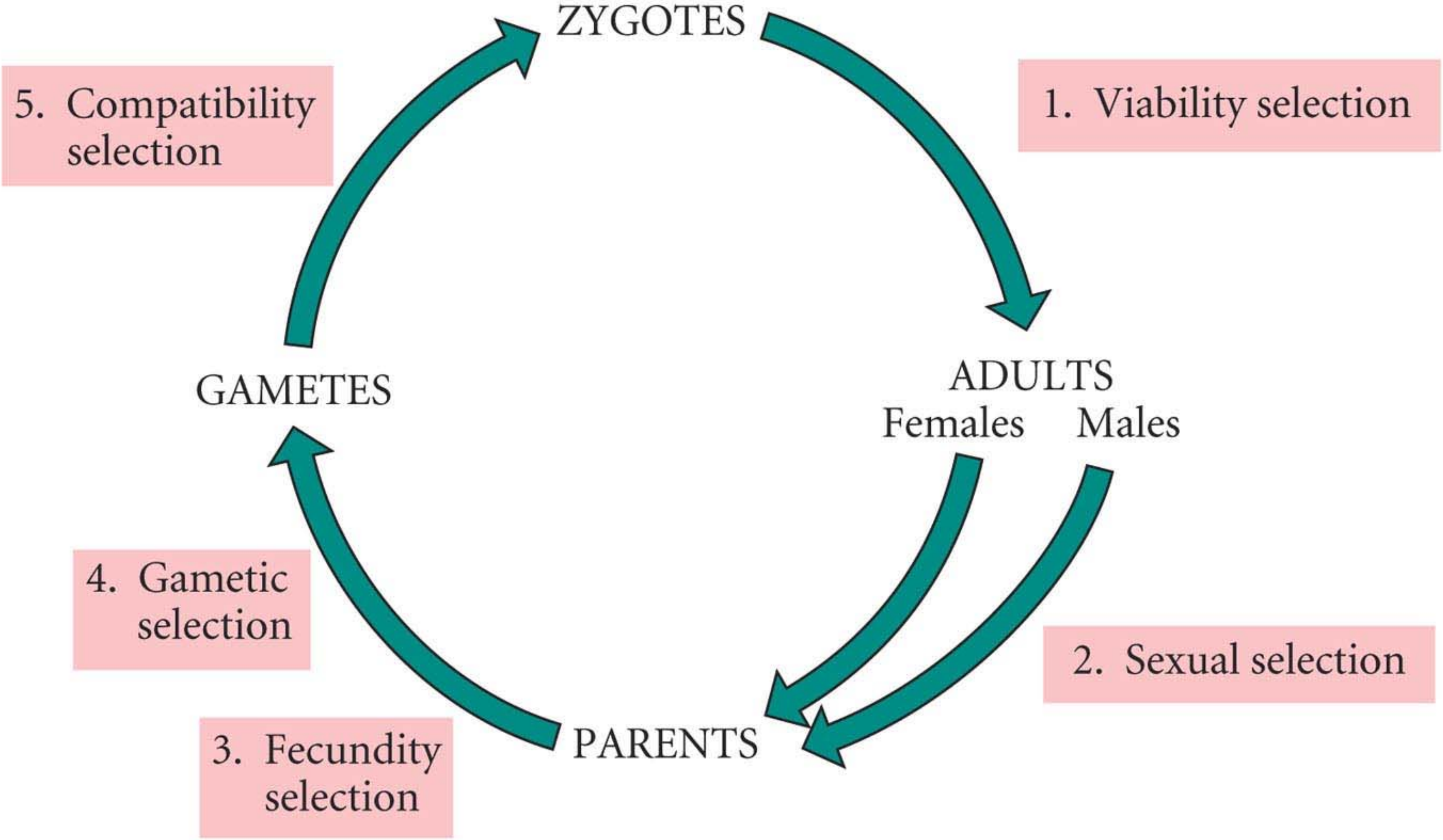


TABLE 12.1 *Components of selection in sexually reproducing organisms* (Part 1)

I. Zygotic selection

A. *Viability.* The probability of survival of the genotype through each of the ages at which reproduction can occur. After the age of last reproduction, the length or probability of survival does not usually affect the genotype's contribution to subsequent generations, and so does not usually affect fitness.

B. *Mating success.* The number of mates obtained by an individual. Mating success is a component of fitness if the number of mates affects the individual's number of progeny, as is often the case for males, but less often for females, all of whose eggs may be fertilized by a single male. Variation in mating success is the basis of sexual selection.

C. *Fecundity.* The average number of viable offspring per female. In species with repeated reproduction, the contribution of each offspring to fitness depends on the age at which it is produced (see Chapter 17). The fertility of a mating may depend only on the maternal genotype (e.g., number of eggs or ovules), or it may depend on the genotypes of both mates (e.g., if they display some reproductive incompatibility).

TABLE 12.1 *Components of selection in sexually reproducing organisms* (Part 2)

II. Gametic selection

D. *Segregation advantage* (meiotic drive or segregation distortion). An allele has an advantage if it segregates into more than half the gametes of a heterozygote.

E. *Gamete viability.* Dependence of a gamete's viability on the allele it carries.

F. *Fertilization success.* An allele may affect the gamete's ability to fertilize an ovum (e.g., if there is variation in the rate at which a pollen tube grows down a style).

Adaptations

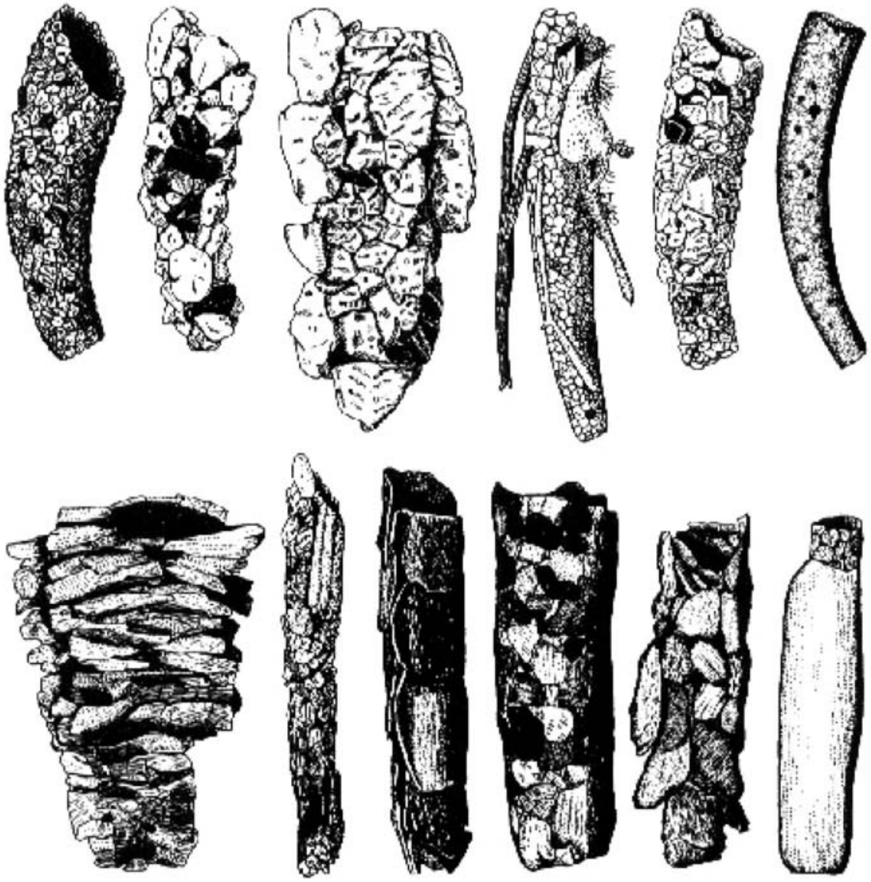
Broad definition: a trait that enhances fitness, relative to other traits.

