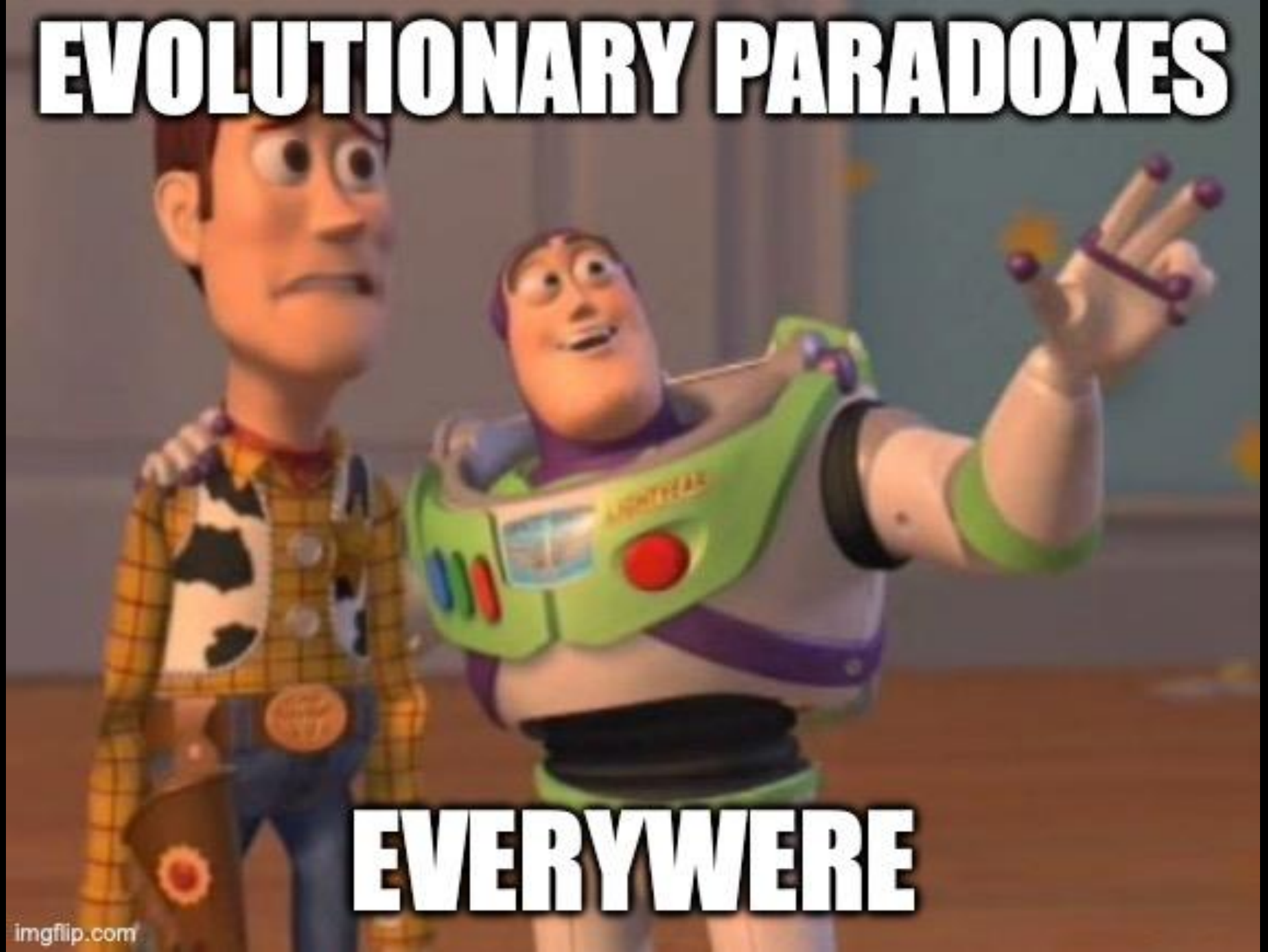
PARADOX OF PREDICTABILITY

EQGW 2025


EVOLUTIONARY PARADOXES
EVERYWERE
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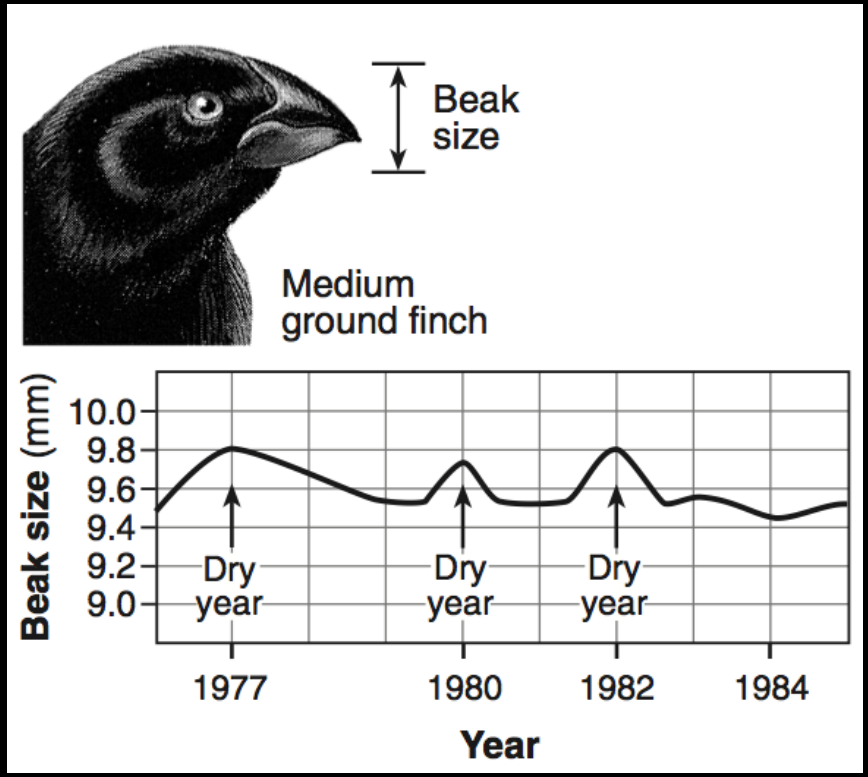
IS MACROEVOLUTION JUST MICROEVOLUTION+TIME?

MICROEVOLUTION

Within species

Small time scale (ys, gens)

Reduced magnitude

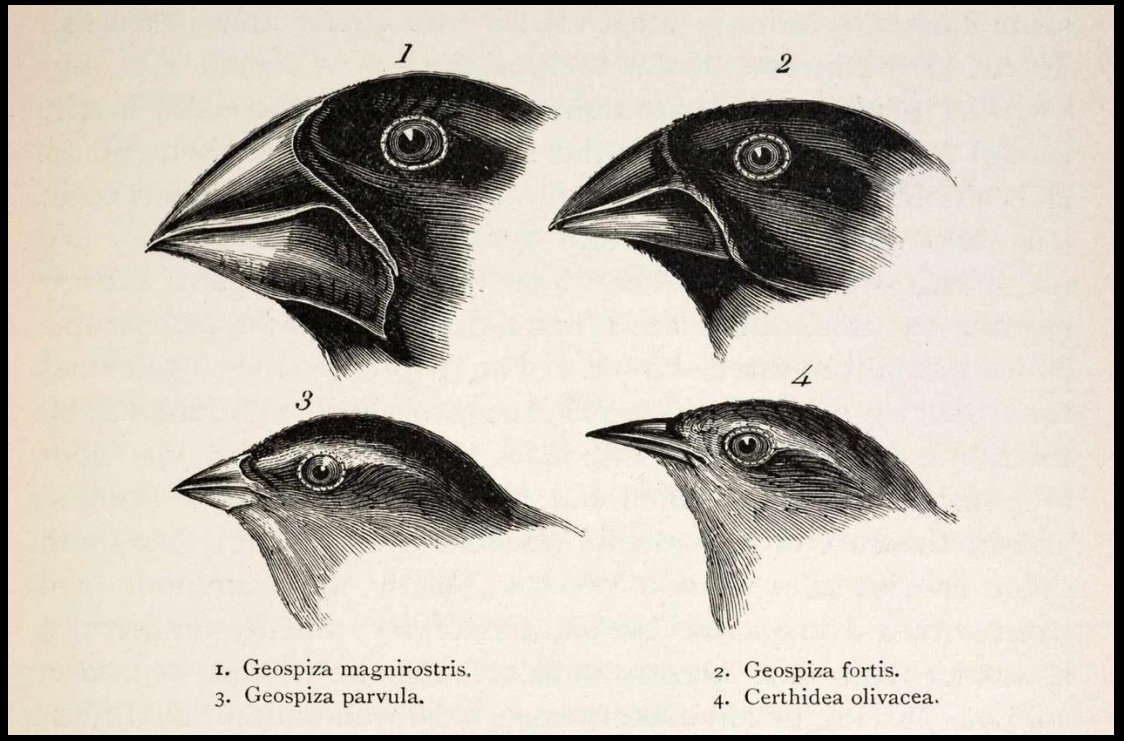


MACROEVOLUTION

Multiple species

Large time scale (mys, geological time)

Larger magnitude



MICROEVOLUTION

Within species

Small time scale (ys, gens)

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MACROEVOLUTION

Multiple species

Large time scale (mys, geological time)

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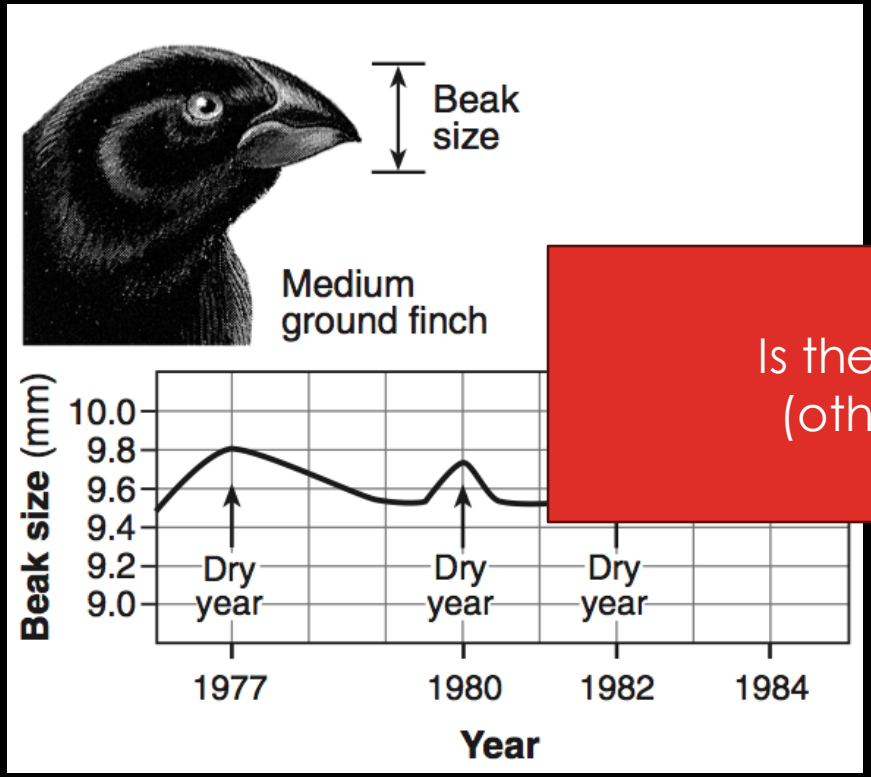
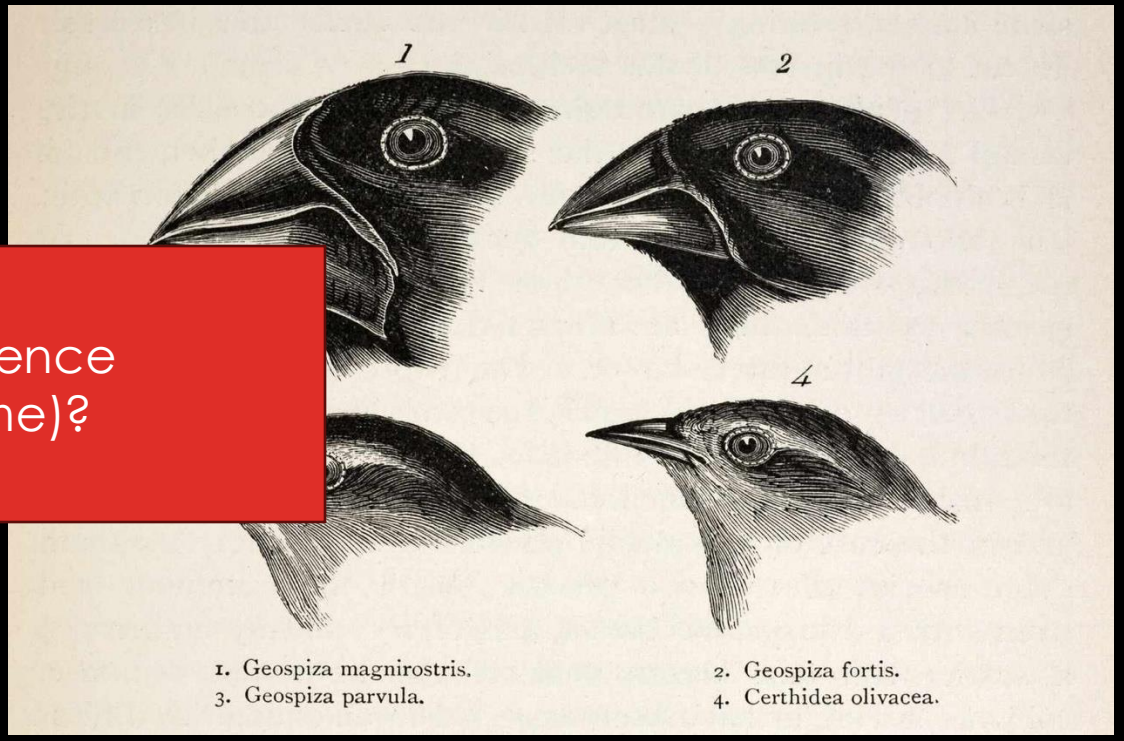
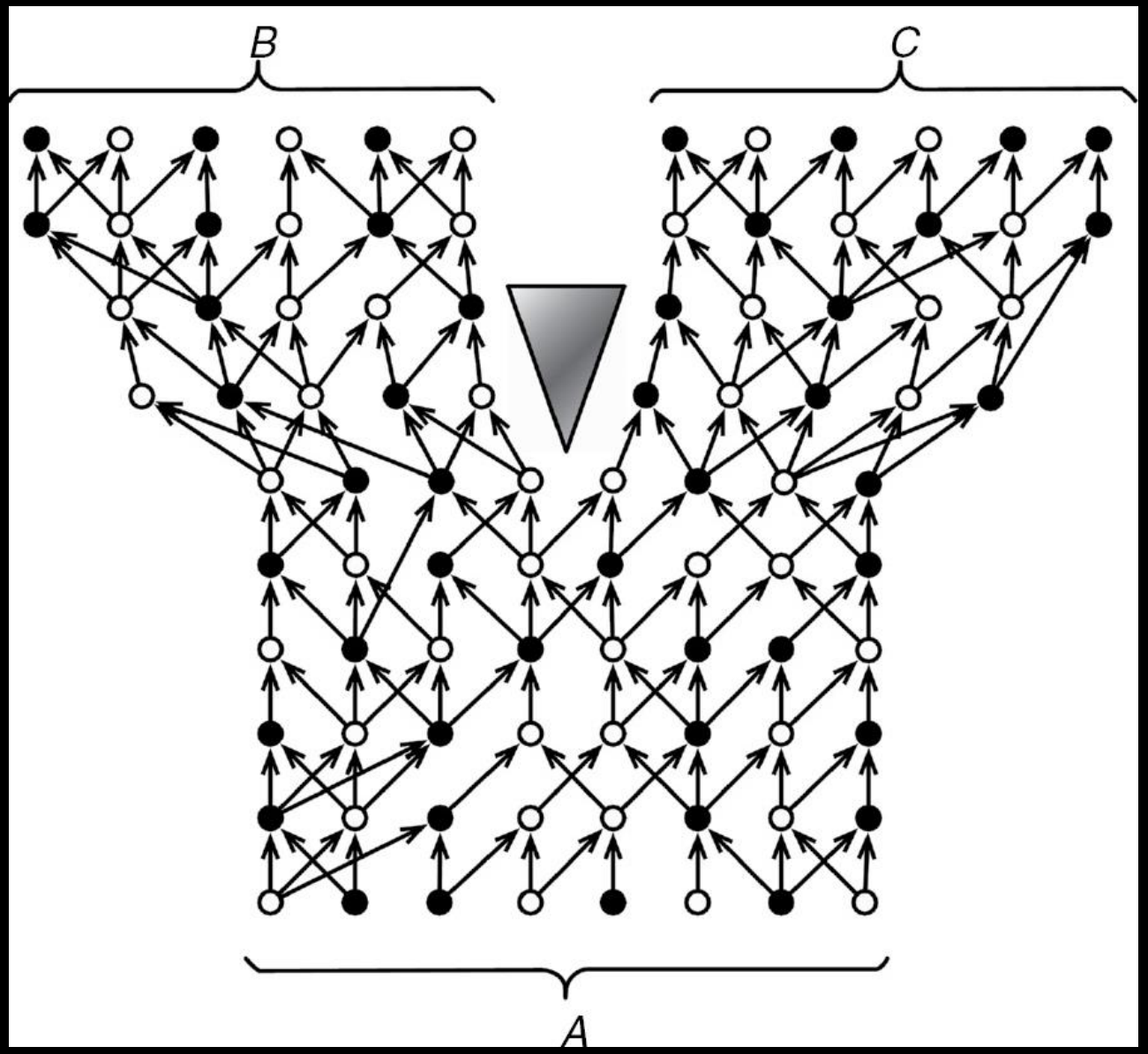


Is there a difference (other than time)?

