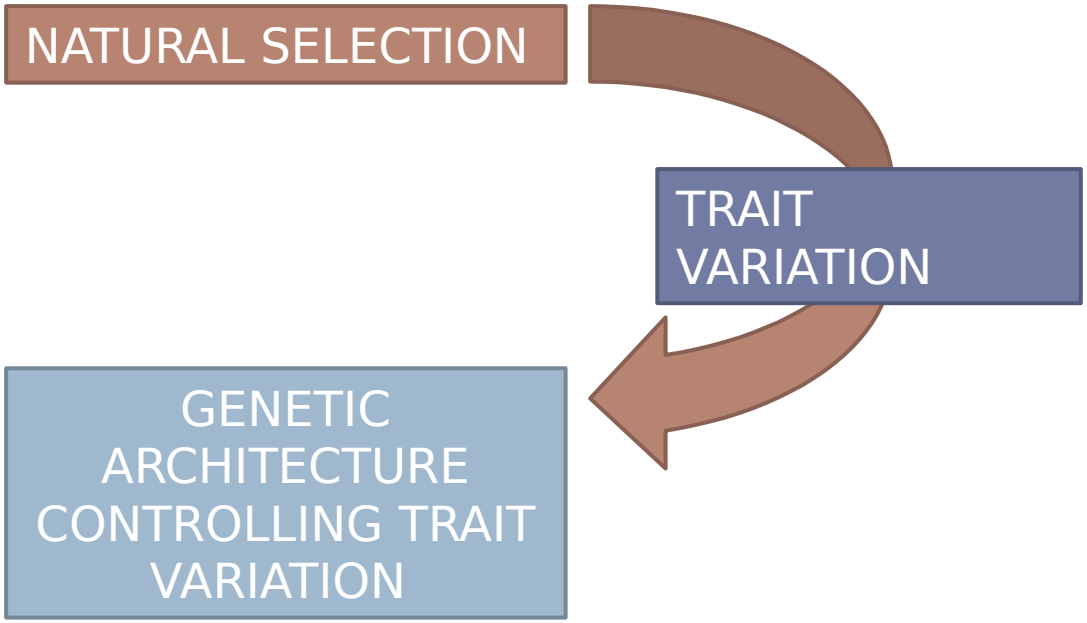
Violaine Llaurens & Claire Spottiswoode

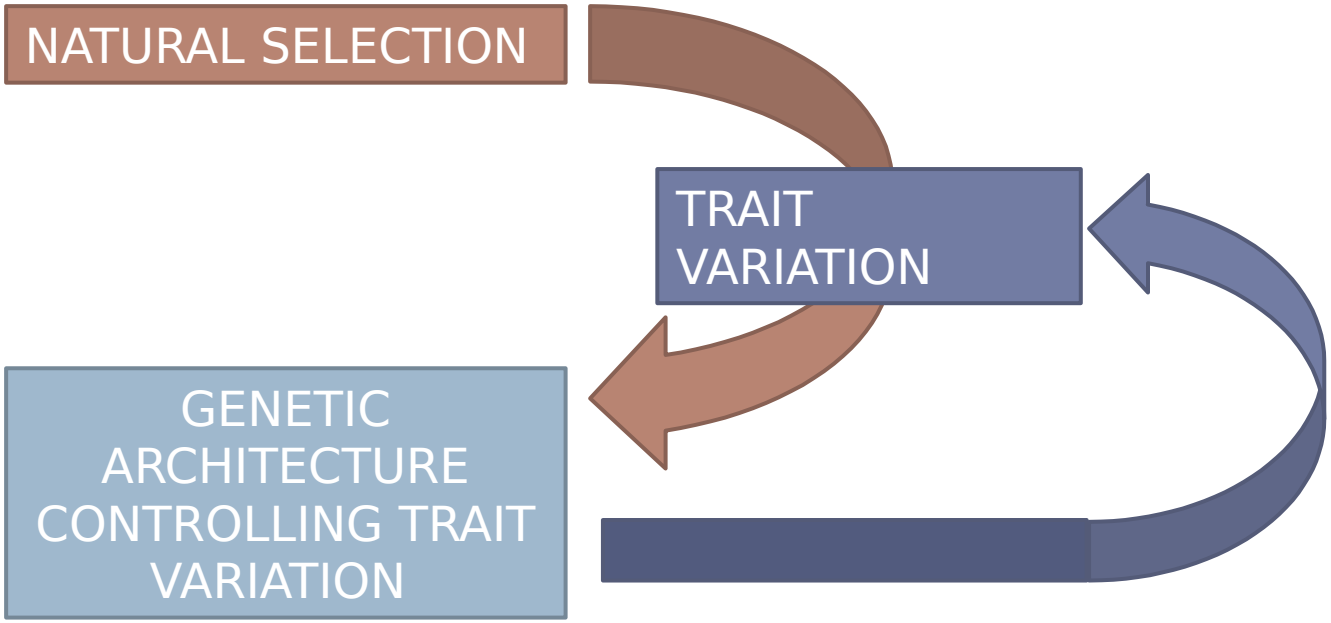
Evolution of egg mimicry in brood parasitism: on the role of genetic architecture.