Narrow definition: a trait that evolved under natural selection for its present function. Distinguishes from…

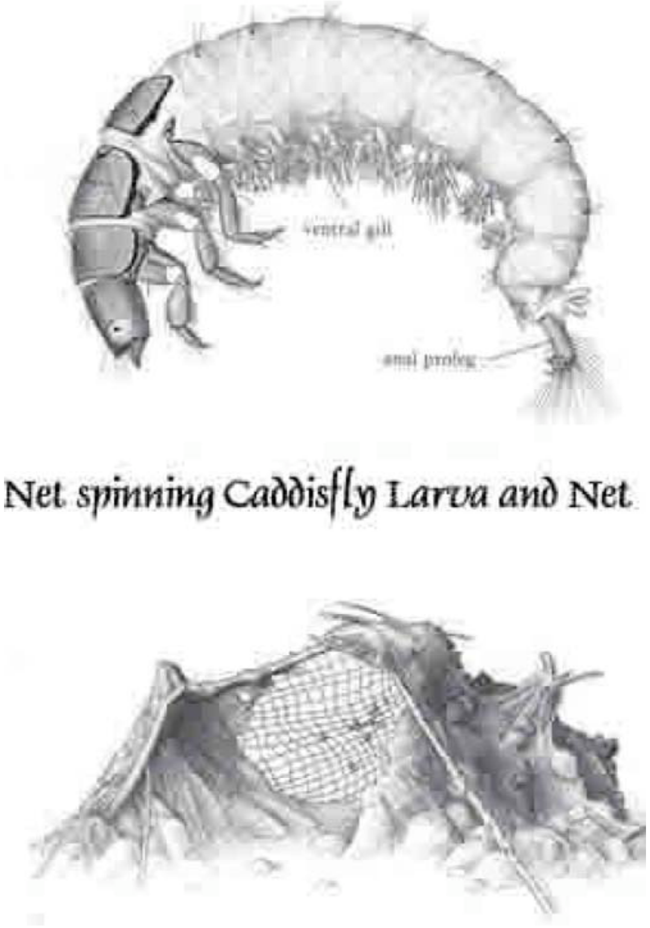
Preadaptations - existing traits that happen to serve a new function.

Exaptations - traits that are co-opted to serve a new function.

Preadaptations



Exadaptations



Net spinning Caddisfly Larva and Net

Adaptation – Generated by **natural selection** on whole organisms.

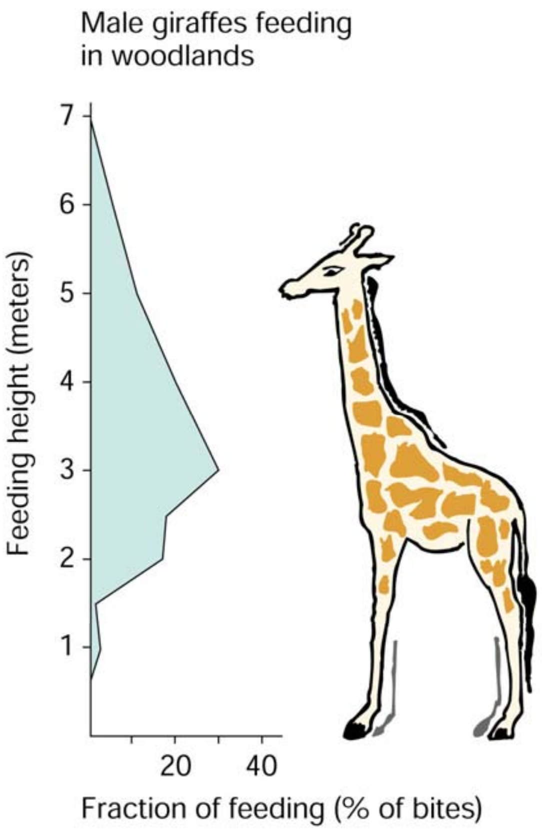
1. Not a function of **mutation**, **migration**, or **genetic drift**!

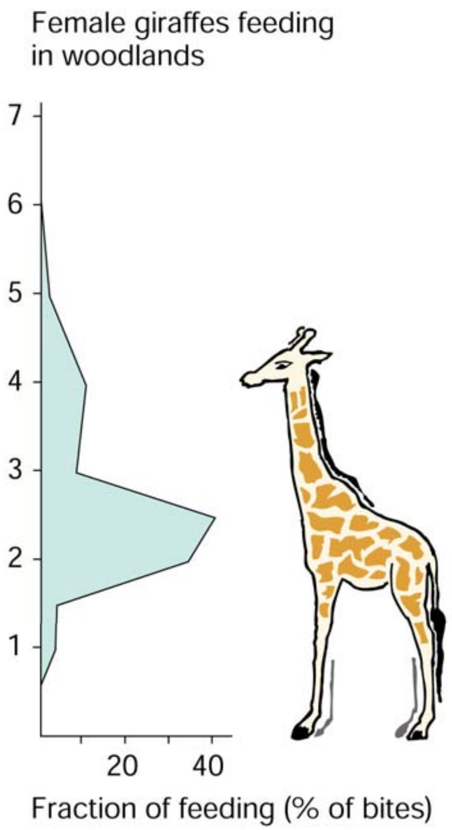
2. **Hypothesis testing** – Giraffe’s Neck reconsidered.

3. **Phenotypic Plasticity** is a factor.