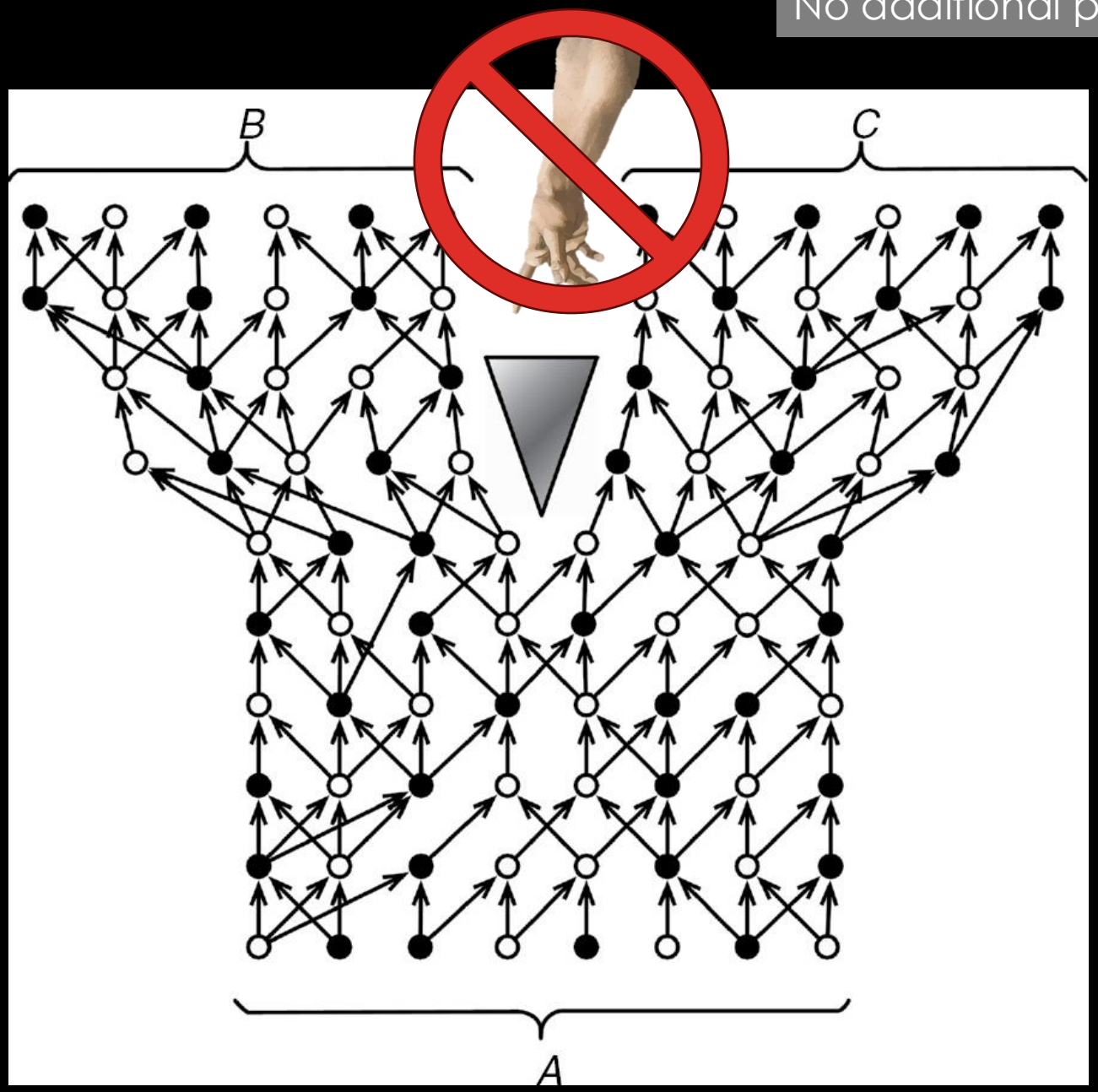




Population dynamics

Hennig, 1966

No additional processes required



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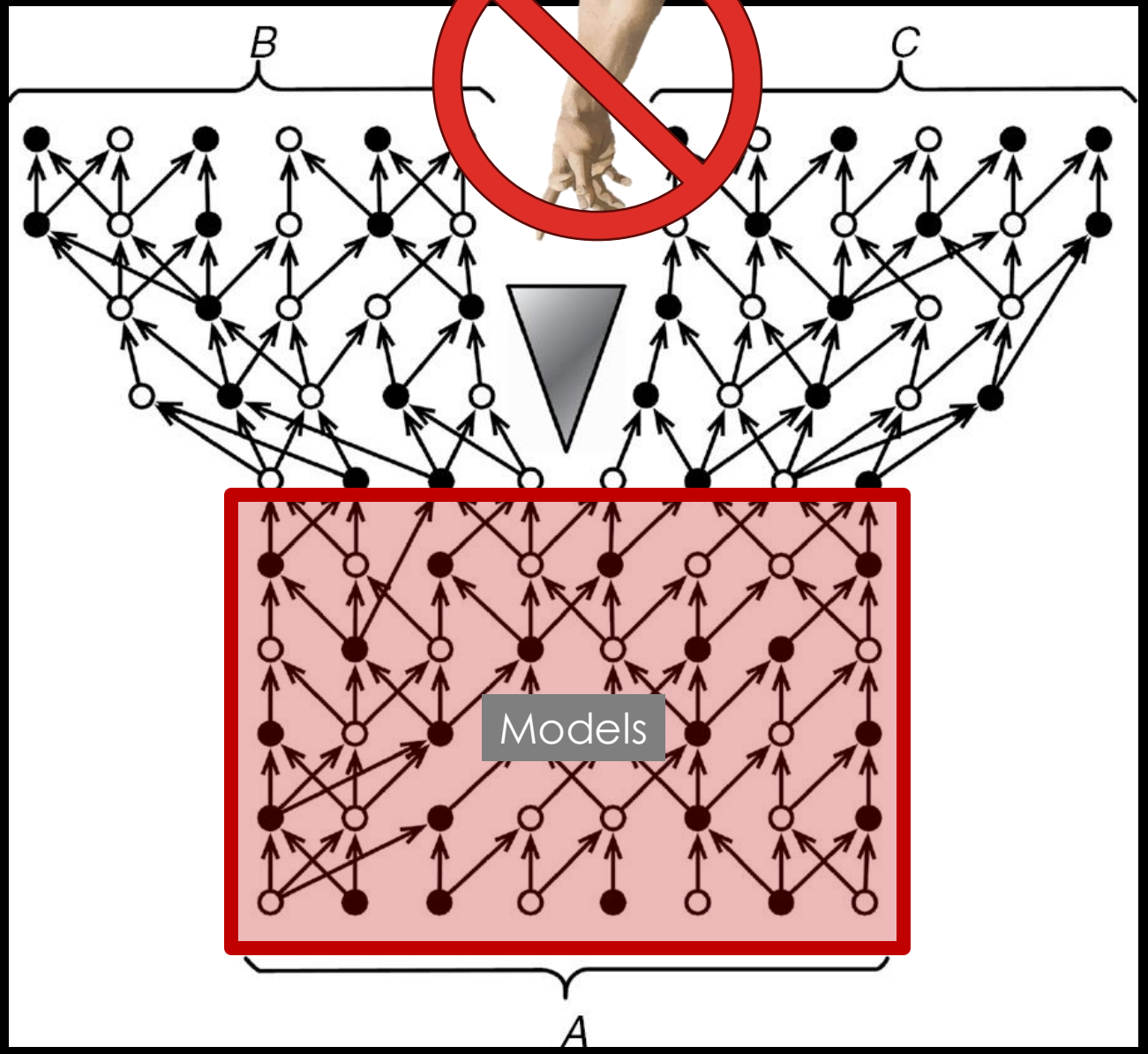
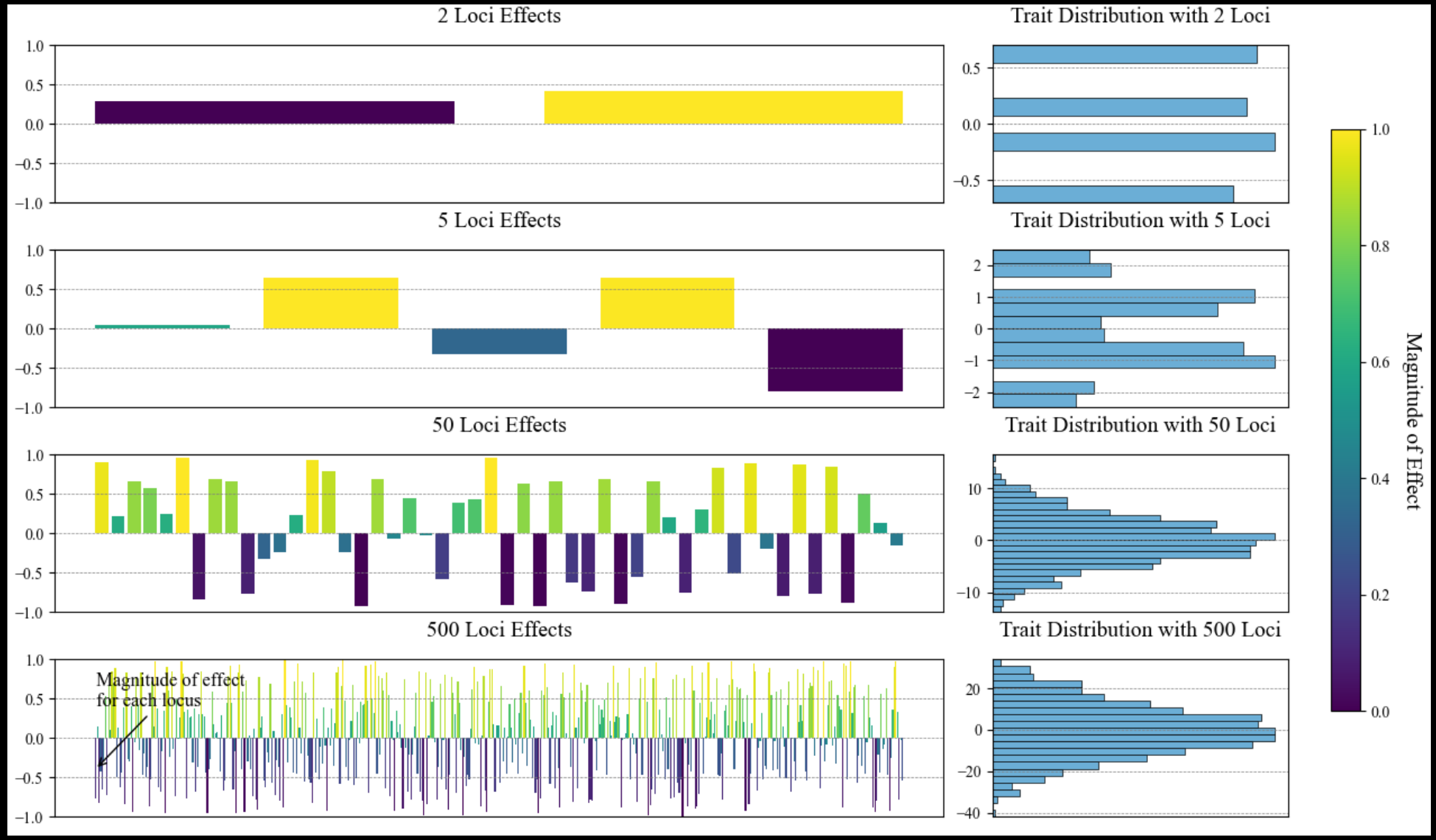


Population dynamics

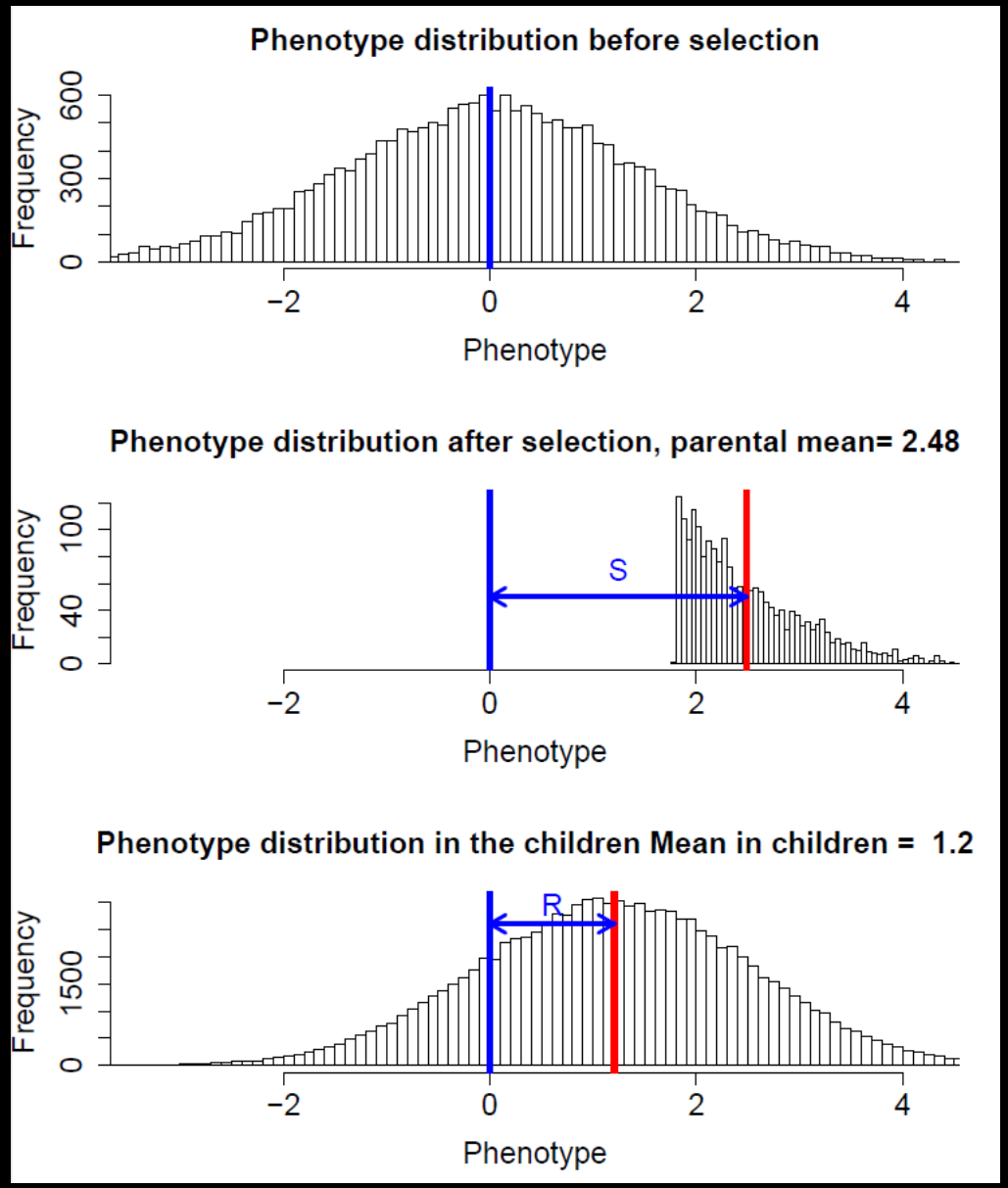
Hennig, 1966

Infinitesimal model of trait variation



Allows for the statistical treatment of the evolution of continuous traits

Models of trait evolution based on evolutionary processes

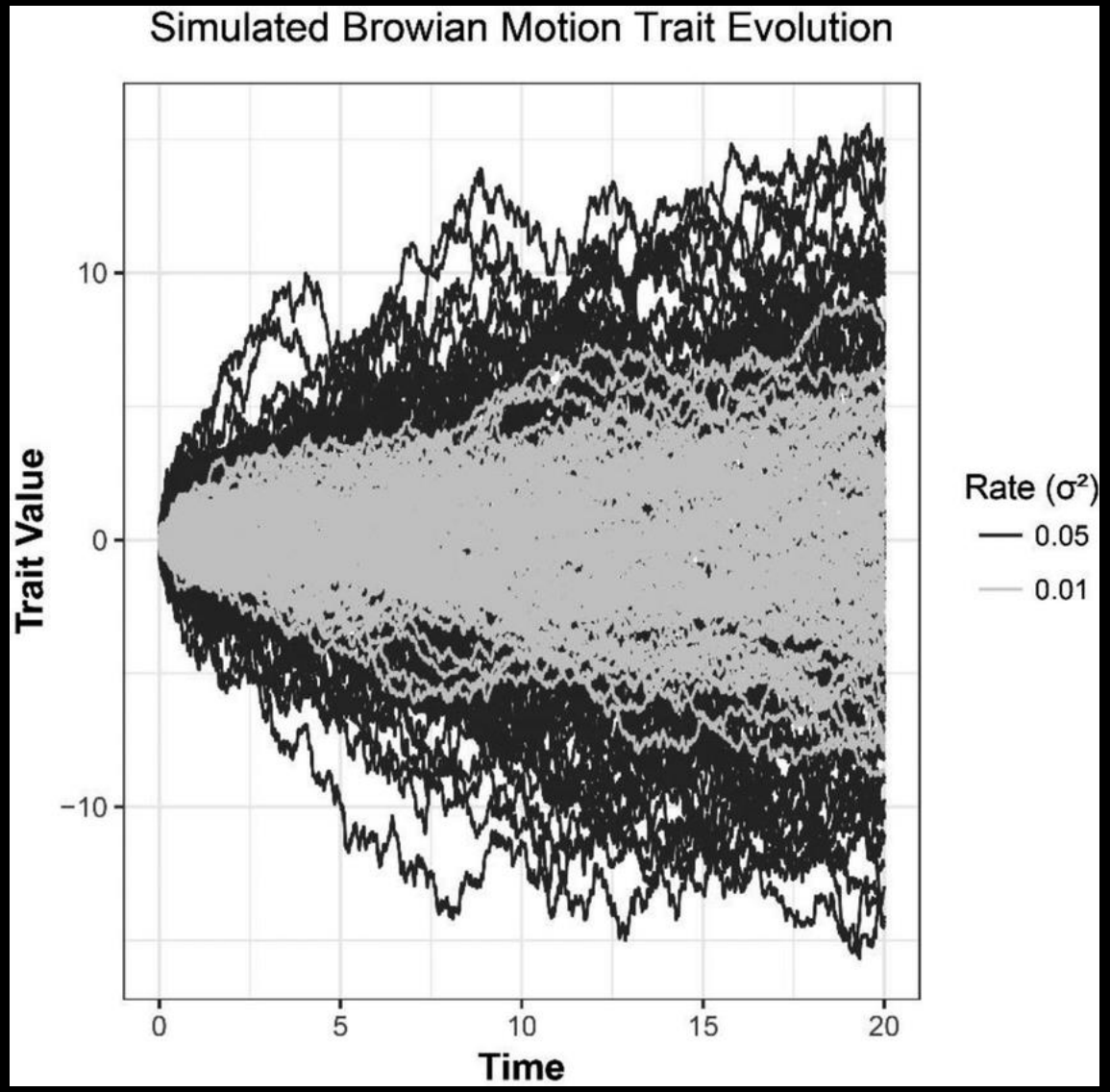


Directional selection

$$R = Sh^2$$

$$\Delta\bar{z}(t) = [\bar{z}_w(t) - \bar{z}(t)]\,\frac{\sigma_a^2}{\sigma_p^2}$$