Aussois: May 16th 2018

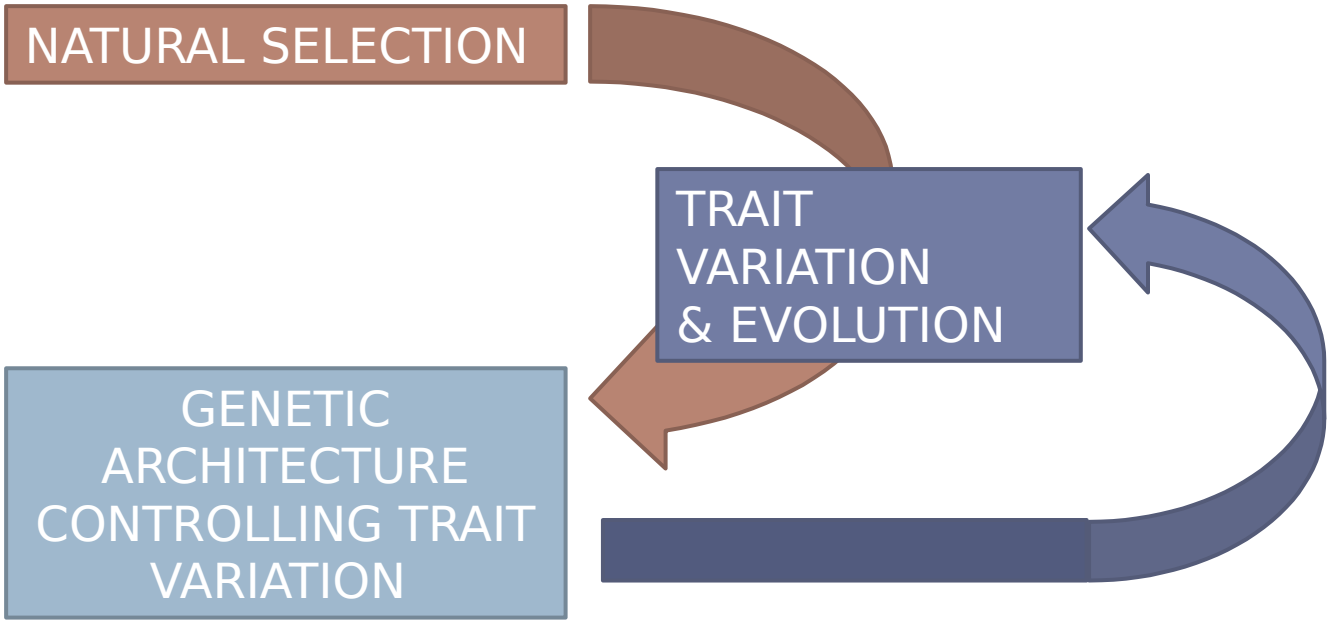
Genetic architecture & polymorphism



Genetic architecture & polymorphism



Genetic architecture & polymorphism



Brood parasitism

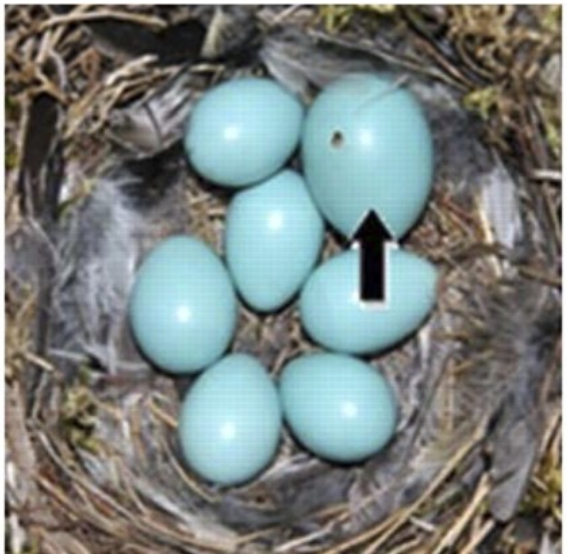
- Eggs laid in other species nest
  - Parental care provided by the host parents

Egg mimicry in cuckoos

- Evolution of mimicry in parasite species
  - Mimicry in egg colour and/or pattern

Hungary
great reed warbler
Acrocephalus arundinaceus

Finland
common redstart
Phoenicurus phoenicurus



Czech Republic
reed warbler
Acrocephalus scirpaceus

Branislav et al. 2011

Polymorphic mimicry in cuckoos

- In cuckoo finch parasiting host ne
  - Polymorphic mimicry in egg colour p

Cuckoos eggs

Host eggs

Spottiswoode & Stevens 2012

Polymorphic mimicry in cuckoos

- In cuckoo finch parasiting host nests
  - Most parasite species specialize on a single egg colour pattern
  - Few cases of polymorphic mimicry