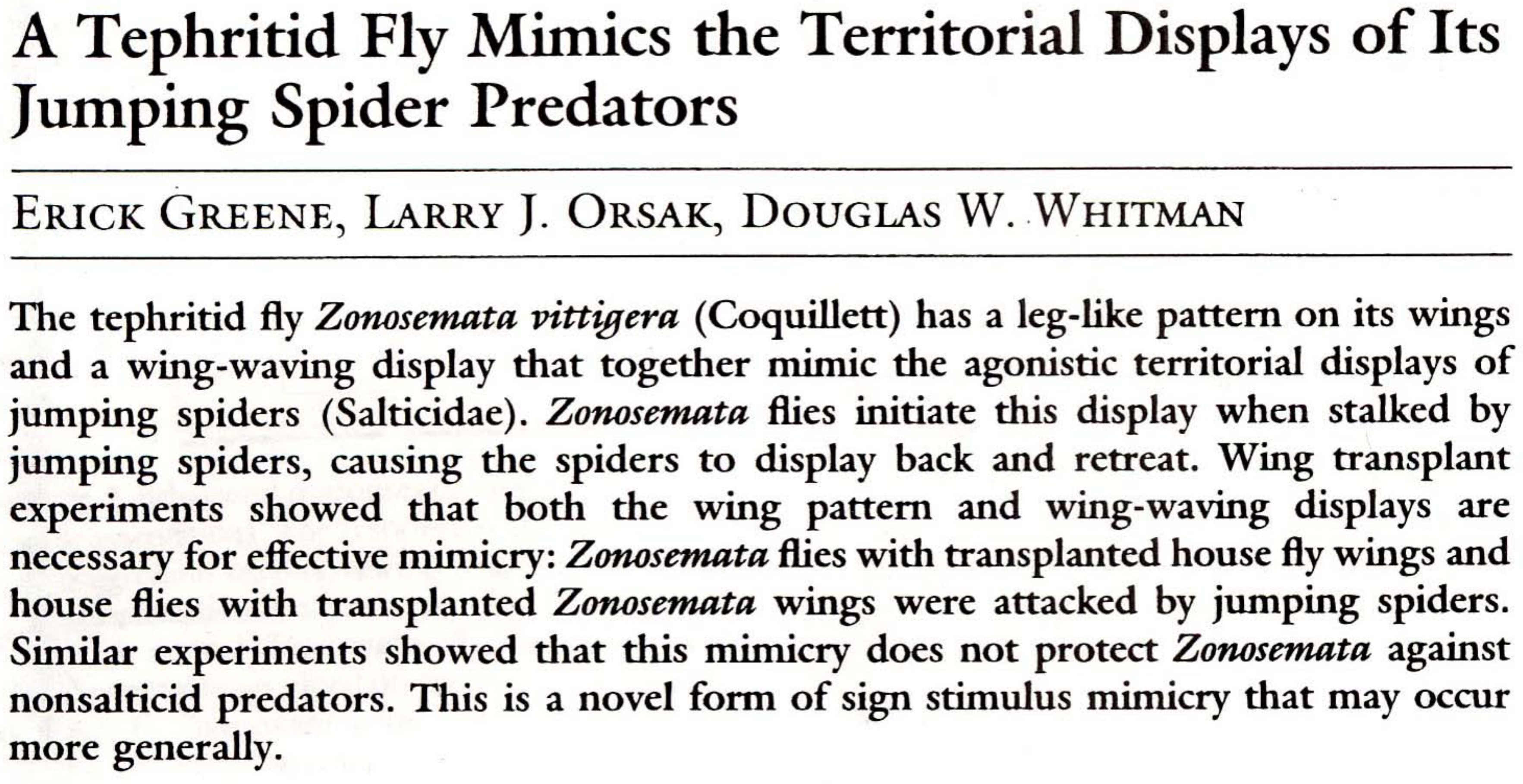
4. **Adaptive Radiation** driven by habitat.

Hypothesis testing – Giraffe’s Neck reconsidered.


Male giraffes feeding in woodlands


Female giraffes feeding in woodlands

Classic Experimental Study of Adaptation: The Sheep in Wolf's Clothing

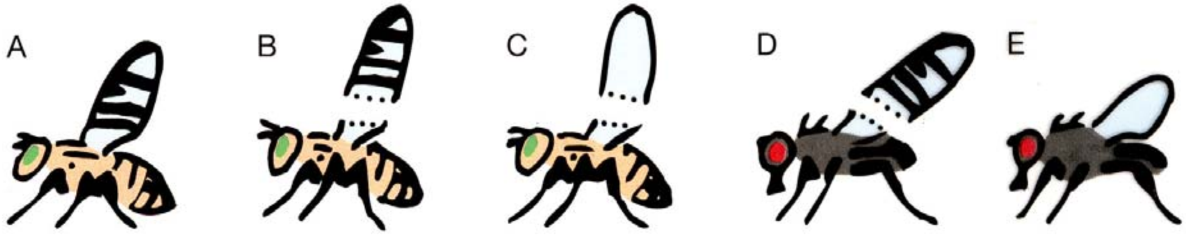


A Tephritid Fly Mimics the Territorial Displays of Its Jumping Spider Predators

ERICK GREENE, LARRY J. ORSAK, DOUGLAS W. WHITMAN

The tephritid fly *Zonosemata vittigera* (Coquillett) has a leg-like pattern on its wings and a wing-waving display that together mimic the agonistic territorial displays of jumping spiders (Salticidae). *Zonosemata* flies initiate this display when stalked by jumping spiders, causing the spiders to display back and retreat. Wing transplant experiments showed that both the wing pattern and wing-waving displays are necessary for effective mimicry: *Zonosemata* flies with transplanted house fly wings and house flies with transplanted *Zonosemata* wings were attacked by jumping spiders. Similar experiments showed that this mimicry does not protect *Zonosemata* against nonsalticid predators. This is a novel form of sign stimulus mimicry that may occur more generally.

Science. 1987. 236:310-312.



	A	B	C	D	E
Treatment	*Zonosemata* untreated	*Zonosemata* with own wings cut and reglued	*Zonosemata* with housefly wings	Housefly with *Zonosemata* wings	Housefly untreated
Purpose	Test effect of wing markings plus wing waving	Control for effects of operation	Test effect of wing waving without wing markings	Test effect of wing markings without wing waving	Test effect of no wing markings and no waving