Models of trait evolution based on evolutionary processes



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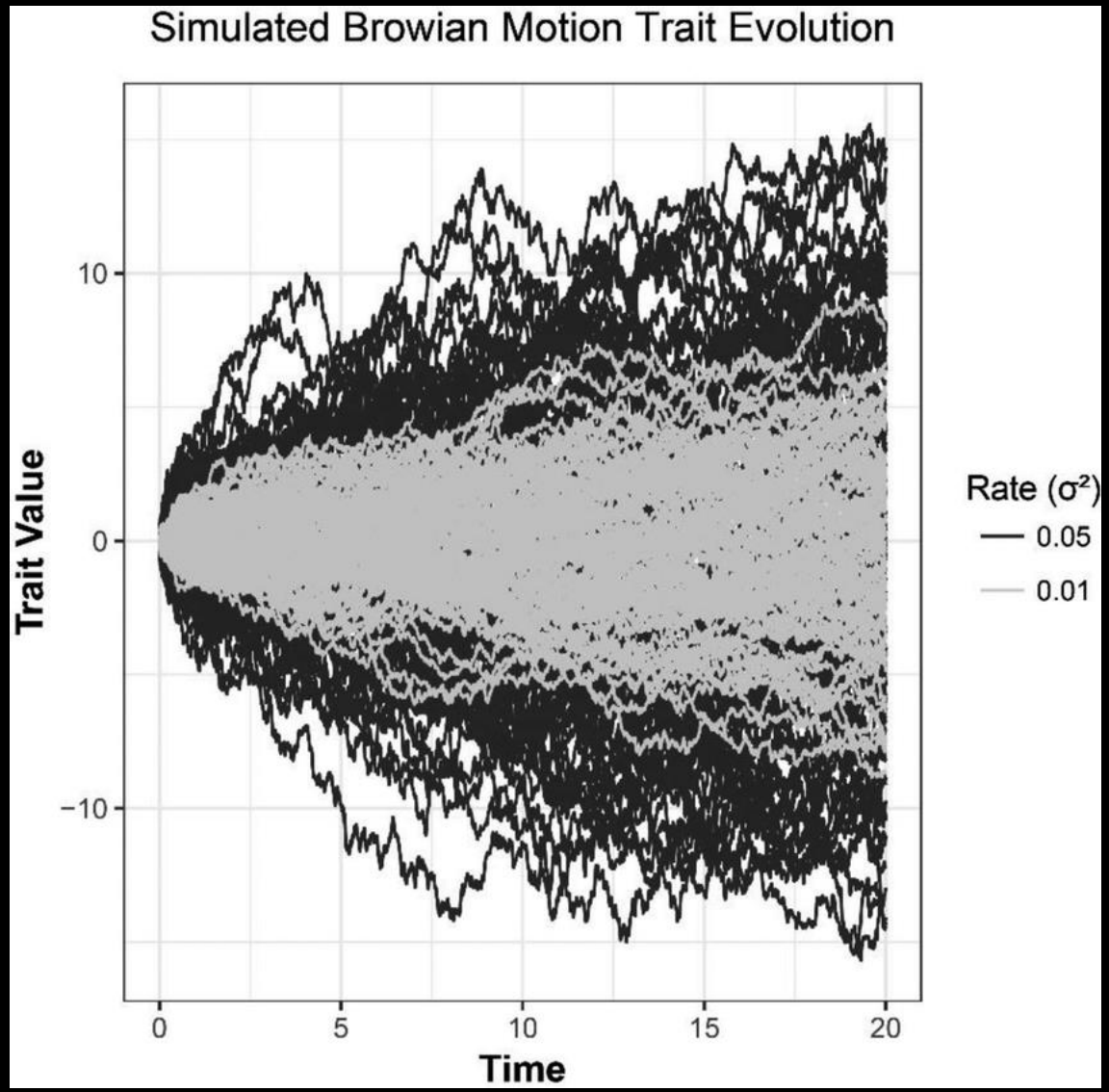
Genetic Drift

$$\sigma_b^2(t) = \sigma_a^2\,\frac{t}{N}$$

Models of trait evolution based on evolutionary processes



Directional selection

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Genetic Drift

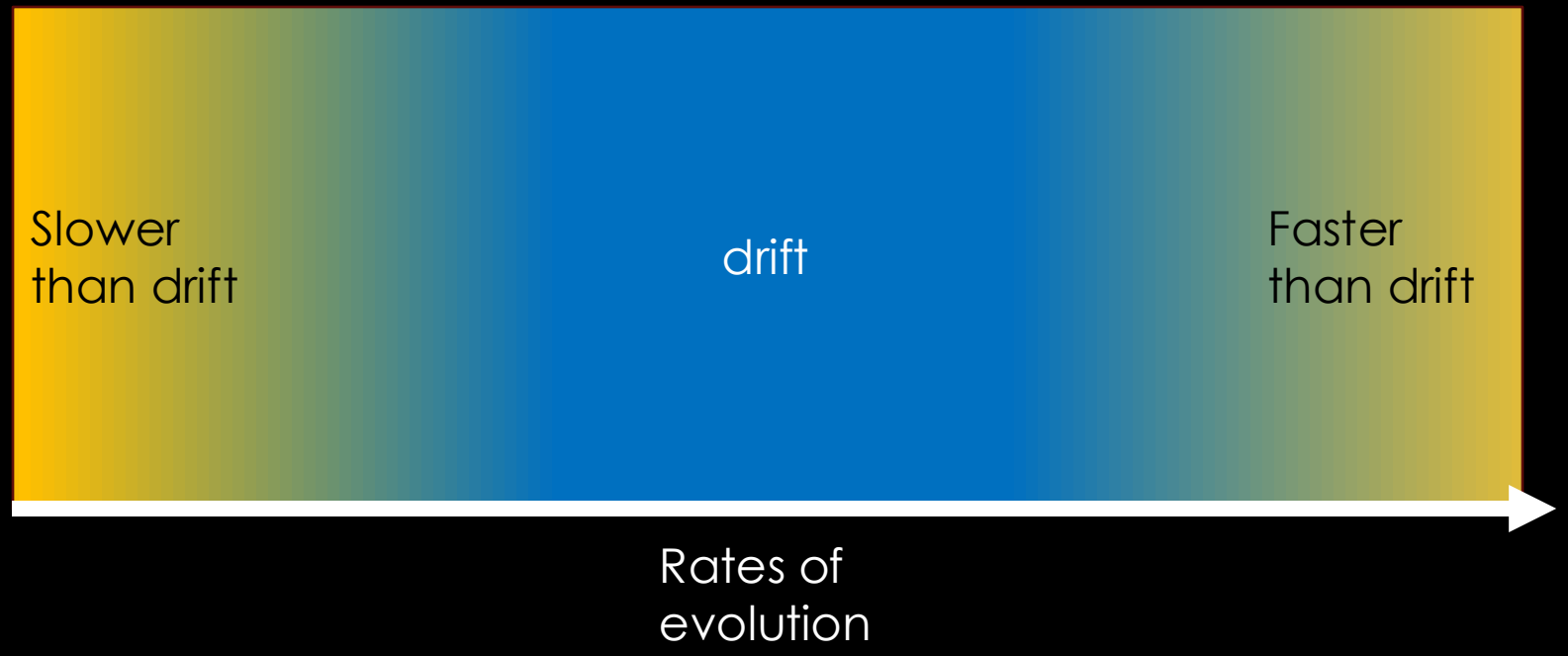
$$\sigma_b^2(t) = \sigma_a^2\,\frac{t}{N}$$

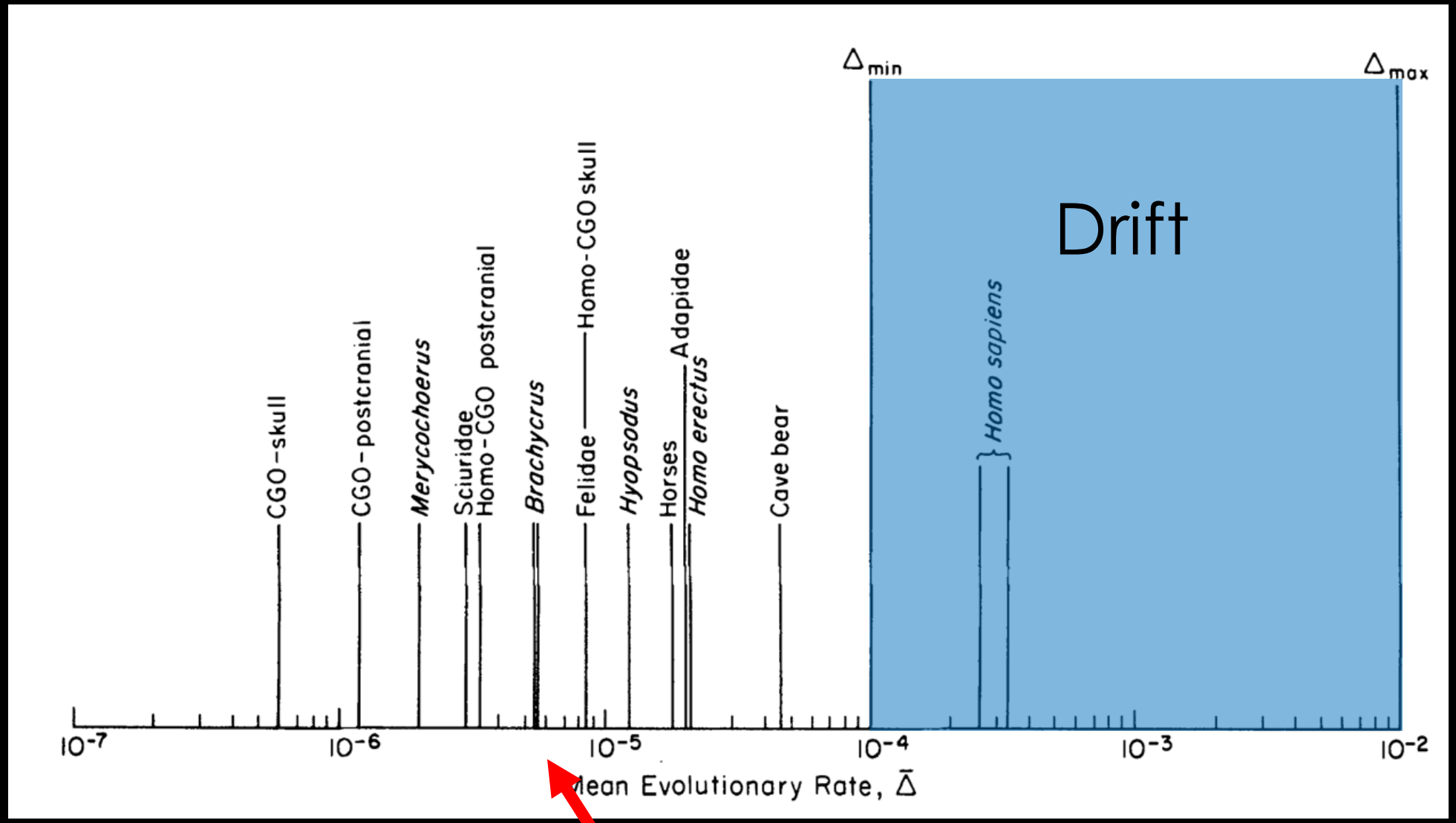
Null model

USING GENETIC DRIFT AS A NULL MODEL OF MACROEVOLUTION

Make assumptions of quantitative genetic traits
Generate null expectation under drift
Calculate empirical rates of evolution
Confront them

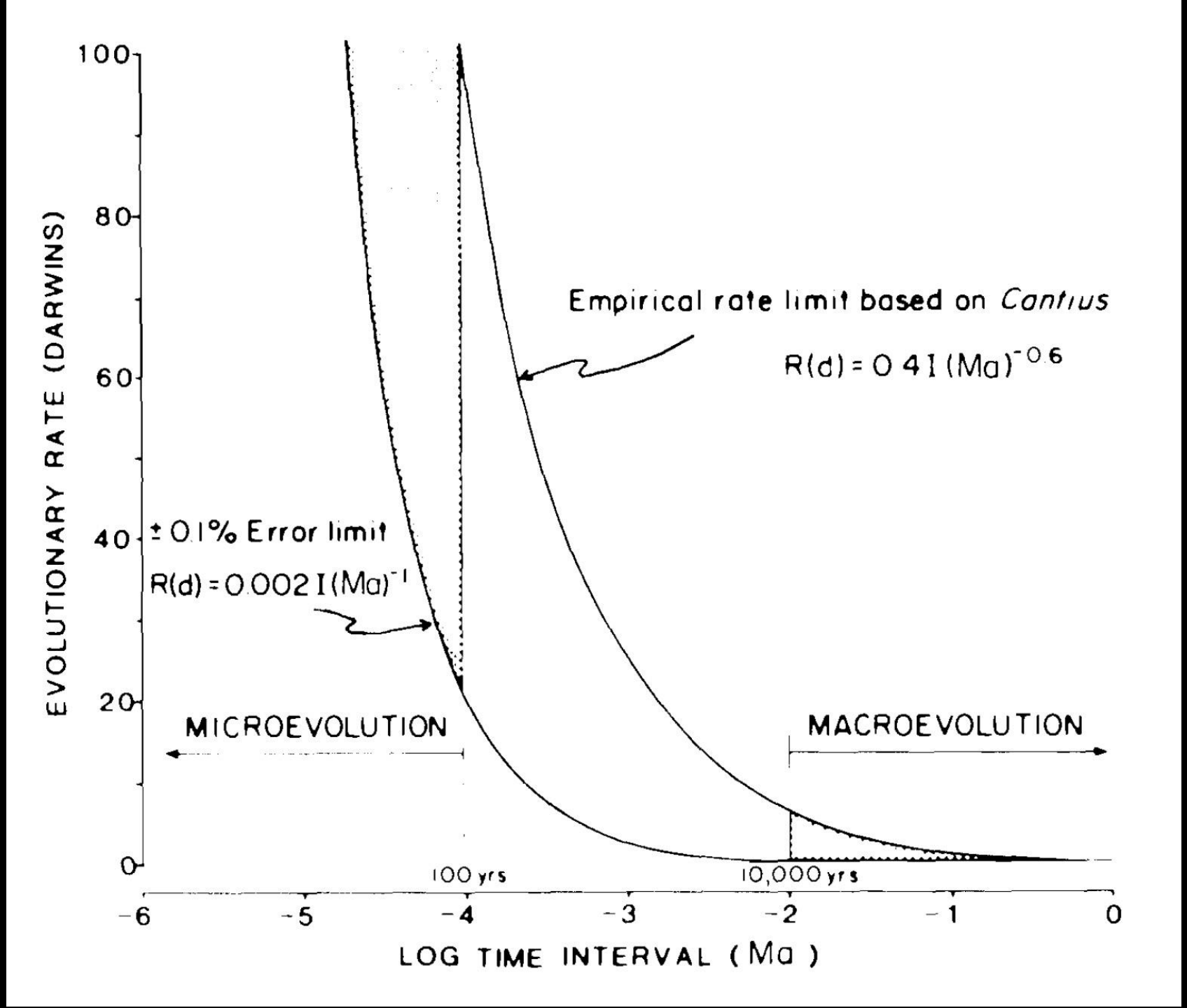
$$\sigma_b^2(t) = \sigma_a^2 \frac{t}{N}$$



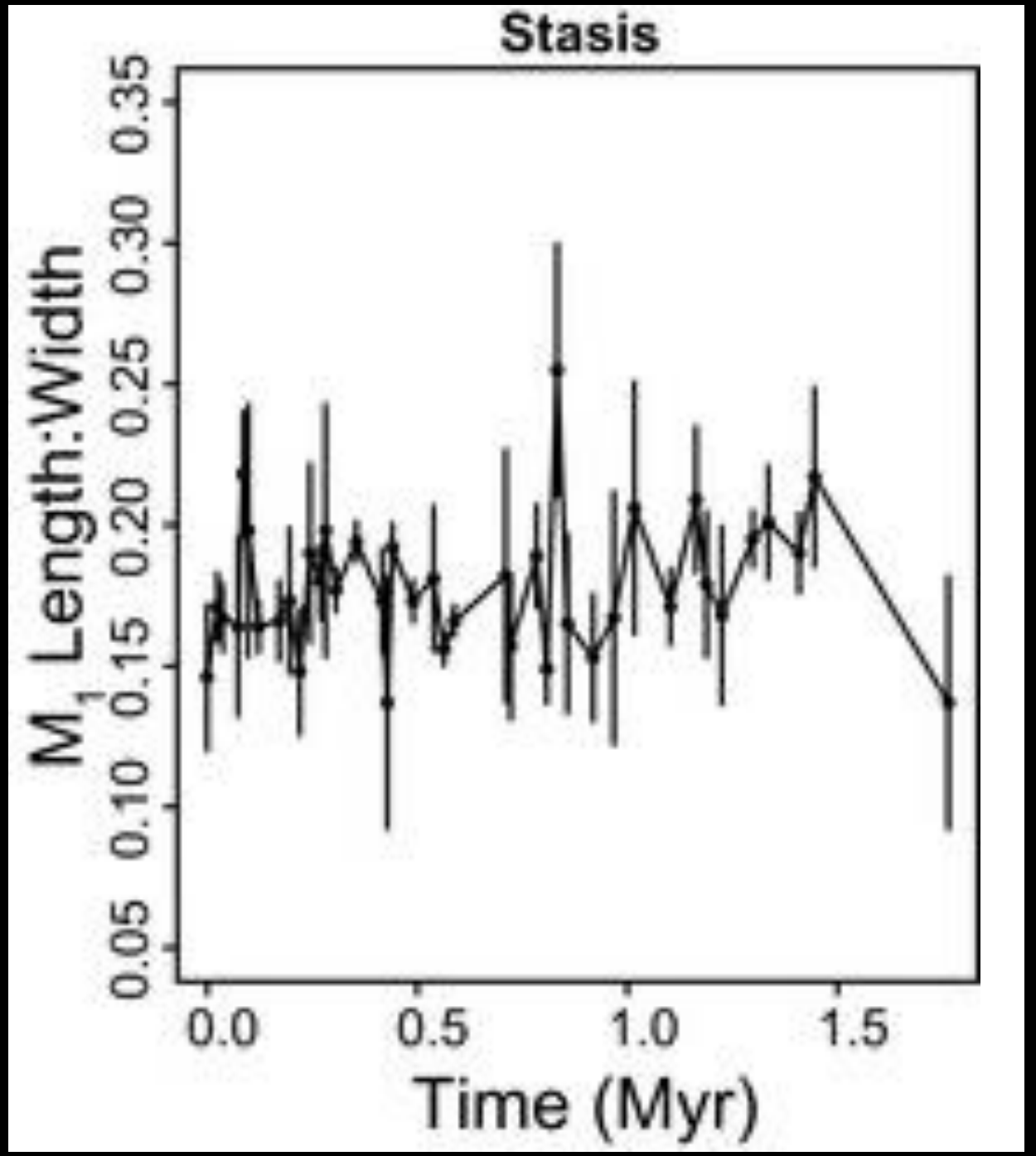


Consistent with …?