Predictions under Hypothesis 1: No mimicry

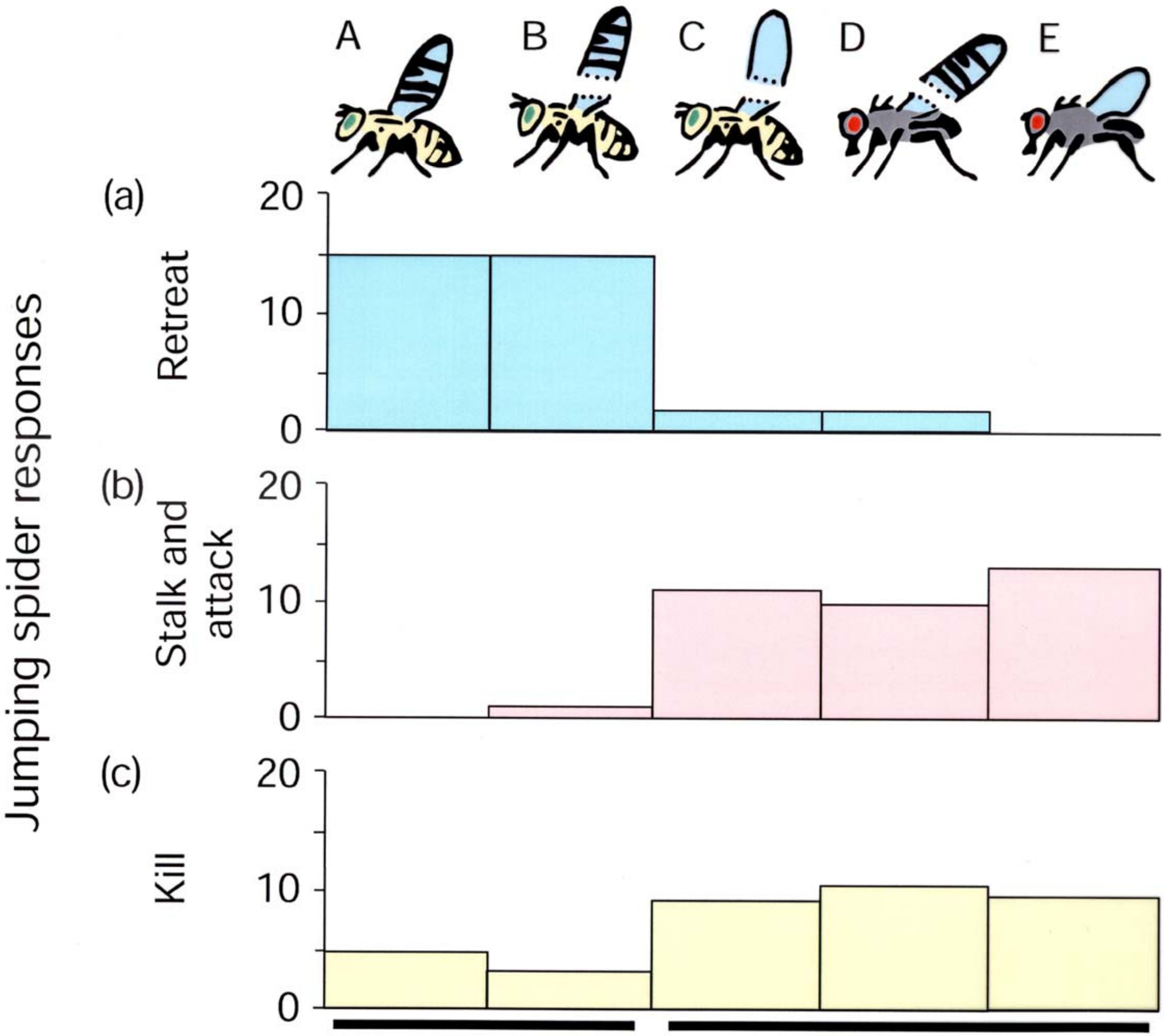
Jumping spider will:	Attack	Attack	Attack	Attack	Attack
Other predator will:	Attack	Attack	Attack	Attack	Attack

Predictions under Hypothesis 2: Mimcry deters other predators

Jumping spider will:	Attack	Attack	Attack	Attack	Attack
Other predator will:	Retreat	Retreat	Attack	Attack	Attack

Predictions under Hypothesis 3: Mimicry deters jumping spiders

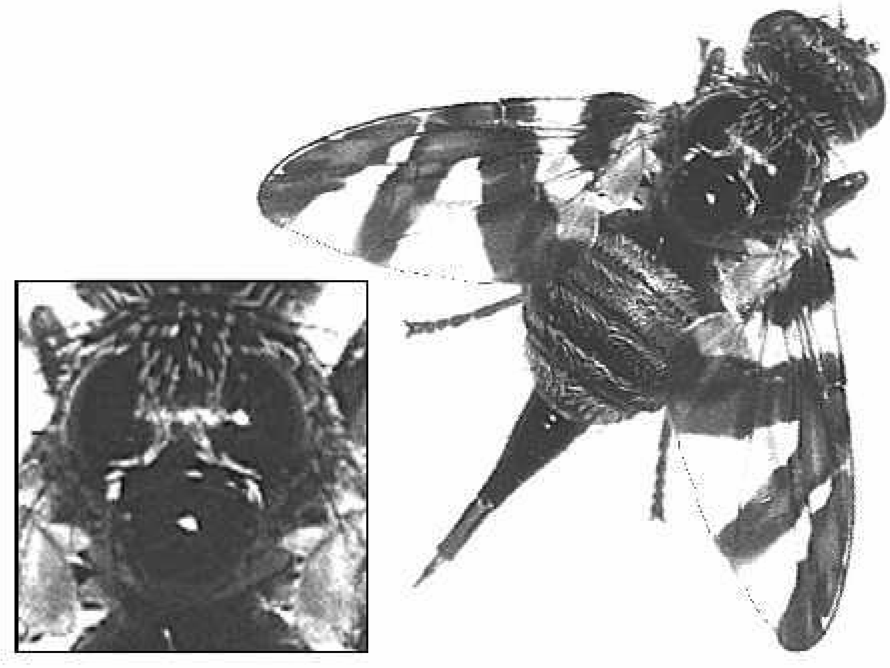
Jumping spider will:	Retreat	Retreat	Attack	Attack	Attack
Other predator will:	Attack	Attack	Attack	Attack	Attack



A
B
C
D
E
Jumping spider responses
(a)
Retreat
20
10
0
(b)
Stalk and attack
20
10
0
(c)
Kill
20
10
0

Tephritid flys are mimics of salticid spiders.

Significance: adaptation of both phenotypic and behavior responses.

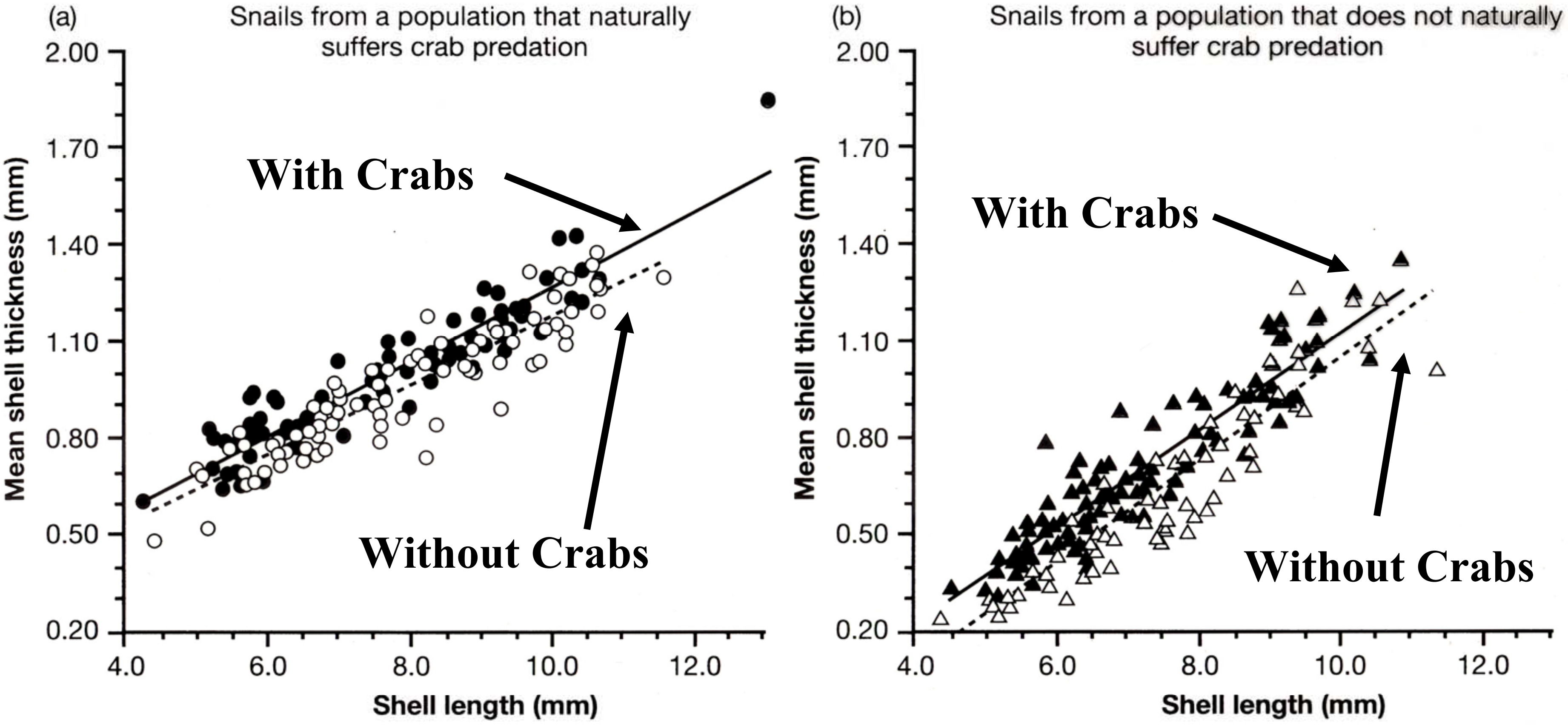


The wings of these flies carry a distinctive pattern that definitely looks like the legs of a crouching salticid.

In addition, these flies exhibit the behavior of continuously move their wings up and down.

???

Phenotypic Plasticity


(a) Snails from a population that naturally suffers crab predation

(b) Snails from a population that does not naturally suffer crab predation

With Crabs

Without Crabs

With Crabs

Without Crabs

Phenotypic plasticity and population differences in shell thickness in *Littorina obtusata* Each plot shows the relationship between shell thickness and overall size (shell length) for snails reared in the lab in the presence (filled symbols and solid lines) or absence (open symbols and dashed lines) of crabs. Plot (a) is for snails collected from a population that naturally suffers crab predation; plot (b) is for snails collected from a population that does not naturally suffer crab predation. In both populations, larger shells are thicker. In both populations, shell thickness is phenotypically plastic: Snails reared with crabs have thicker shells for their size. Nonetheless, the snails from the population normally exposed to crabs have thicker shells, regardless of treatment, than snails from the population not normally exposed to crabs. To see this, note that the best-fit lines have different *y*-intercepts. From Trussell (1996).

Marine iguanas shrink to survive El Niño

Changes in bone metabolism enable these adult lizards to reversibly alter their length.

Change in body length is considered to be unidirectional in vertebrates[1], but we have repeatedly observed shrinkage in the snout-to-vent length of individual adult iguanid lizards. In two studies, one lasting 18 years and one 8 years, of two island populations of Galápagos marine iguanas (*Amblyrhynchus cristatus*), we found that individuals became shorter by as much as 20% (6.8 cm) within two years. This shrinking coincided with low availability of food, resulting from El Niño events. Body length increased again during subsequent La Niña conditions, when algal food was abundant[2]. We found that lizards that shrank more survived longer than larger iguanas during harsh periods because their foraging efficiency increased and their energy expenditure decreased[3,4].

Marine iguanas (Fig. 1) are herbivorous reptiles that feed on submerged intertidal and subtidal algae along the rocky island shores of the Galápagos archipelago,

Figure 1 The marine iguana *Amblyrhynchus cristatus.*

means that it cannot simply be explained by decreases in cartilage and connective tissue, which together make up only 10% of total body length[11]. We believe that bone absorption accounts for much of the reduction.

Shrinking in marine iguanas may be an adaptive response to low food availability and energetic stress. Measurements of a cohort of adults more than 300 mm long

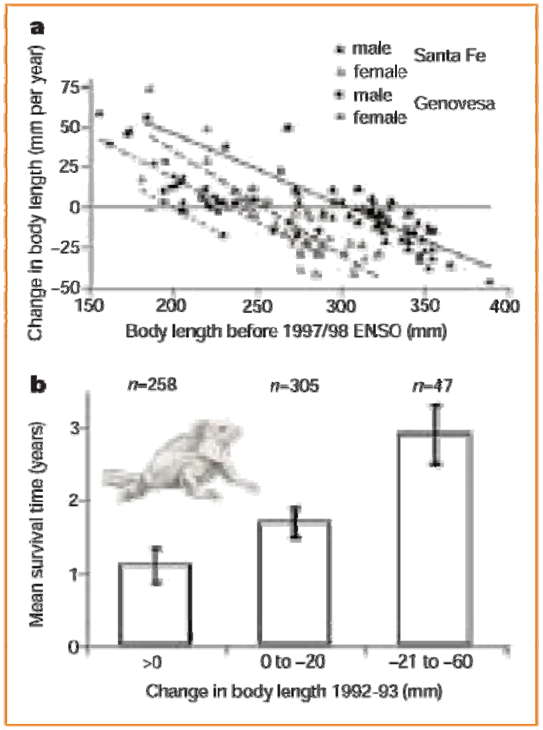
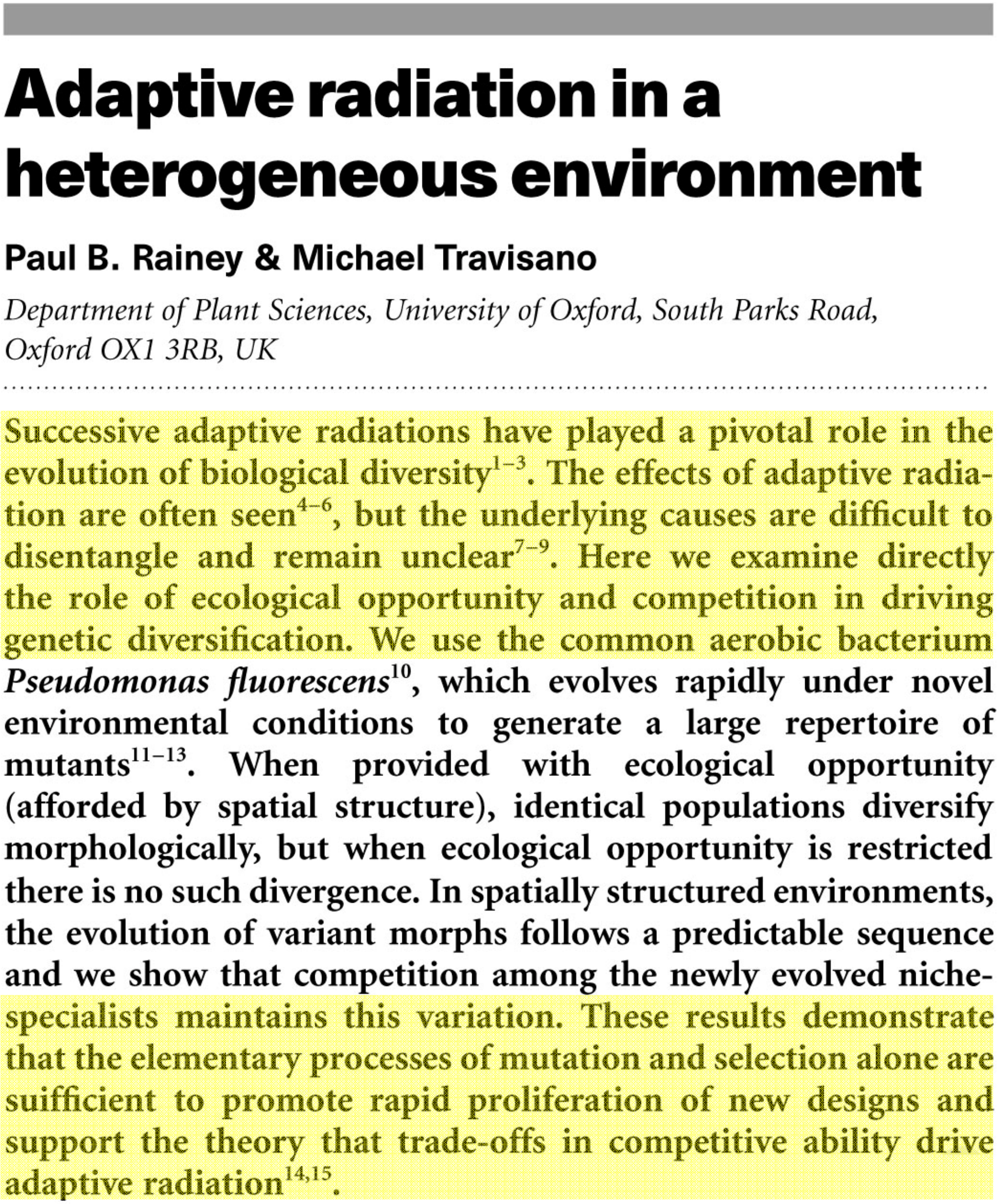