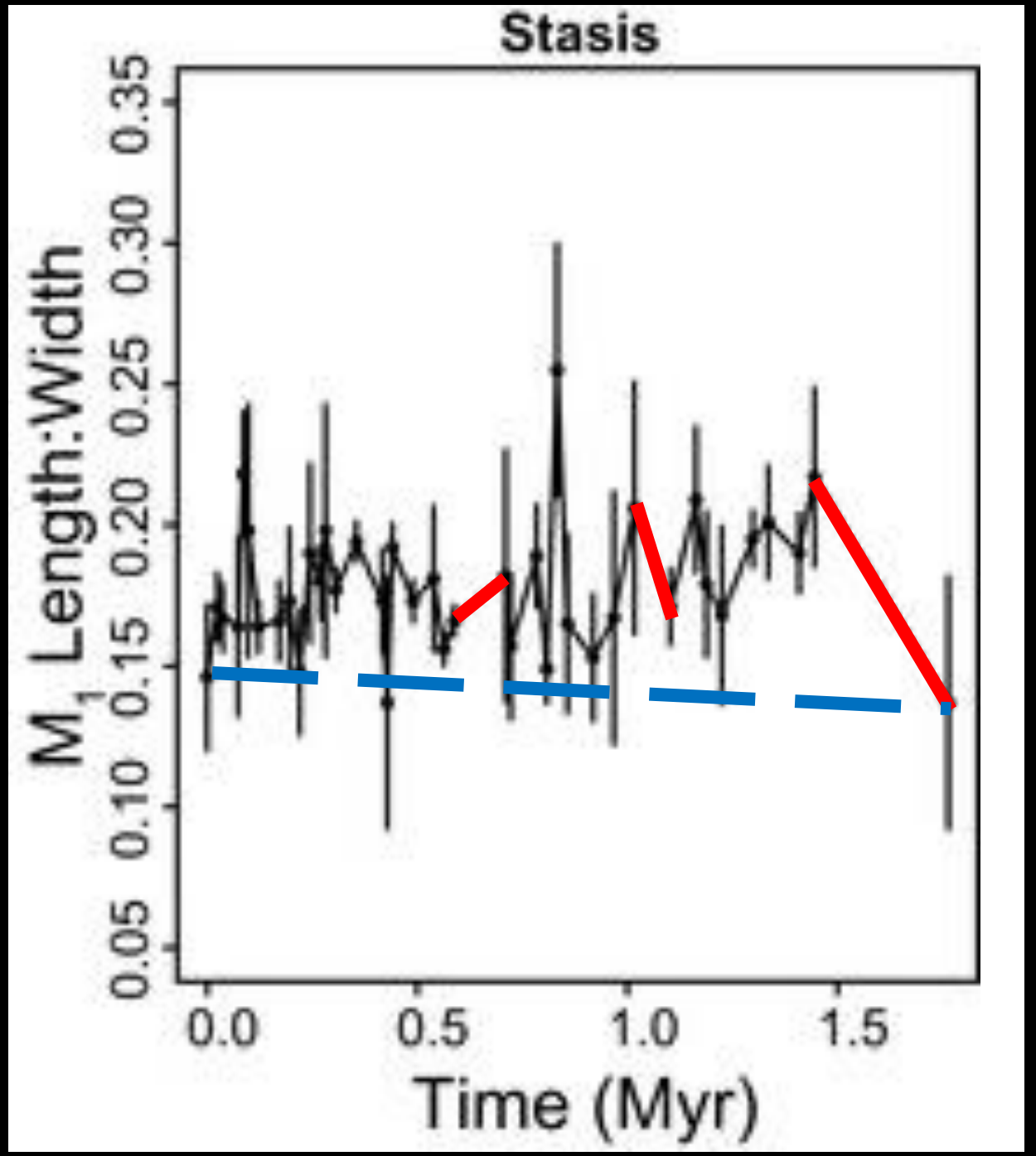
Lynch, 1990



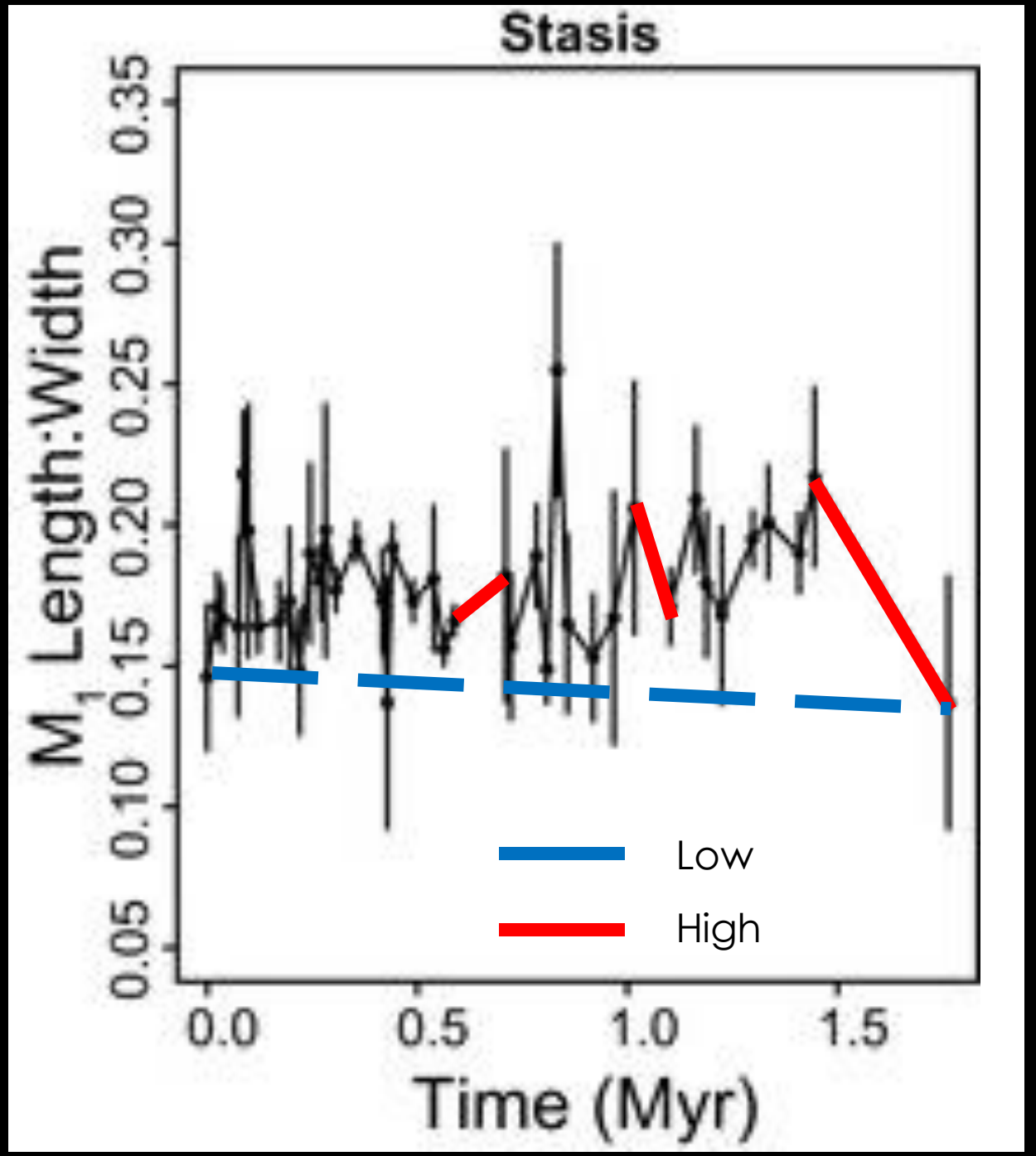
Gingerich, 1987



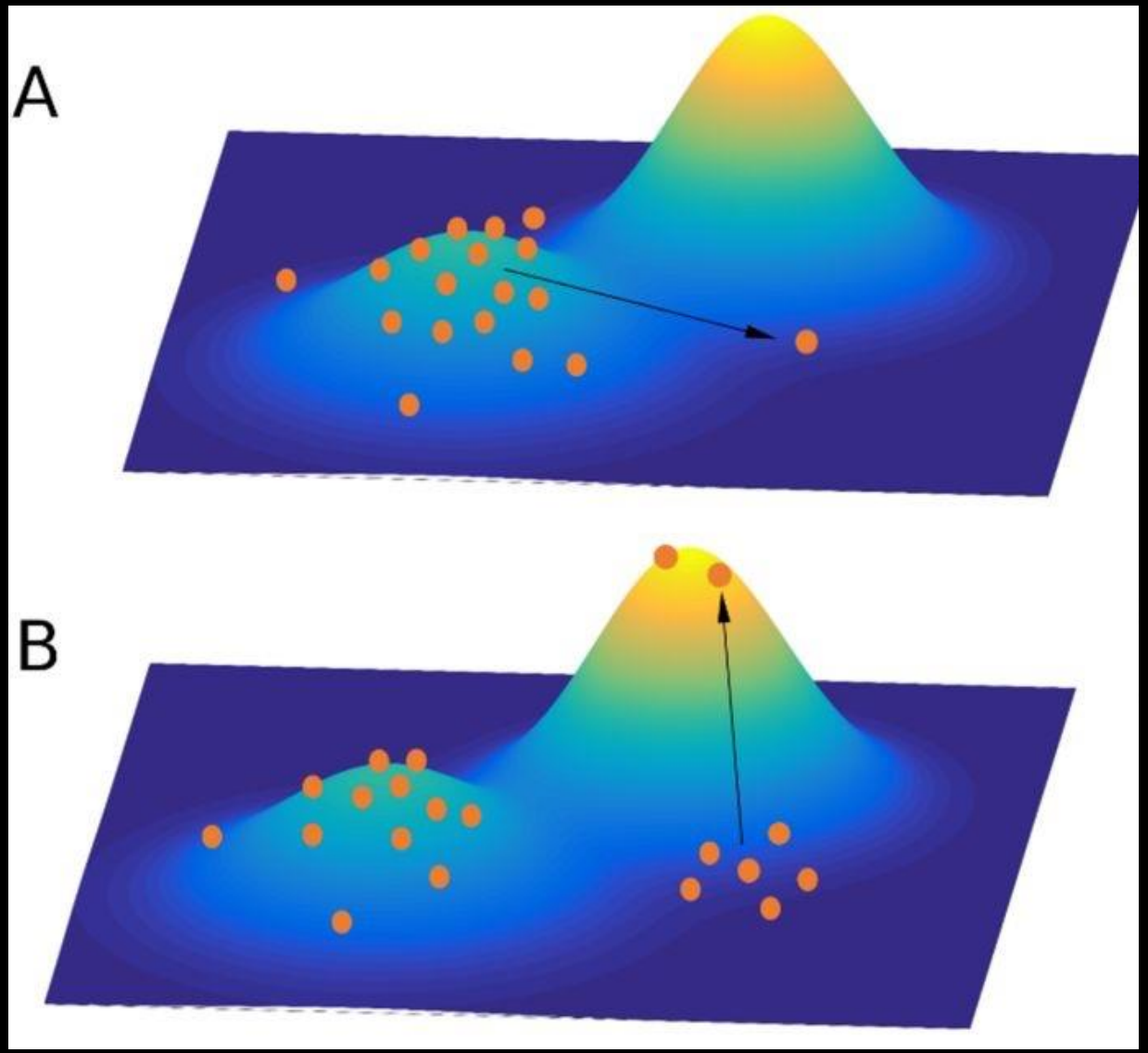
Clyde and Gingerich 1994



Clyde and Gingerich 1994



Clyde and Gingerich 1994



Climbing new peaks is very fast (given the availability of additive genetic variance), **so large scale macroevolutionary dynamics are the result of peak dynamics**

IS MACROEVOLUTION JUST MICROEVOLUTION+TIME?

YES.

IS MACROEVOLUTION JUST MICROEVOLUTION+TIME?

YES. Well, sort of.

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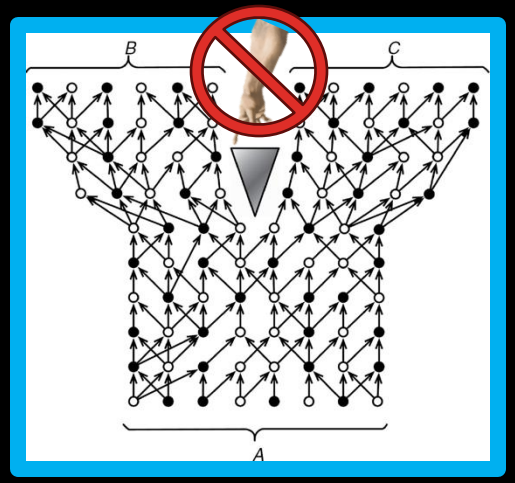

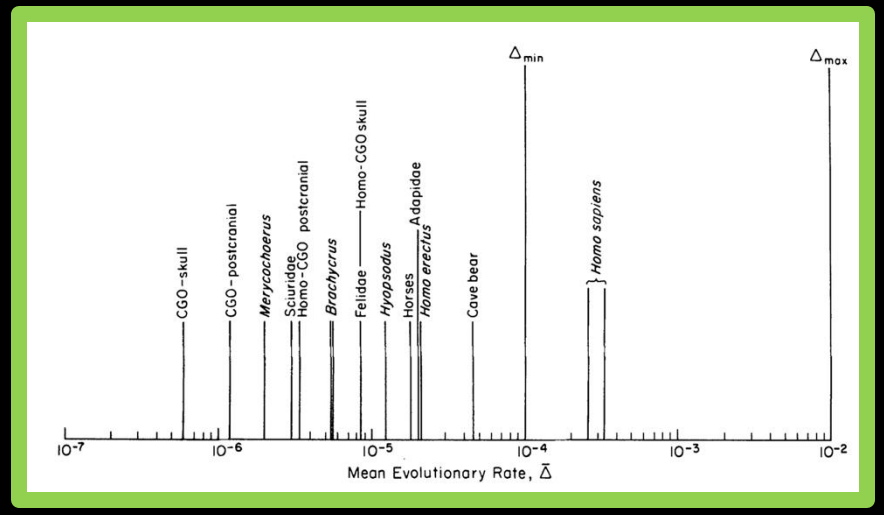


MICRO-TO-MACRO
RESEARCHER
VOID
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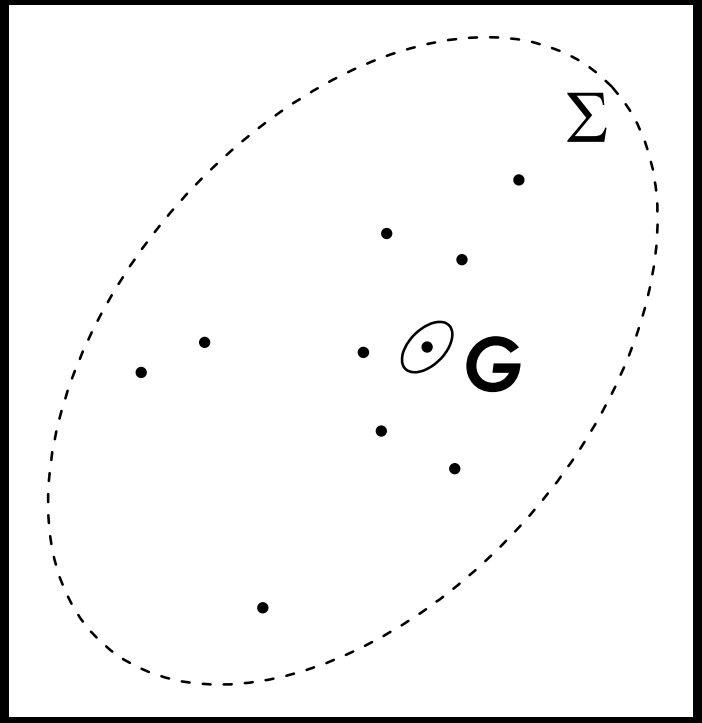
GENETIC DRIFT

Univariate case - rate of evolution is a function of additive genetic variance and a constant

$$\sigma_b^2(t) = \sigma_a^2 \frac{t}{N}$$

Univariate

Multivariate case- rates of evolution are a function of additive genetic variance for each trait and a constant (t/Ne)



$$\Sigma(t) = \mathrm{G} \frac{t}{N}$$

Multivariate

Divergence should be proportional to the amount of intraspecific variation

Kluge & Kerfoot (1976)

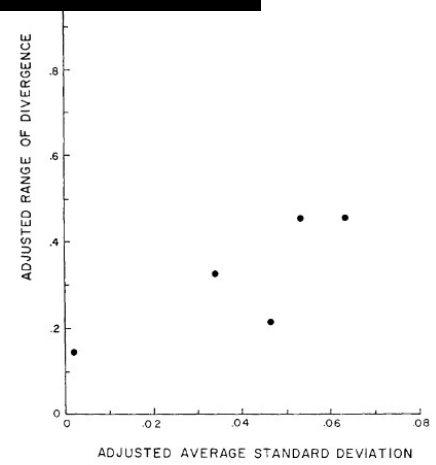


FIG. 3.—Bivariate plot of RD_A against $\bar{s}_A$ in *Catostomus*

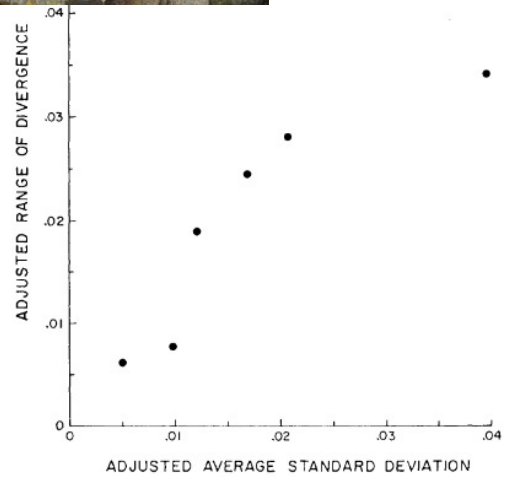
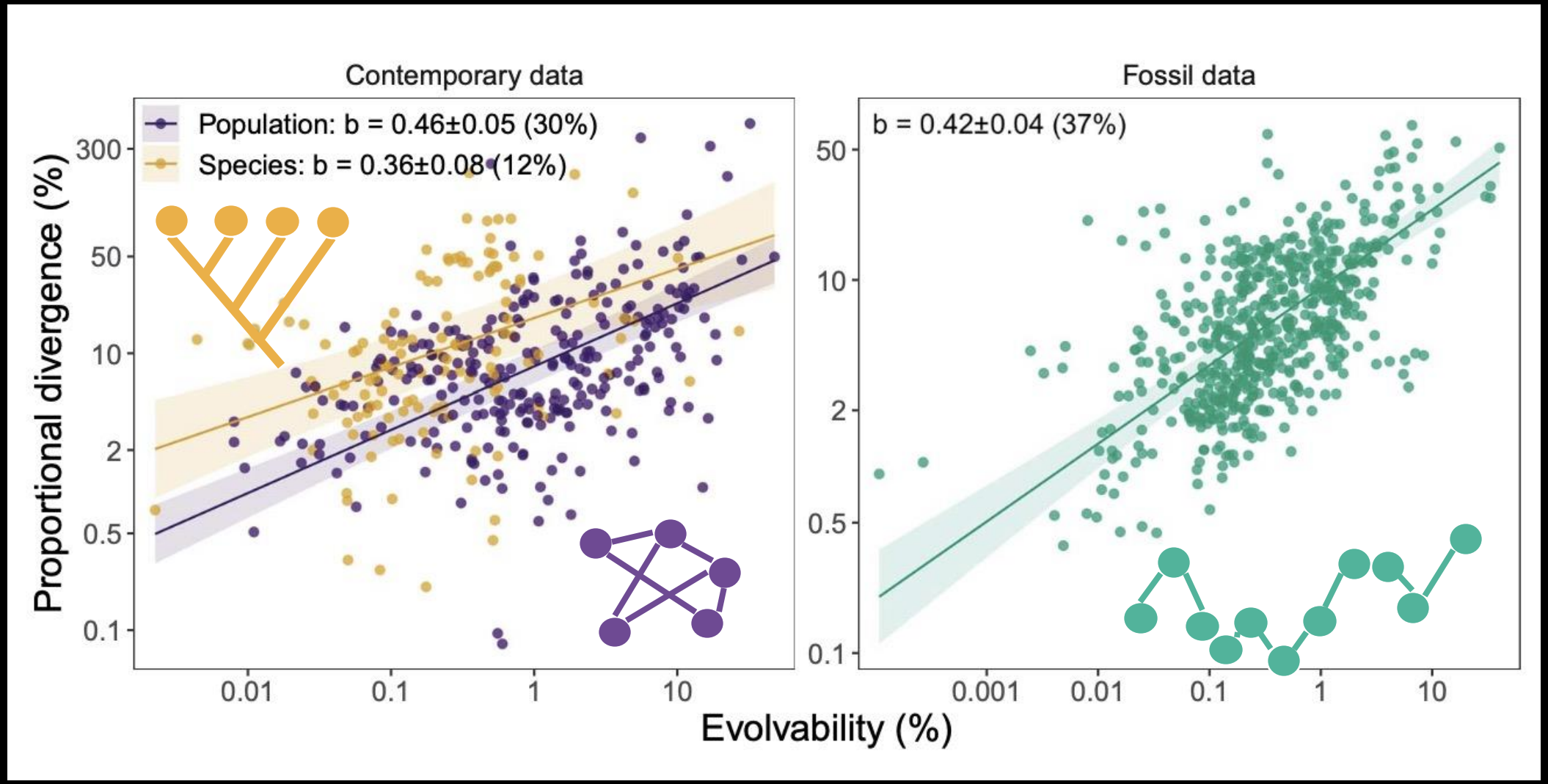


FIG. 4.—Bivariate plot of RD_A against $\bar{s}_A$ in *Notropis*

FIG. 5.—Bivariate plot of RD_A against $\bar{s}_A$ in *Eumeces*

FIG. 6.—Bivariate plot of RD_A against $\bar{s}_A$ in *Uta*[2]

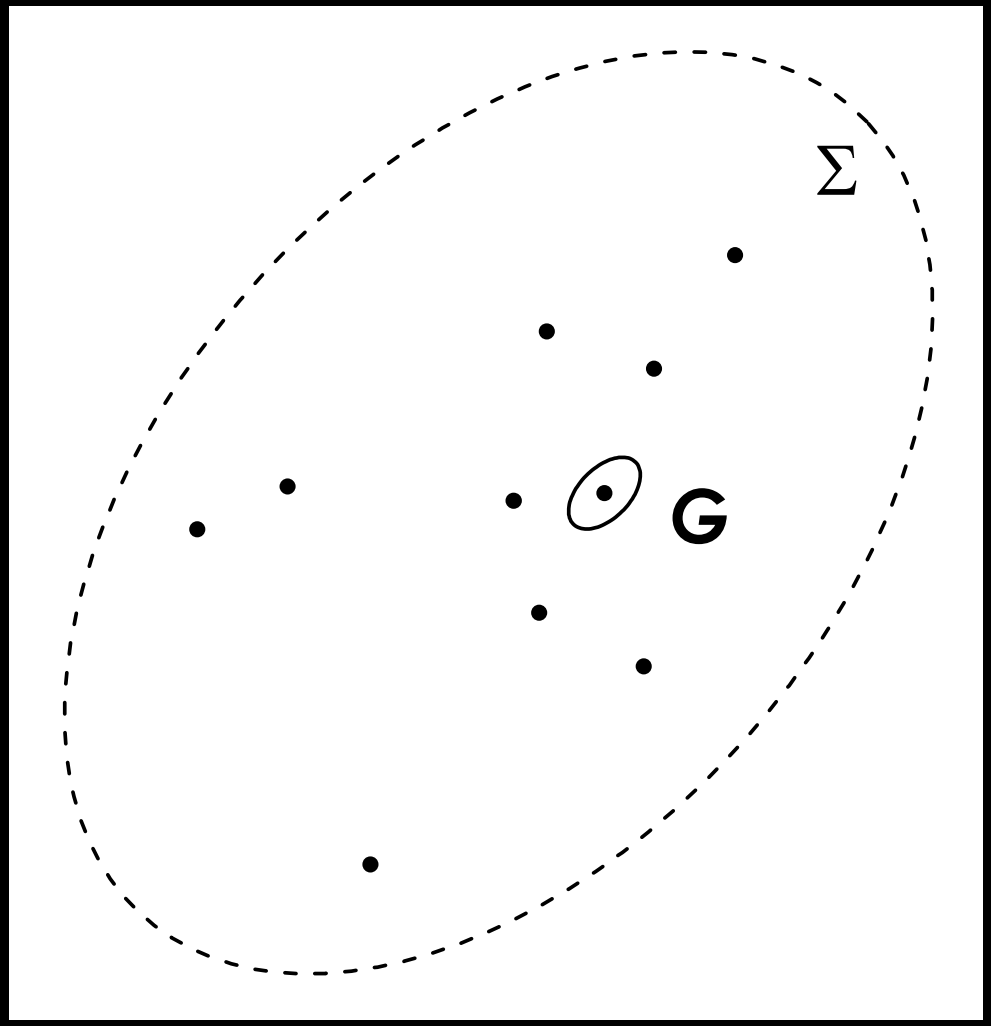
FIG. 9.—Bivariate plot of RD_A against $\bar{s}_A$ in *Passer*



But why?

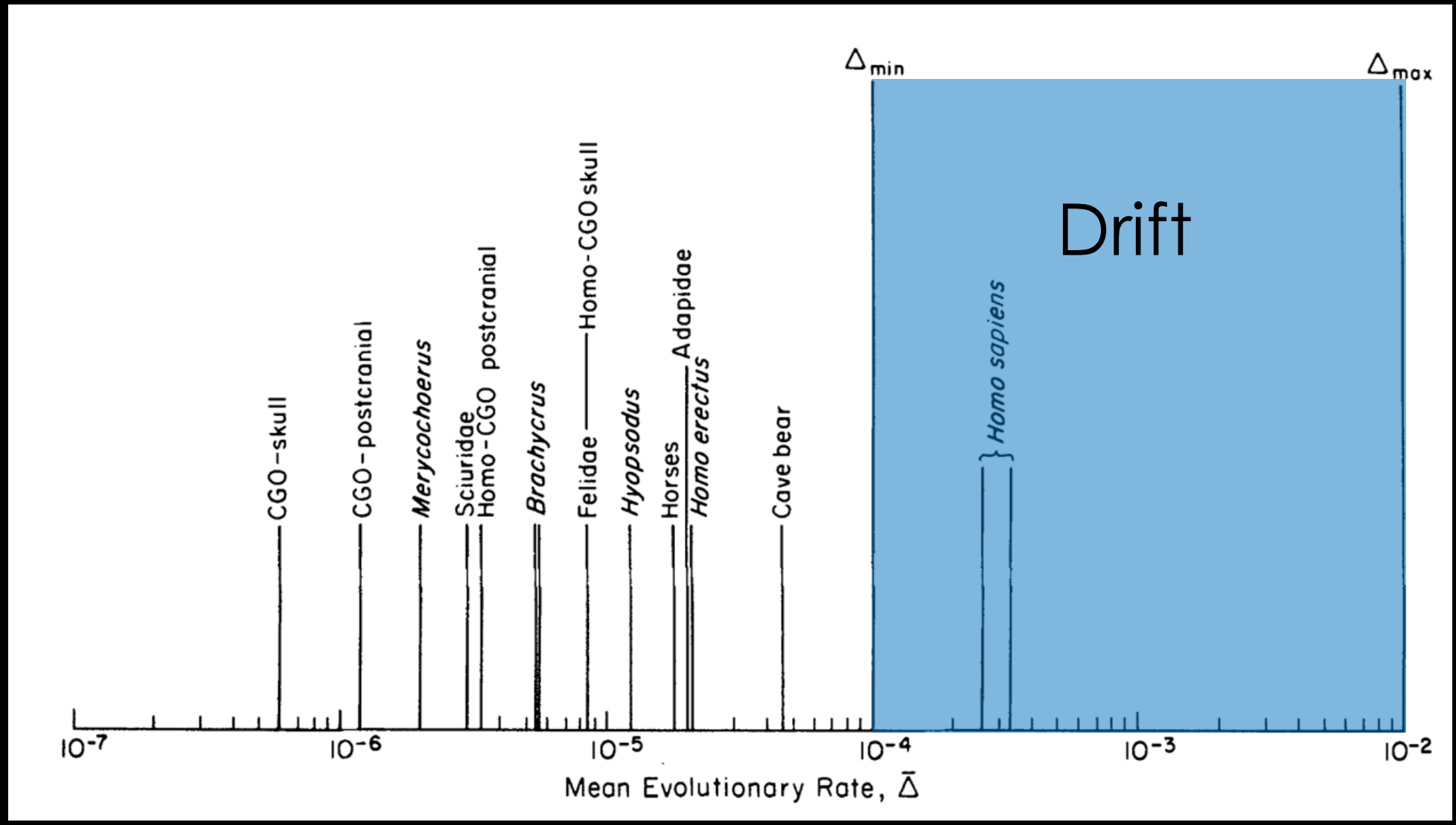
Holstad et al. 2024

GENETIC DRIFT



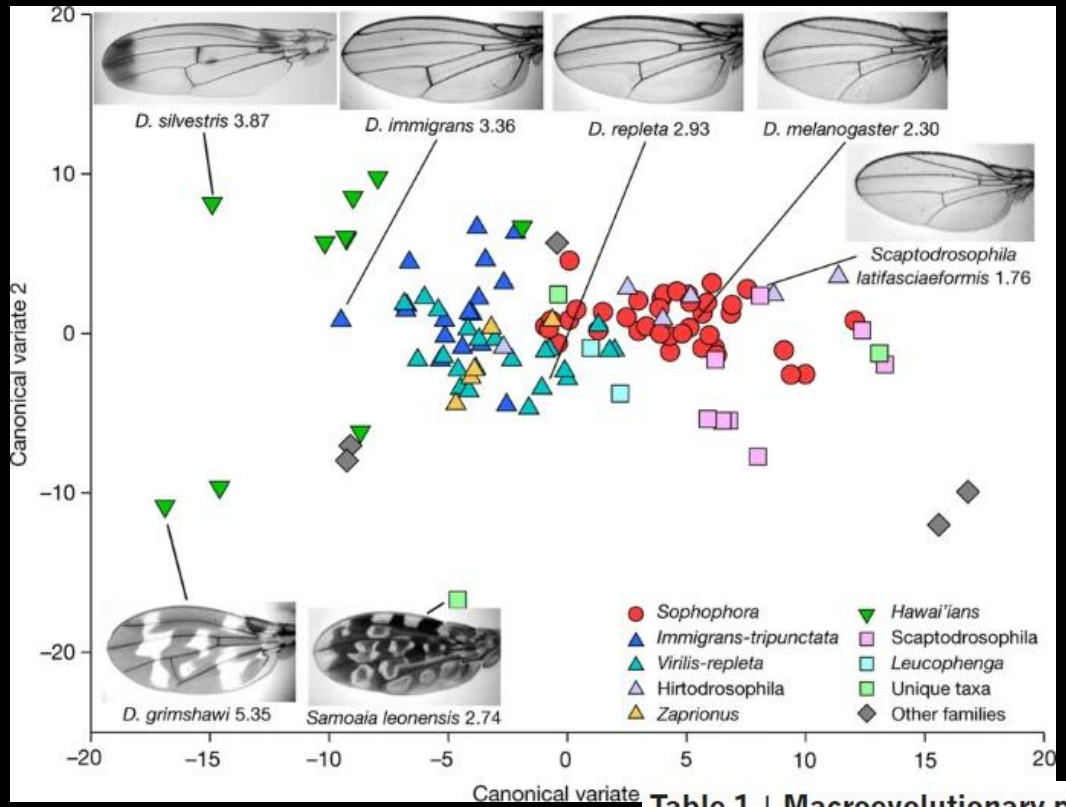
$$\Sigma(t) = \mathrm{G}\frac{t}{N}$$

- Under genetic drift divergence should be proportional to the amount of intraspecific variation
- Variation and divergence are proportional
- It's possible that traits are evolving neutrally



Drift seams unlikely

Lynch, 1990



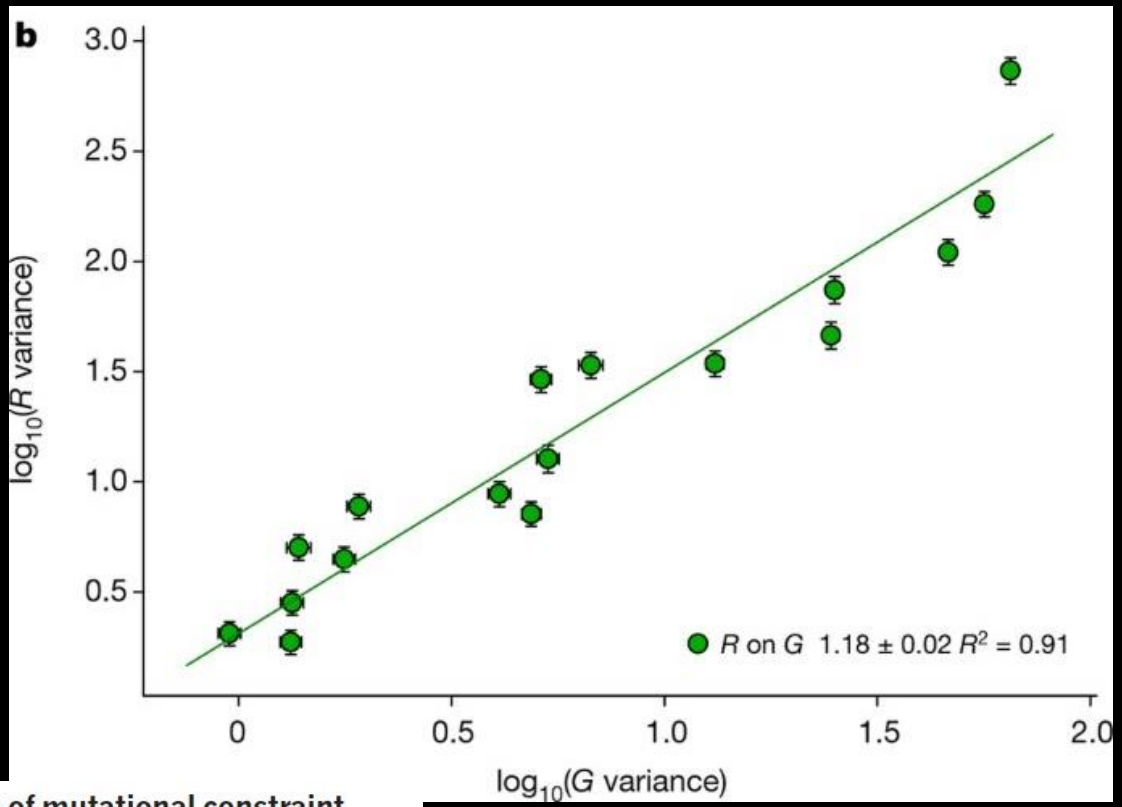


Table 1 | Macroevolutionary predictions of mutational constraint models

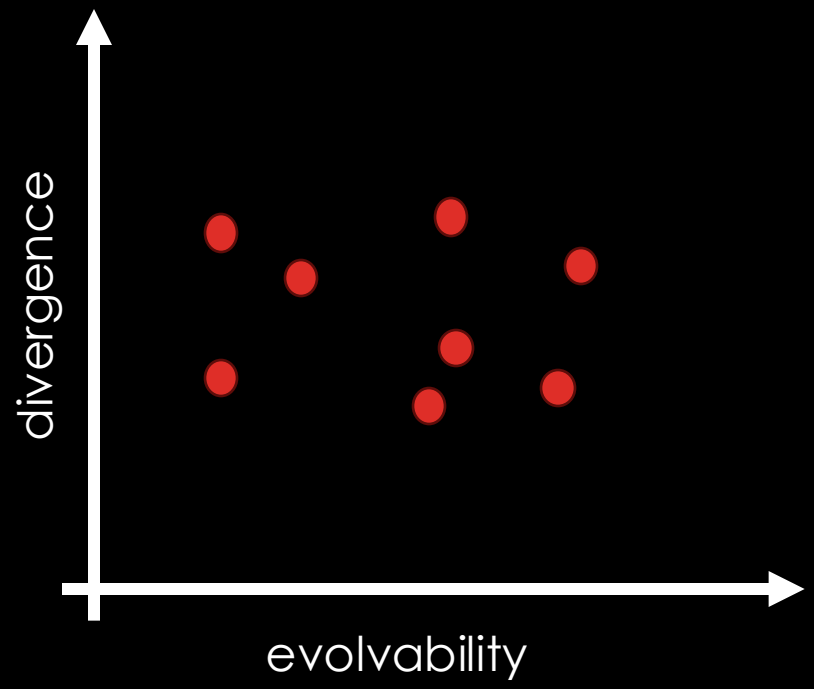
Evolutionary model[7]	Fitness function	Divergence rate*	Scaling exponent	Phylogenetic heritability
Neutral evolution	Flat	High ($2V_M$†)	**1**	**High**
Fluctuating directional selection	Linear	High	2	**High**
Divergent selection‡	Linear	Very high $>2V_M$	2	Intermediate
BM§ slow‖	Moving optimum¶	**Low**	~0	**High**
BM§ fast‖	Moving optimum	Very high	~0	**High**
White noise**	Moving optimum	**Low**	0	0
OU†† slow‖	Moving optimum	**Low**	~0	Intermediate
OU†† intermediate‖	Moving optimum	**Low**	**0–1**	Low
OU†† fast‖	Moving optimum	**Low**	~0	~0
Observed		**Low**	**~1**	**High**

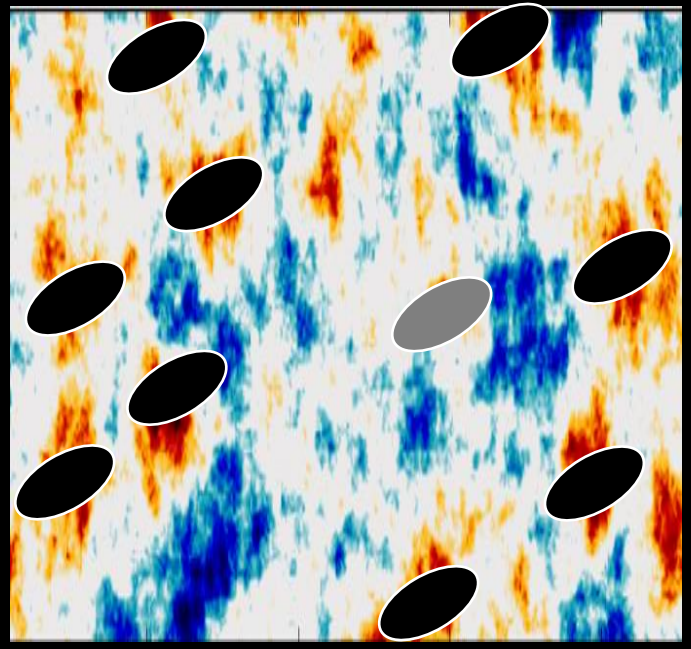
Houle et al. 2017

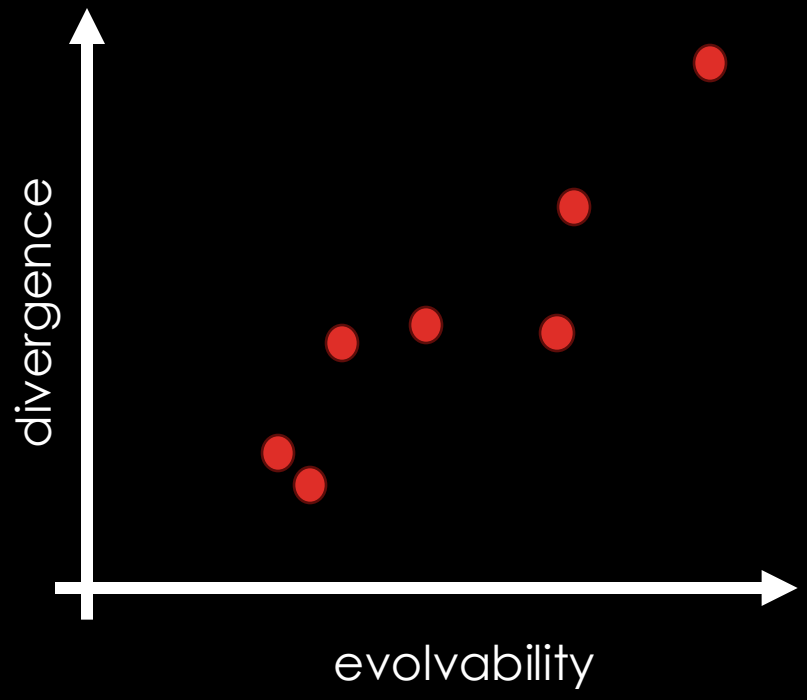
"PARADOX OF PREDICTABILITY"

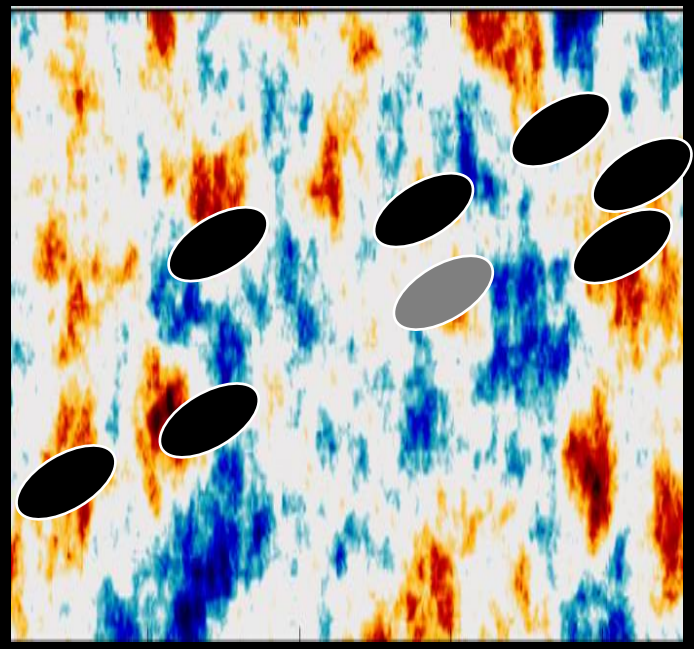
Tsuboi et al. 2024

- Species can reach peaks rapidly (unlikely to be maladapted)
- Rates of evolution are too slow, implying strong influence of stabilizing selection
- Evolution is likely dominated by peak distribution and stabilizing selection
- Peak distribution should have no relation to phenotypic variation
- Still, the amount of trait variation predicts how traits will evolve on large time scales.