Figure 2 Change in body length as an adaptation to harsh conditions. **a,** Reduction in body length (snout-to-vent length, SVL) of

Nature. 2000. 403:37-38.



Adaptive radiation in a heterogeneous environment

Paul B. Rainey & Michael Travisano

Department of Plant Sciences, University of Oxford, South Parks Road,
Oxford OX1 3RB, UK

Successive adaptive radiations have played a pivotal role in the evolution of biological diversity[1–3]. The effects of adaptive radiation are often seen[4–6], but the underlying causes are difficult to disentangle and remain unclear[7–9]. Here we examine directly the role of ecological opportunity and competition in driving genetic diversification. We use the common aerobic bacterium *Pseudomonas fluorescens*[10], which evolves rapidly under novel environmental conditions to generate a large repertoire of mutants[11–13]. When provided with ecological opportunity (afforded by spatial structure), identical populations diversify morphologically, but when ecological opportunity is restricted there is no such divergence. In spatially structured environments, the evolution of variant morphs follows a predictable sequence and we show that competition among the newly evolved niche-specialists maintains this variation. These results demonstrate that the elementary processes of mutation and selection alone are suifficient to promote rapid proliferation of new designs and support the theory that trade-offs in competitive ability drive adaptive radiation[14,15].

Nature. 1998. 394:69-72.

Heterogeneous Environment: Media not shaken or stirred!

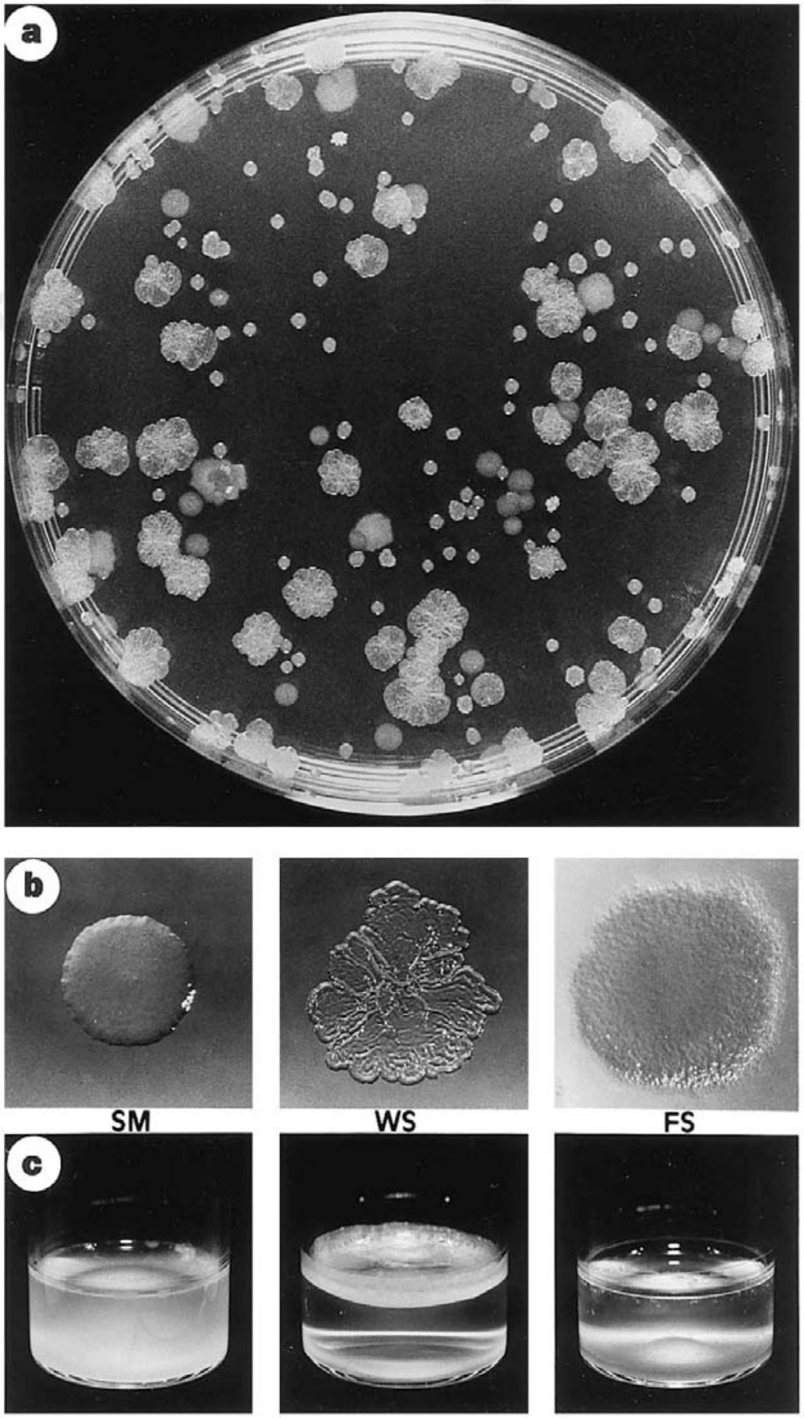


Figure 1 Phenotypic diversity and niche specificity among *P. fluorescens* SBW25 colonies evolved in a spatially heterogeneous environment. Populations were founded from single ancestral 'smooth' (SM morph) cells and propagated in 6-ml King's medium B contained in a 25-ml microcosm at 28 °C. Microcosms were incubated without shaking to produce a spatially heterogeneous environment. **a**, After 7 days, populations show substantial phenotypic diversity which is seen after plating. **b**, Most phenotypic variants can be assigned to one of three principle morph classes: (SM), wrinkly spreader (WS) and fuzzy spreader (FS). **c**, Evolved morphs showed marked niche preferences.