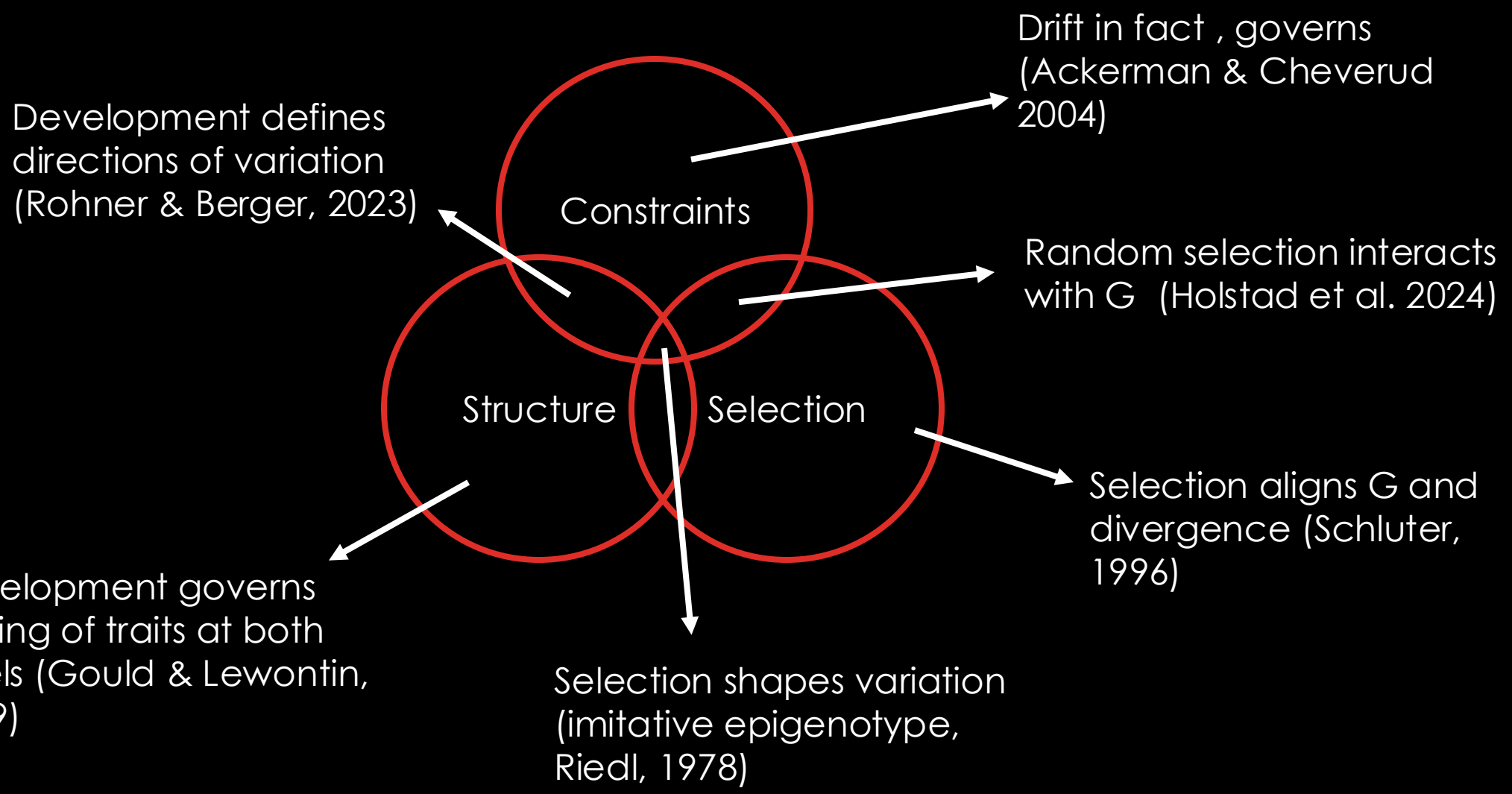




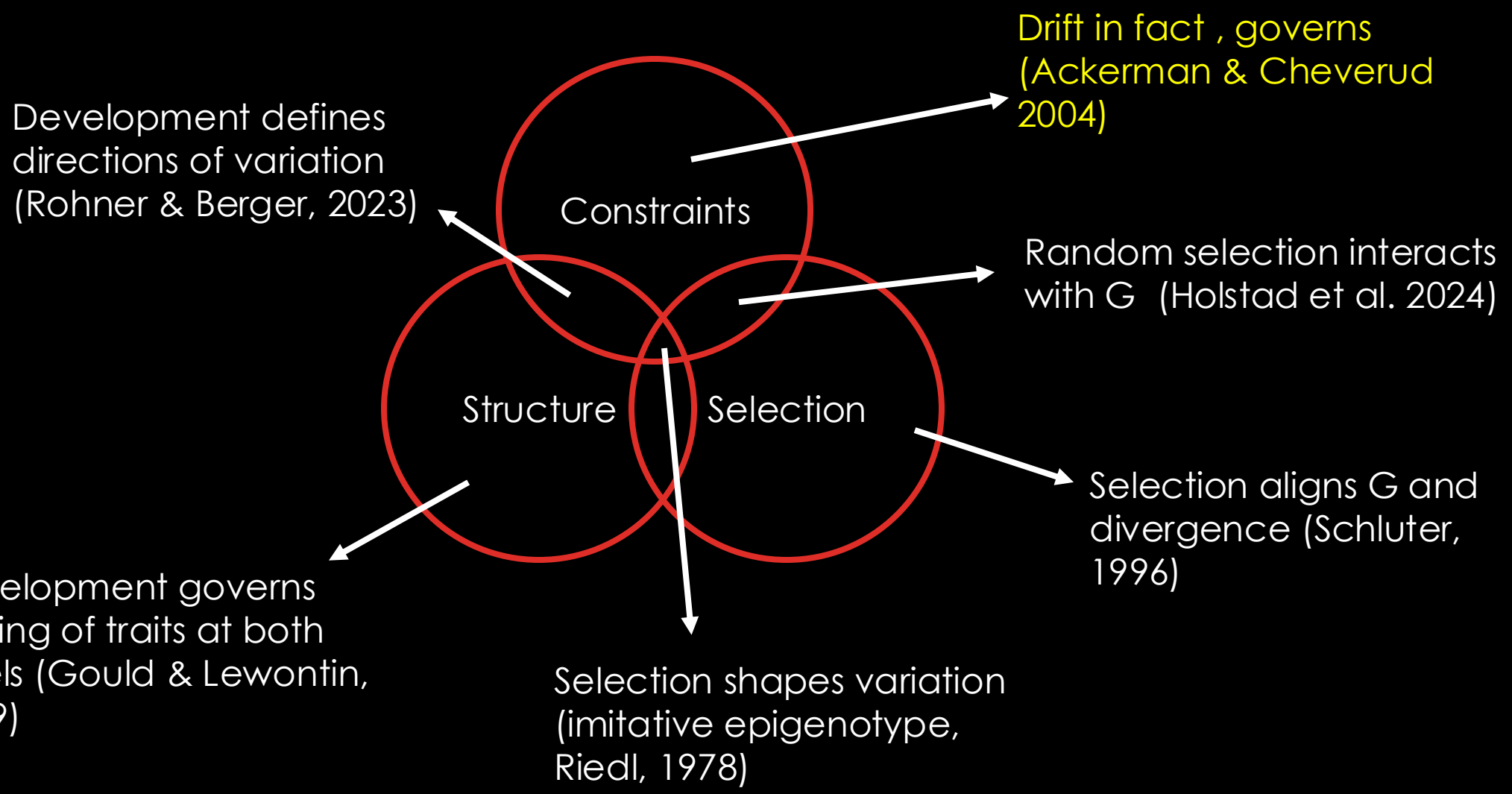


Why?

POTENTIAL EXPLANATIONS



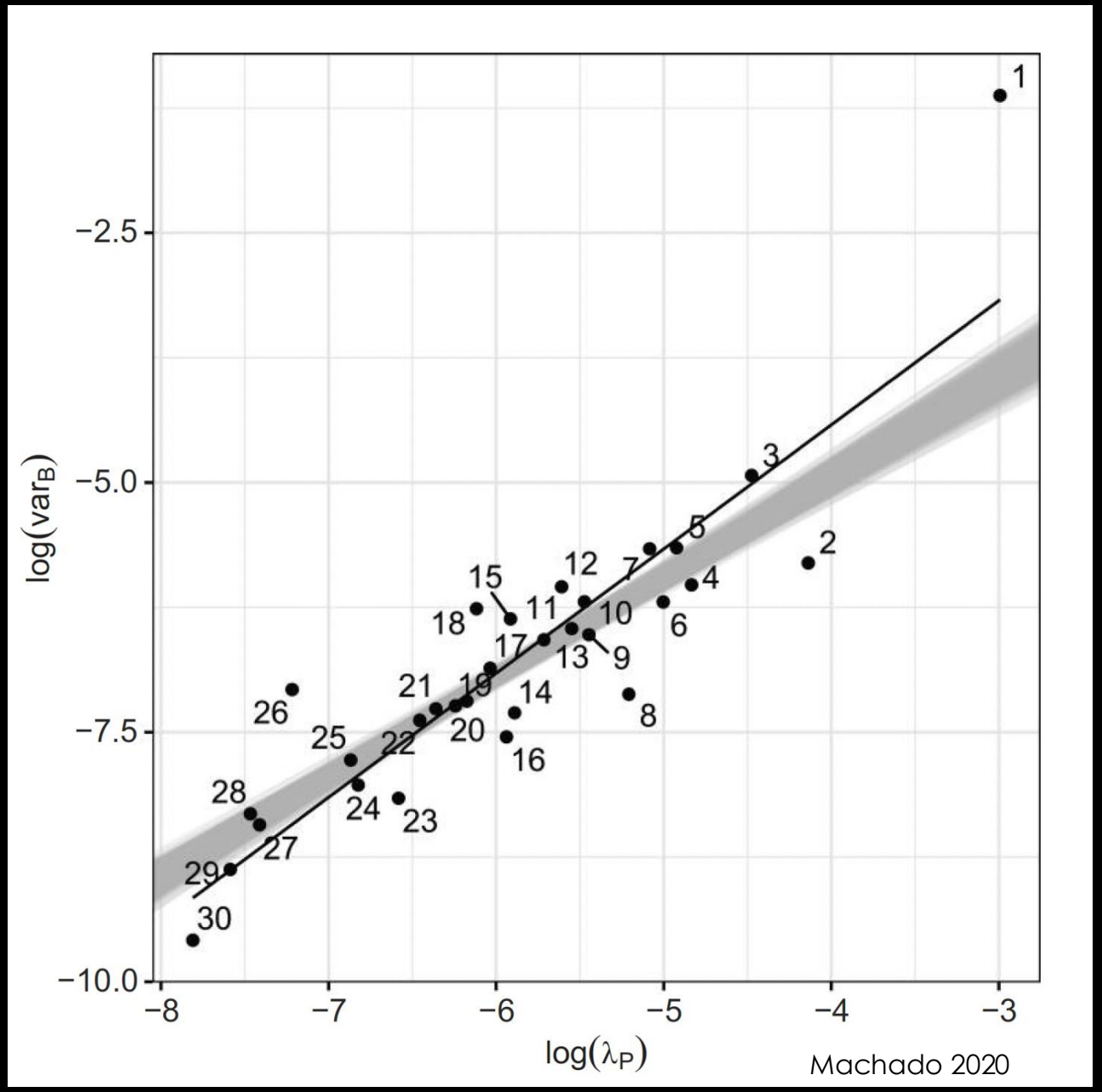
POTENTIAL EXPLANATIONS



$$\mathbf{B} = \frac{t}{N_e}\mathbf{G},$$

$$\log(\mathrm{var}_B) = a + b[\log(\lambda)]$$

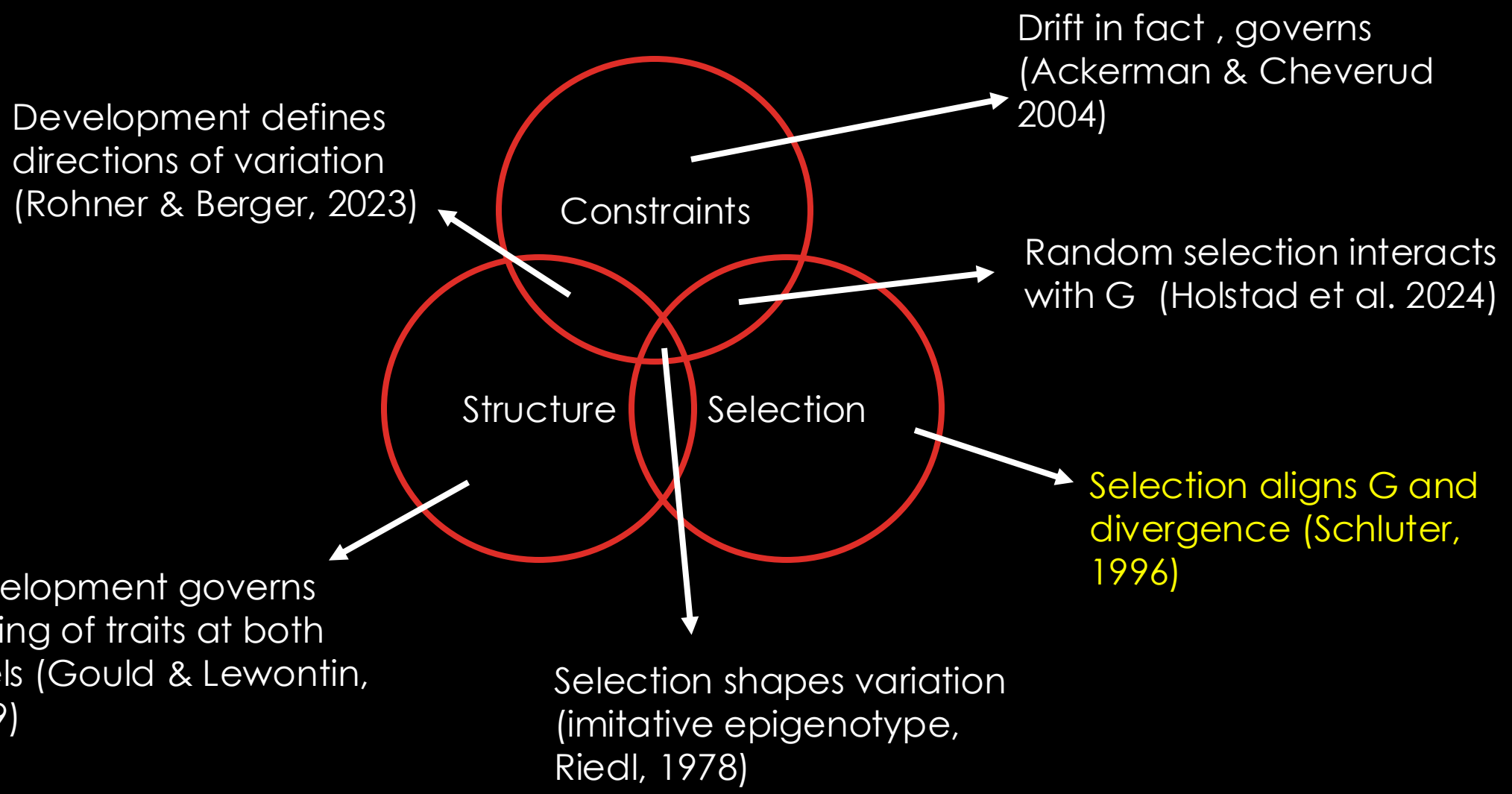
t/Ne -> Nuisance parameter



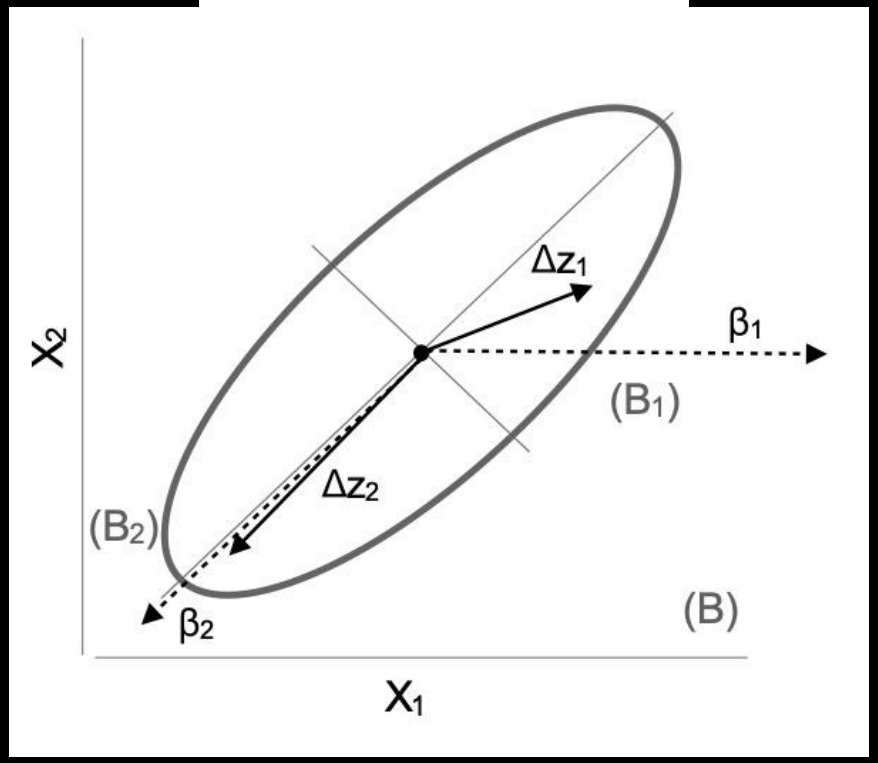
Problems?

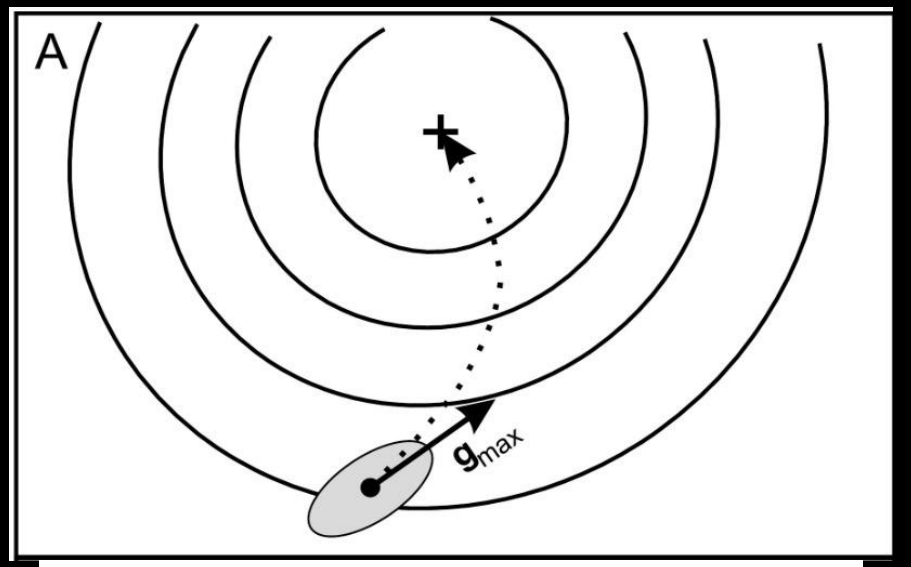
Ackerman & Cheverud 2004

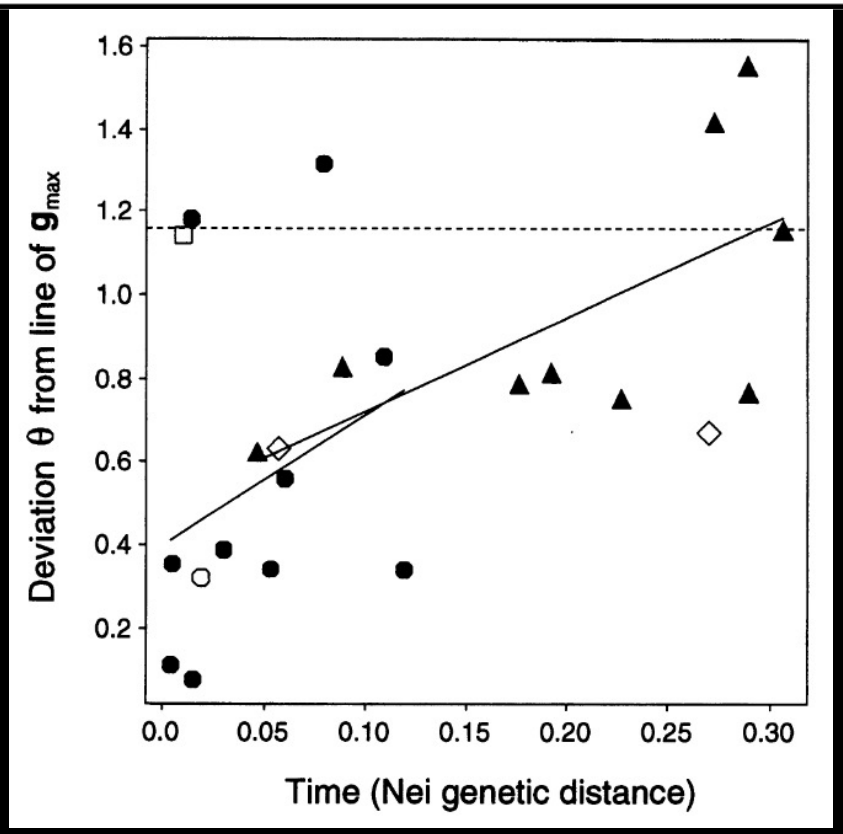
POTENTIAL EXPLANATIONS



$$\Delta z = G\beta$$



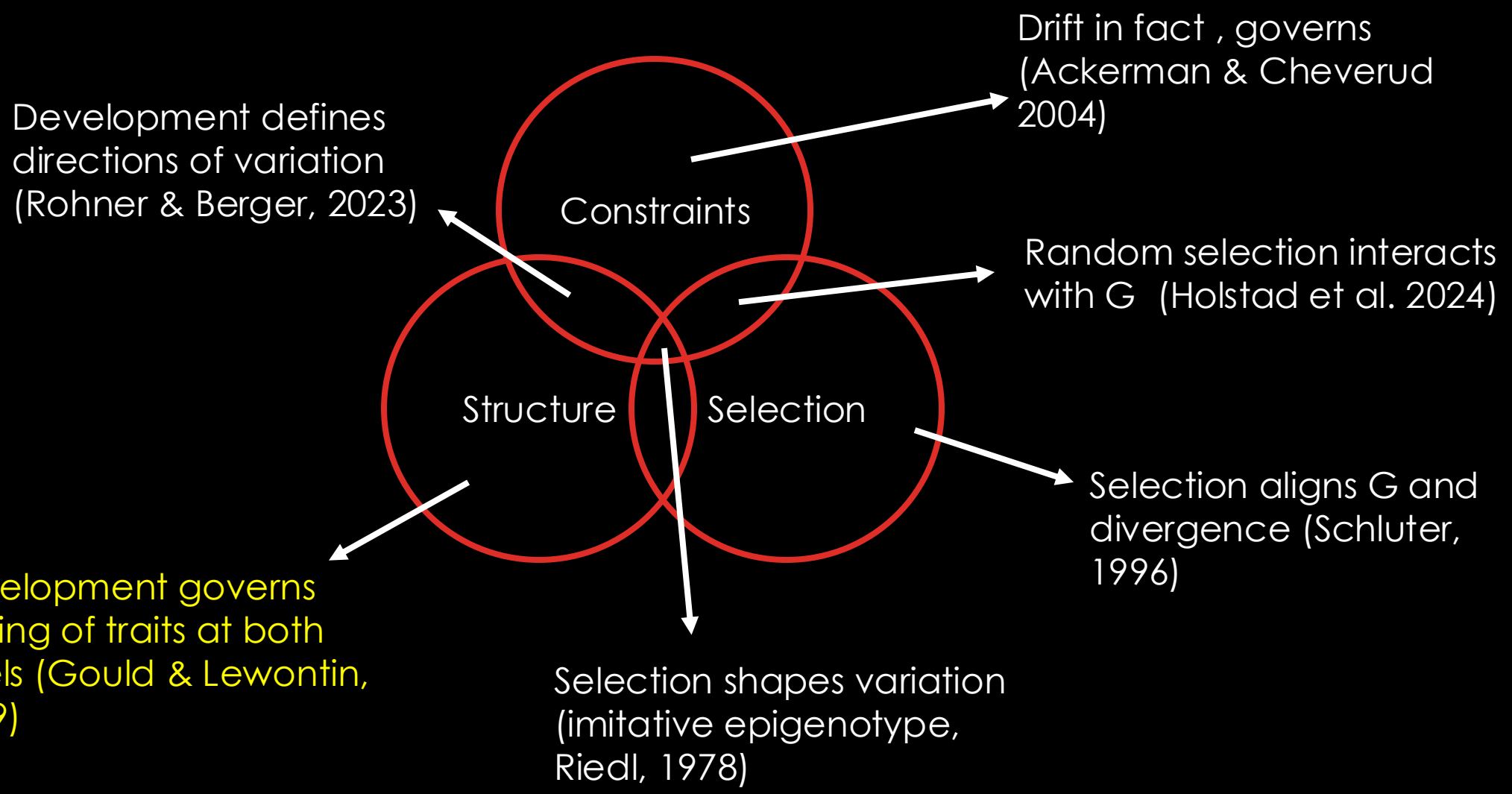


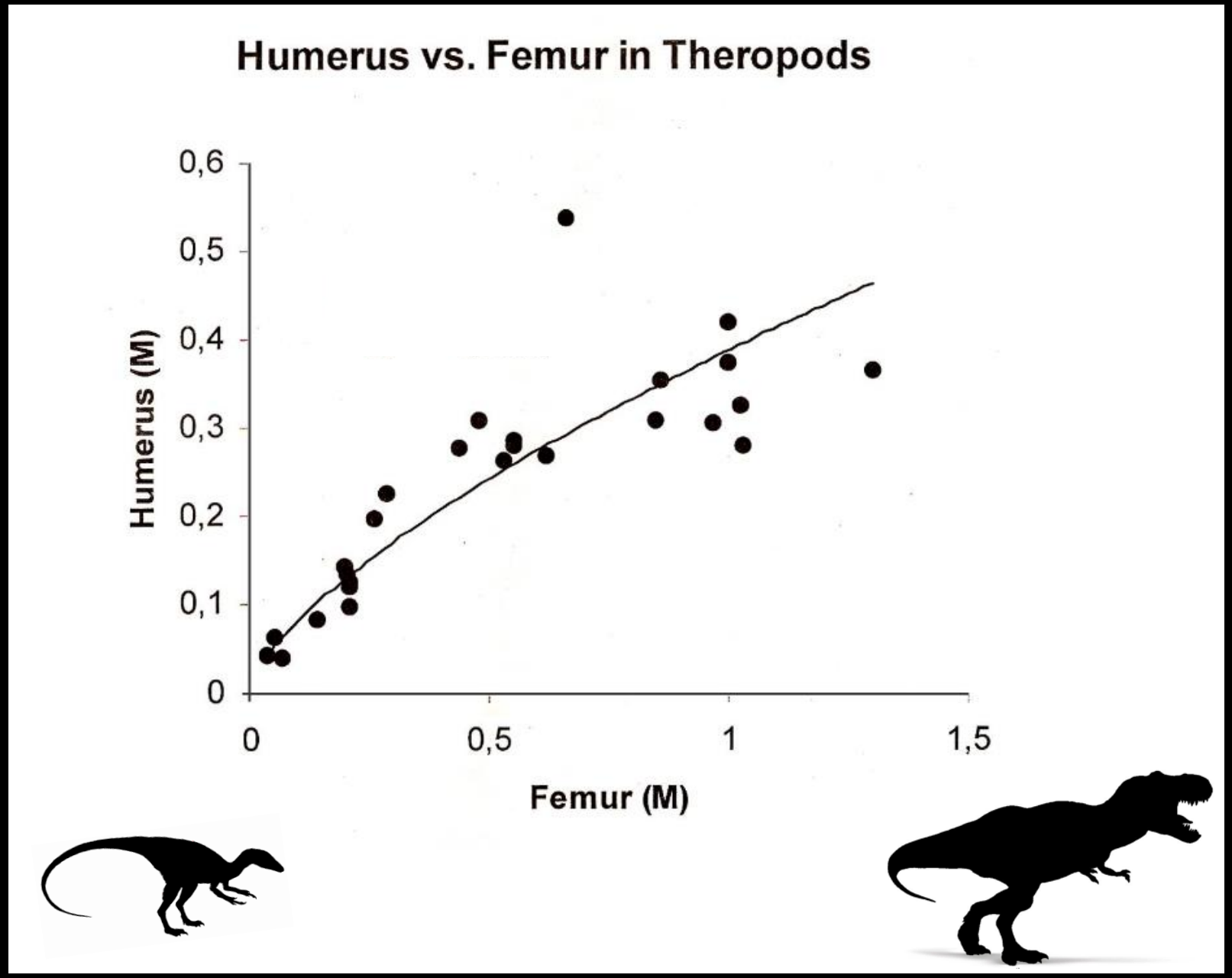


Problems?