Every Adaptive Trait Evolves from Something Else

1. Example: Mammalian inner ear.
2. Example: IgG originates from transposon events.

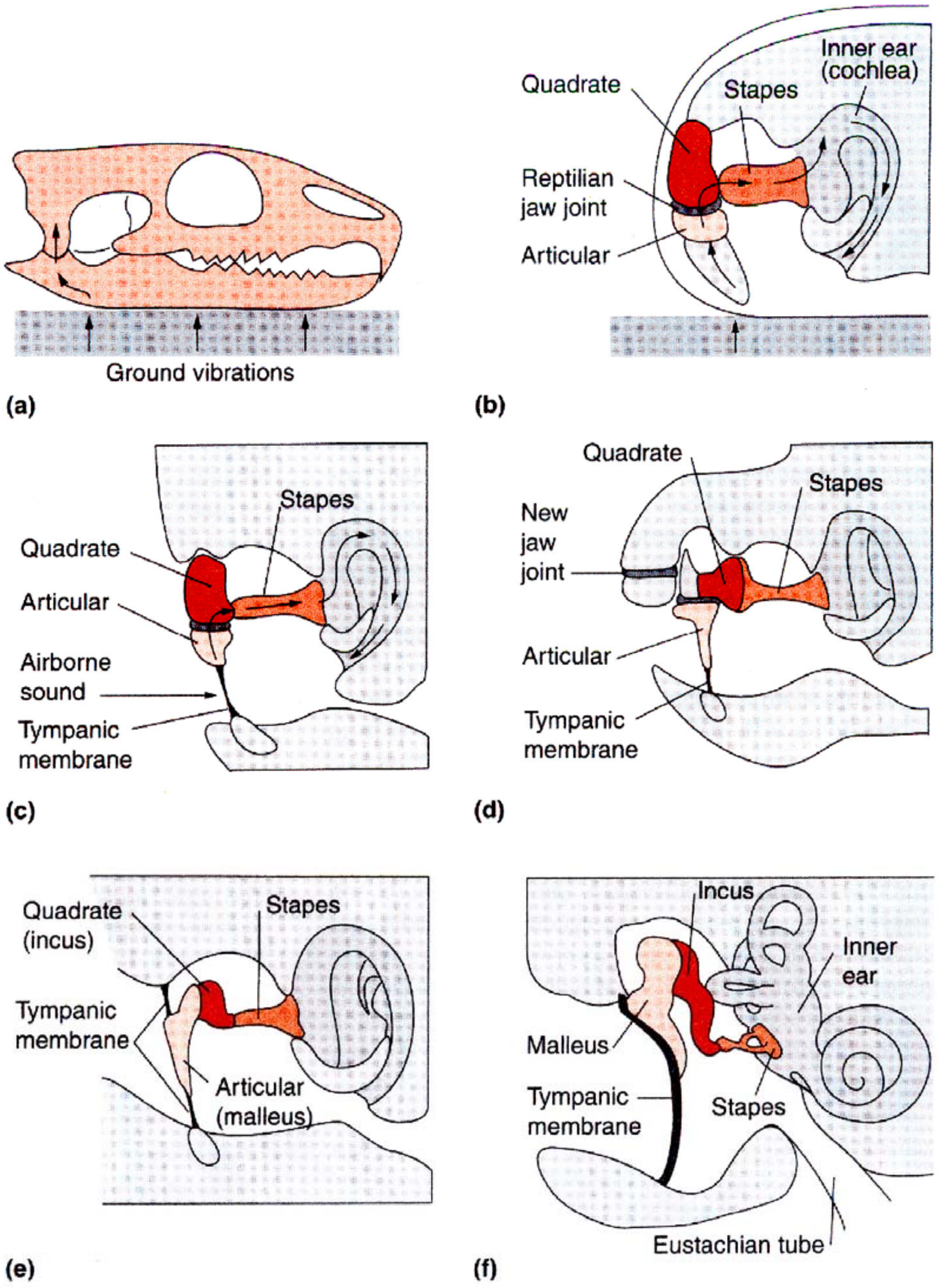
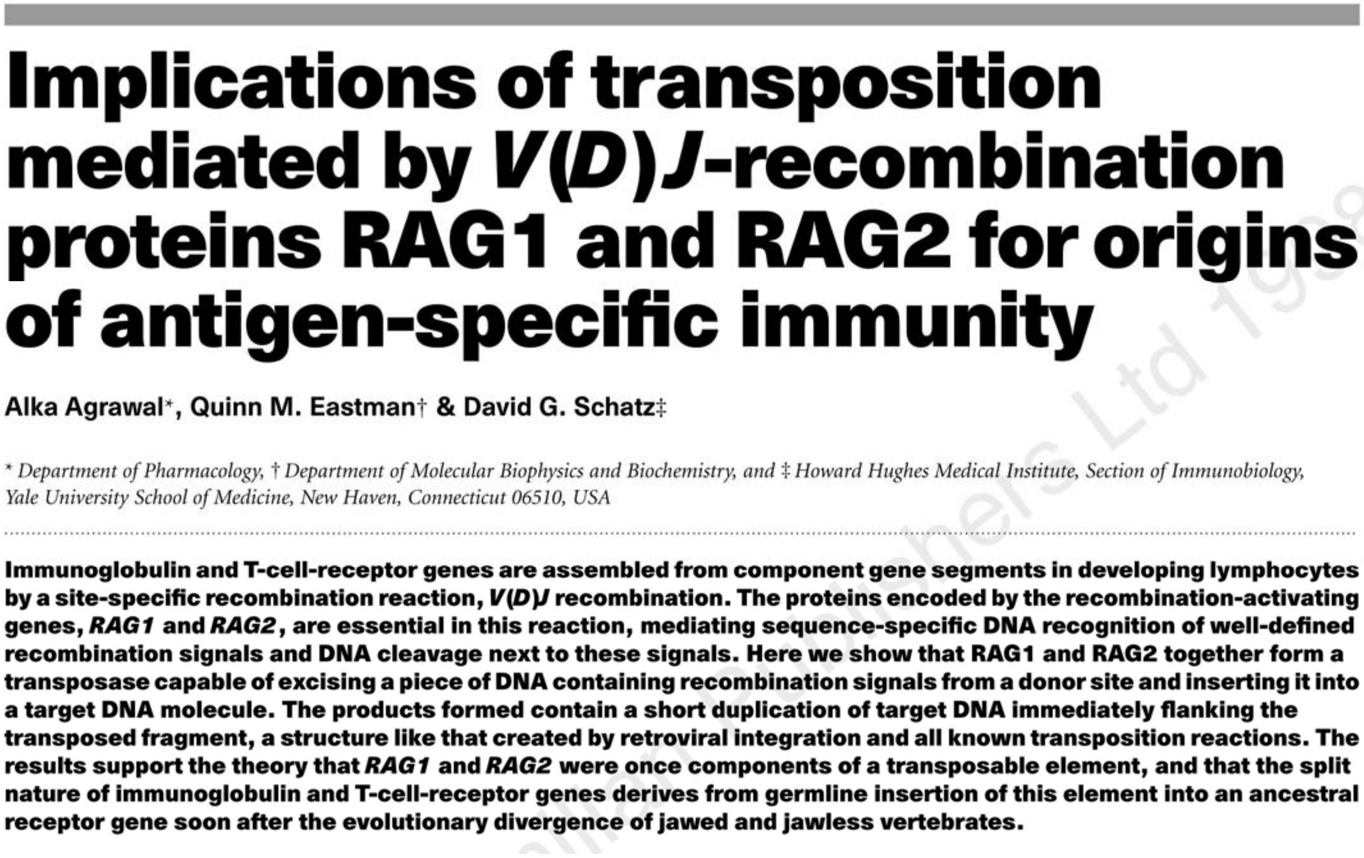