Schluter 1996

POTENTIAL EXPLANATIONS

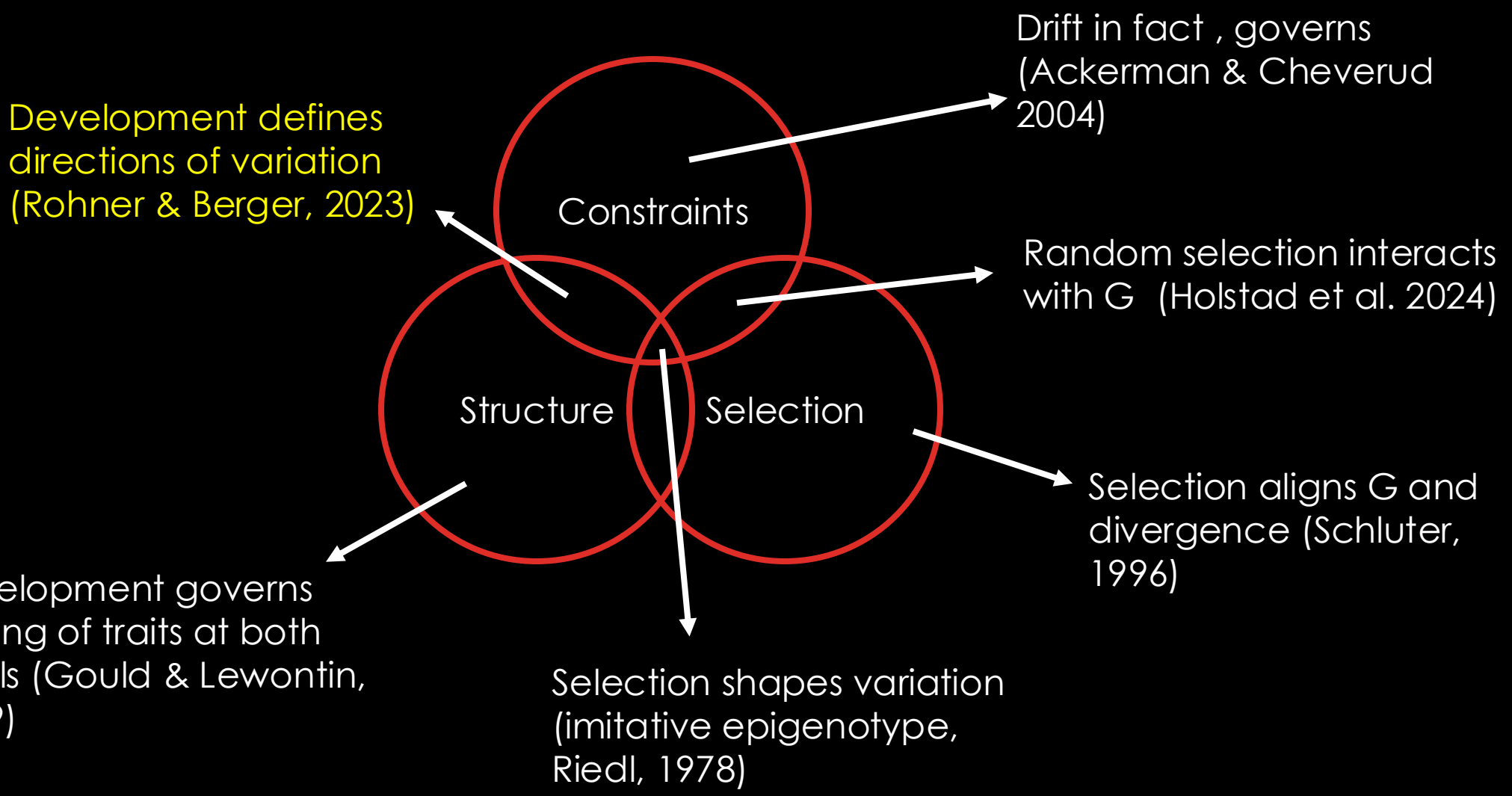


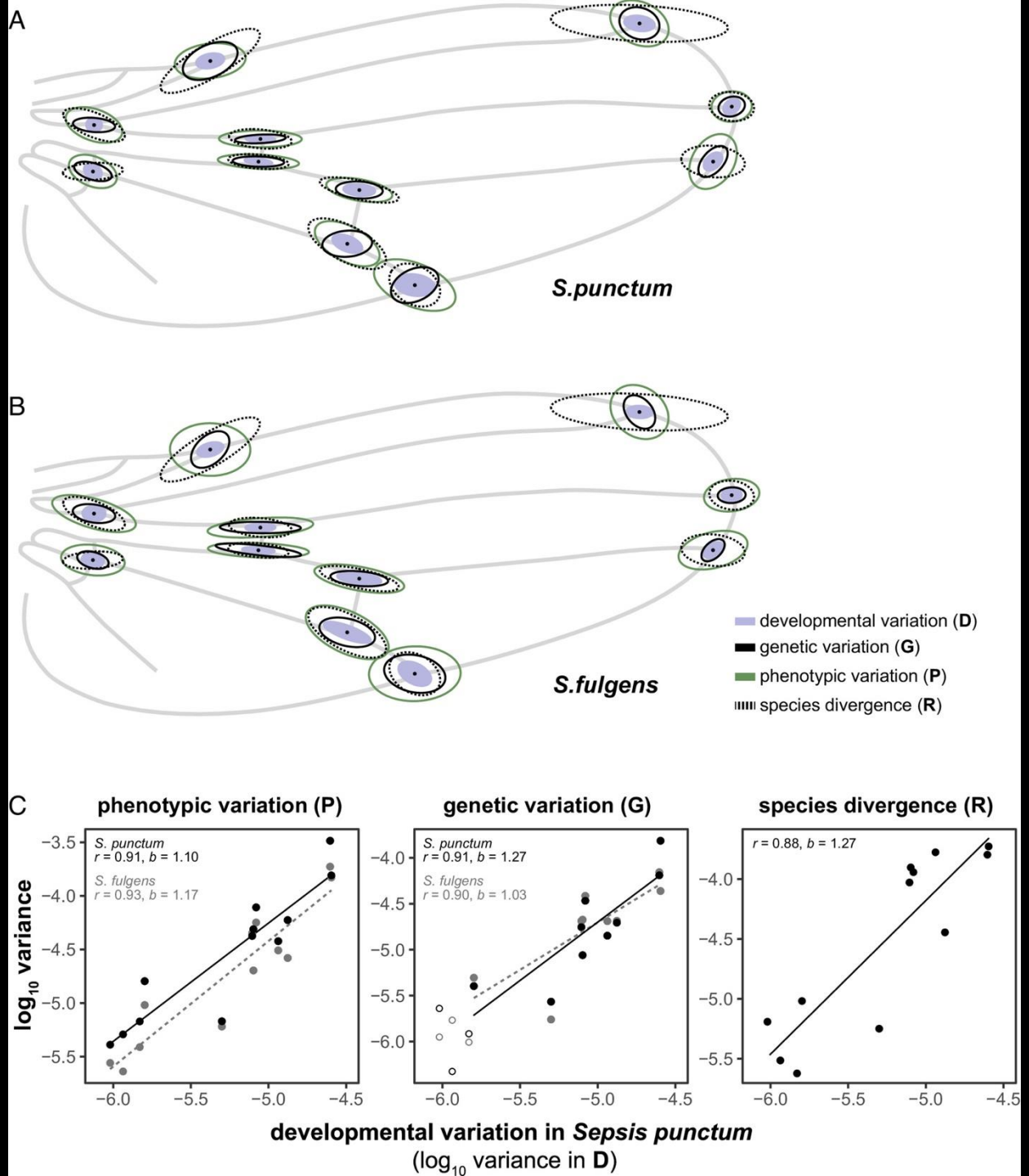


Vargas, 1999

Gould & Lewontin, 1979

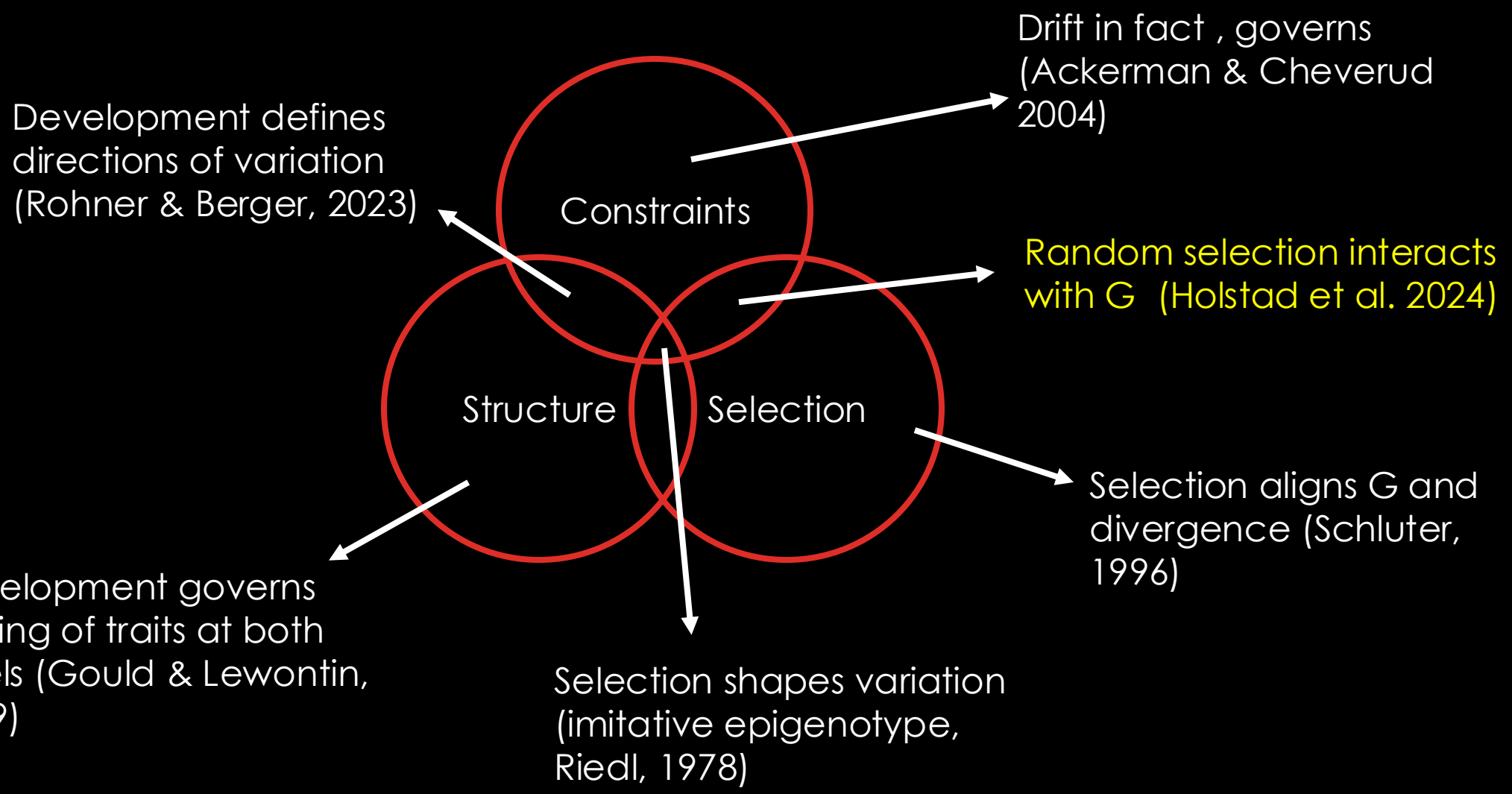
POTENTIAL EXPLANATIONS

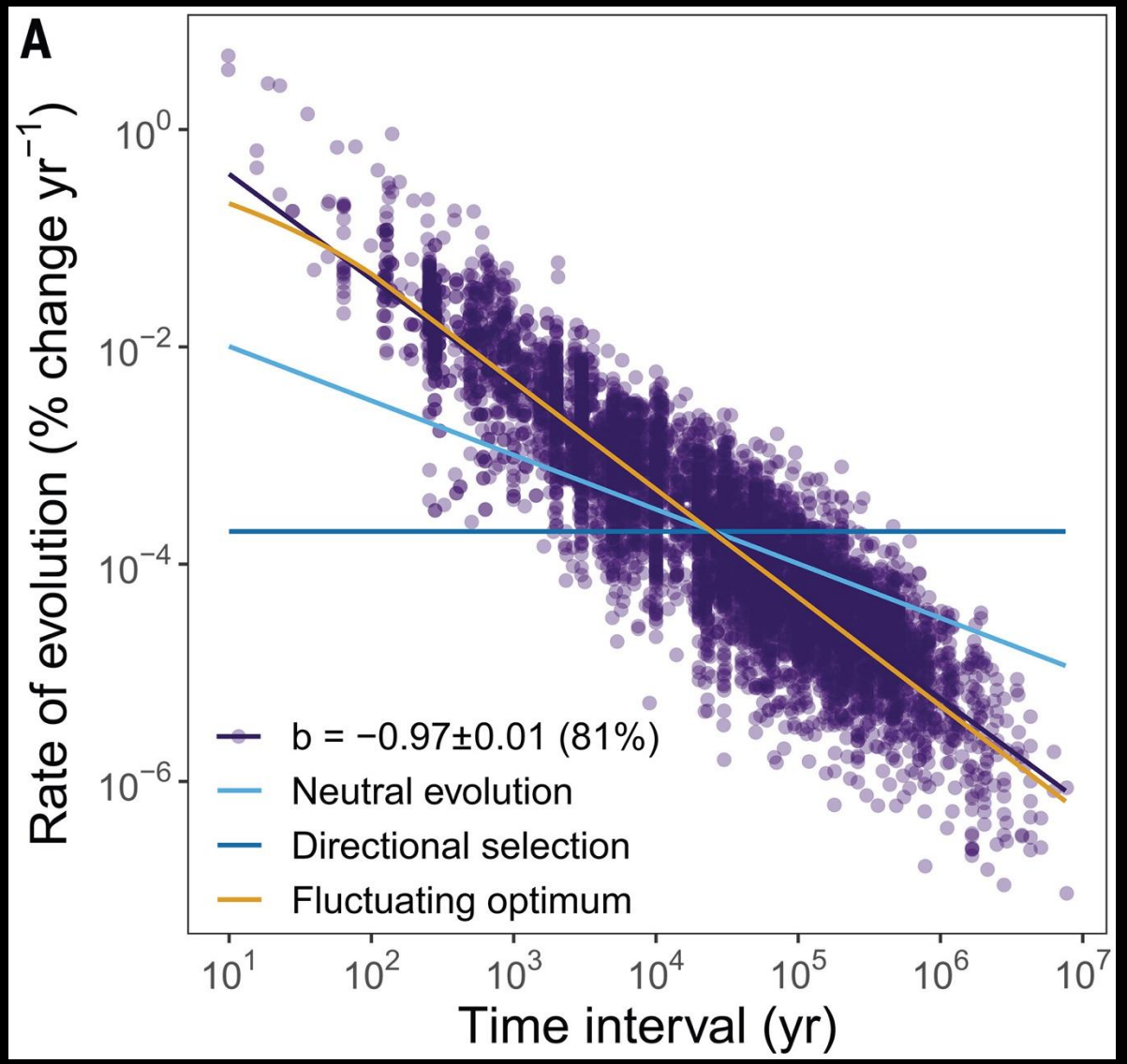




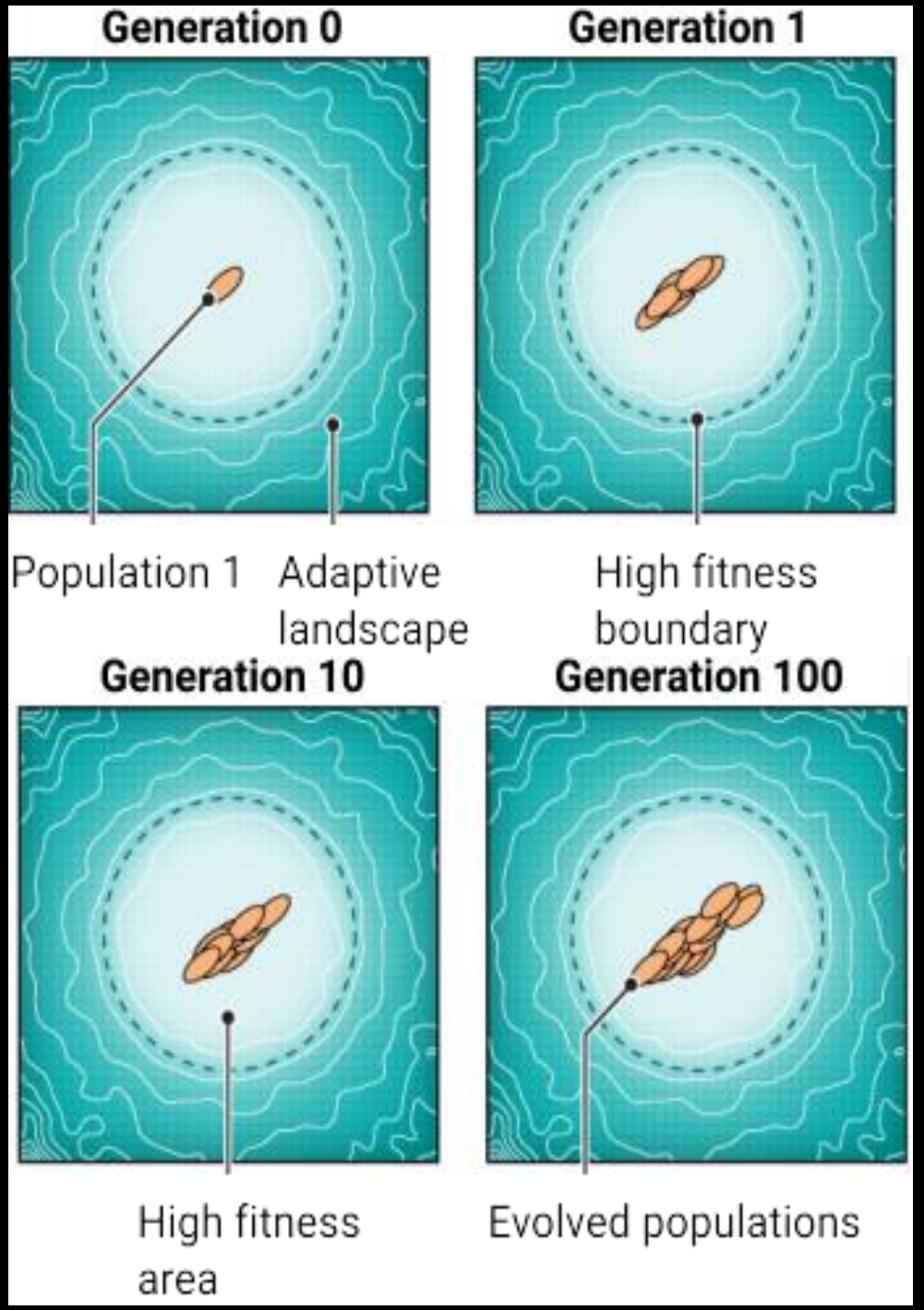
Rohner & Berger, 2023

POTENTIAL EXPLANATIONS



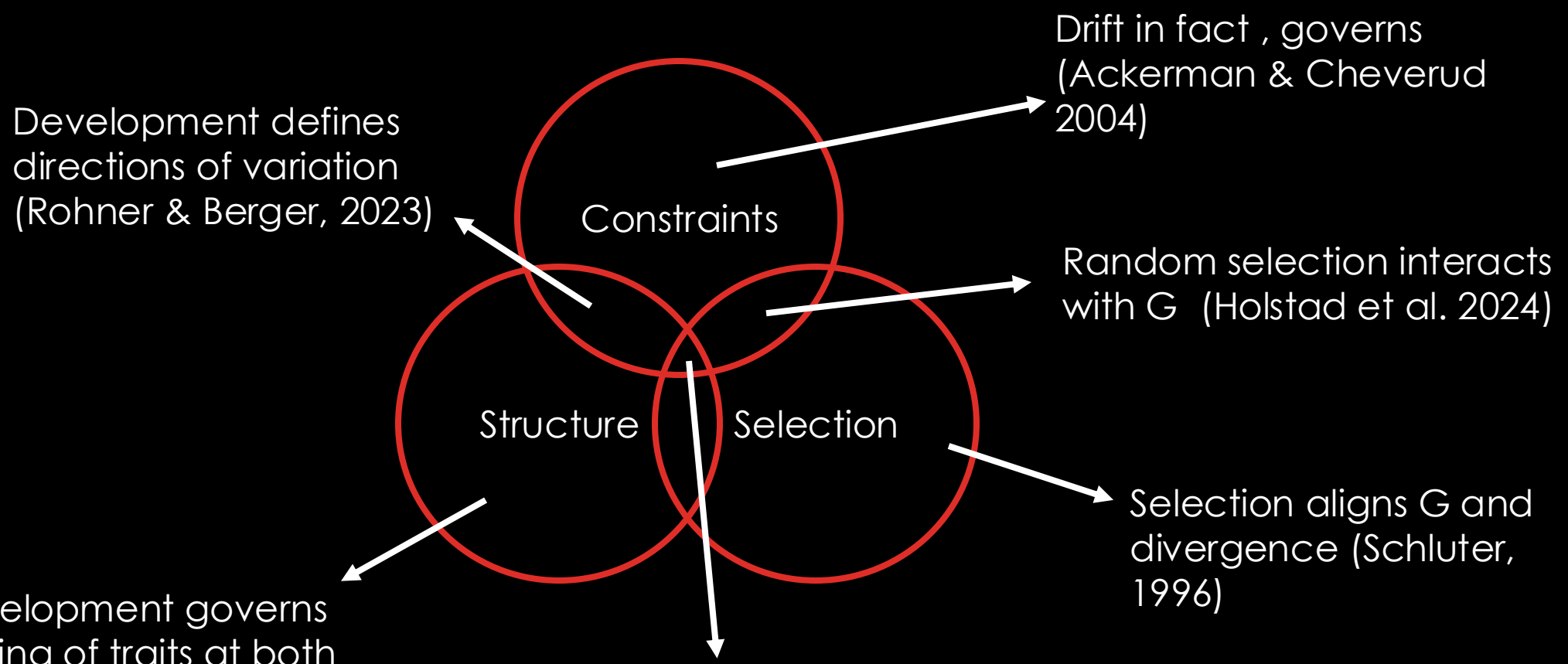


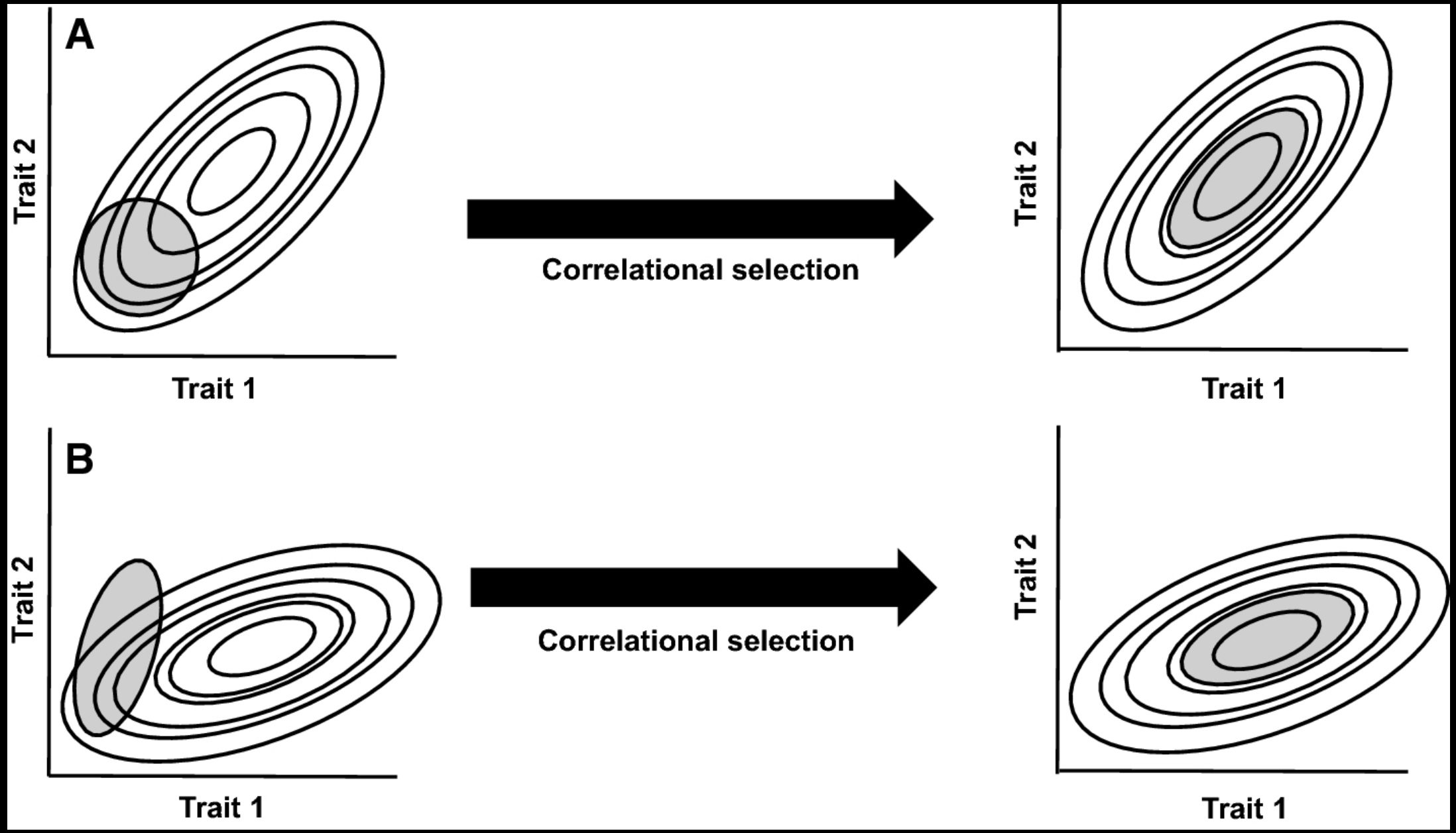
Holstad et al. 2024



Uyeda & McGlothin, 2024

POTENTIAL EXPLANATIONS





Svensoon 2022

Riedl, 1978