FIGURE 19-3 Proposed stages in the evolution of the ear apparatus, beginning with a land tetrapod that picks up ground vibrations through bone conduction (*a*, *b*). In reptilian synapsid lineages that lead to the mammal-like therapsids (*c*), a tympanic membrane picks up airborne sound and transmits it to the articular and quadrate bones of the jaw hinge and into the stapes that connects to the inner ear. As therapsid evolution proceeds, a new mammalian jaw joint evolves (squamosal-dentary) because of selection for improved molar chewing abilities. In *Morganucodon*, an early Triassic mammal (*d*), both jaw joints are present, although the size of the articular-quadrate- stapes bones have diminished. In late Triassic mammals (*e*), the squamosal-dentary joint has become the only jaw hinge, and the articular-quadrate-stapes bones are now entirely involved in hearing. The diagram in (*f*) presents a more anatomical view of the shape and positioning of these bones in the ear of a modern mammal. (*Adapted from Kermack and Mussett.*)



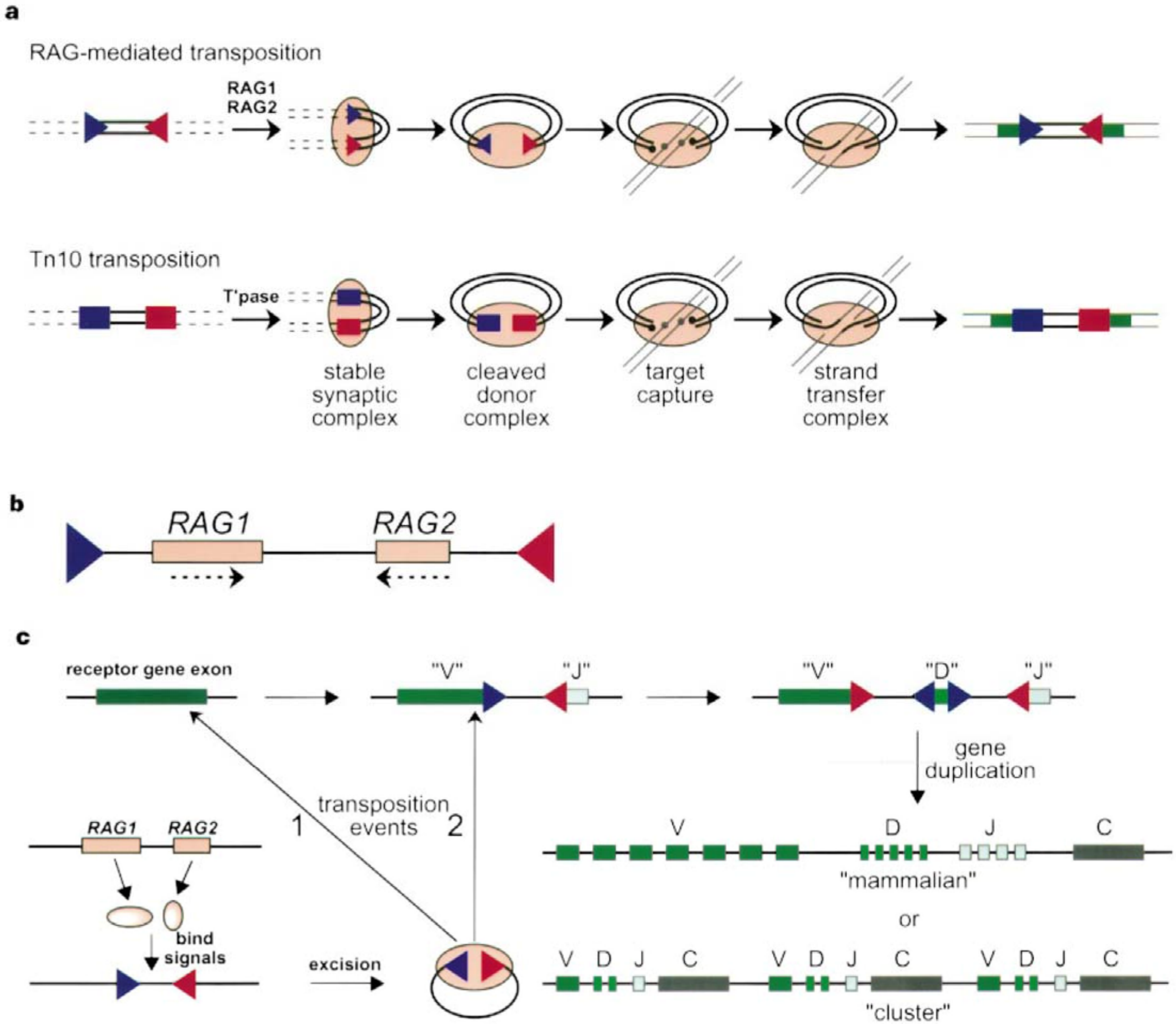
Implications of transposition mediated by *V*(*D*)*J*-recombination proteins RAG1 and RAG2 for origins of antigen-specific immunity

Alka Agrawal[*], **Quinn M. Eastman**[†] **& David G. Schatz**[‡]

[*] Department of Pharmacology, [†] Department of Molecular Biophysics and Biochemistry, and [‡] Howard Hughes Medical Institute, Section of Immunobiology, Yale University School of Medicine, New Haven, Connecticut 06510, USA

Immunoglobulin and T-cell-receptor genes are assembled from component gene segments in developing lymphocytes by a site-specific recombination reaction, *V*(*D*)*J* recombination. The proteins encoded by the recombination-activating genes, *RAG1* and *RAG2*, are essential in this reaction, mediating sequence-specific DNA recognition of well-defined recombination signals and DNA cleavage next to these signals. Here we show that RAG1 and RAG2 together form a transposase capable of excising a piece of DNA containing recombination signals from a donor site and inserting it into a target DNA molecule. The products formed contain a short duplication of target DNA immediately flanking the transposed fragment, a structure like that created by retroviral integration and all known transposition reactions. The results support the theory that *RAG1* and *RAG2* were once components of a transposable element, and that the split nature of immunoglobulin and T-cell-receptor genes derives from germline insertion of this element into an ancestral receptor gene soon after the evolutionary divergence of jawed and jawless vertebrates.

Nature. 1998. 394:744-751.


a
RAG-mediated transposition
RAG1
RAG2
Tn10 transposition
T'pase
stable synaptic complex
cleaved donor complex
target capture
strand transfer complex
b
RAG1
RAG2
c
receptor gene exon
"V"
"J"
"V"
"D"
"J"
gene duplication
RAG1
RAG2
transposition events
1
2
bind signals
excision
V
D
J
C
"mammalian"
or
V D J C
V D J C
V D J C
"cluster"