Anomalospiza imberbis

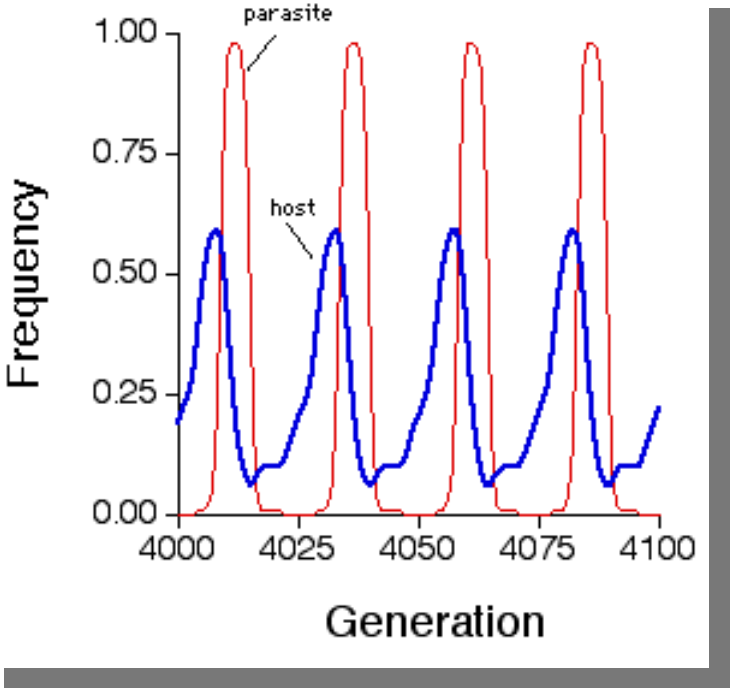
Prinia subflava

Cuckoos eggs

Host eggs

A red queen dynamic ?

- Red queen dynamics on cuckoos and host egg colour pattern ?

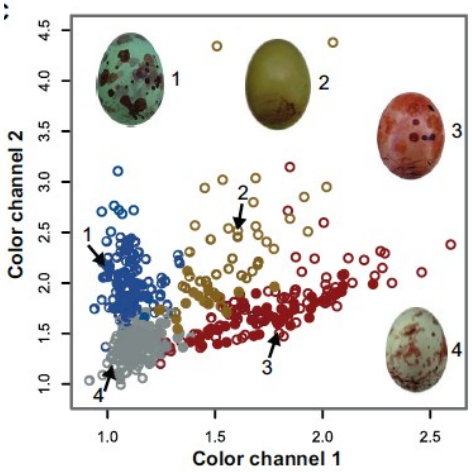


Van Valen 1973

A red queen dynamic ?

- Failed red-queen dynamics in cuckoos ?

P. sublava



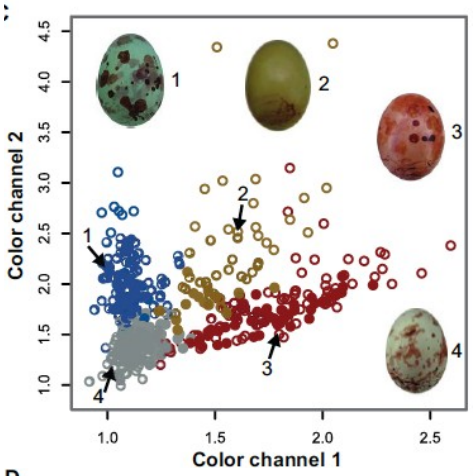
In host, coexistence of white, blue, pink and green eggs

Spottiswoode & Stevens 2012

A red queen dynamic ?

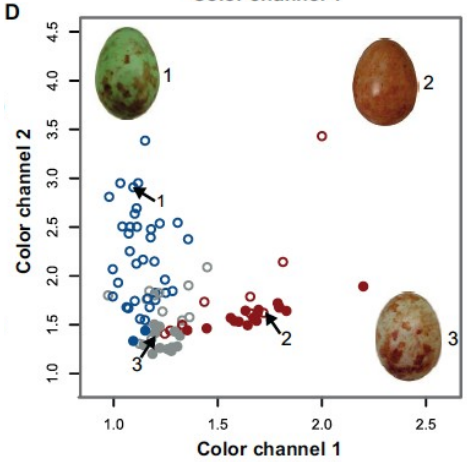
- Failed red-queen dynamics in cuckoos ?

P. sublava



In host, coexistence of white, blue, pink and green eggs

A. imberbis



In parasite, coexistence of white, blue, pink green eggs

BUT: no green eggs ?

Spottiswoode & Stevens 2012

Genetic basis of egg colour in host and parasite

- Distinct genetic architecture of egg coloration:
  - In host: autosomal
  - In cuckoo: maternally inherited (W-linked or mitochondrial)

  i.e. W-linked: limited recombination & immediate expression

- Origins of egg colours:
  - WHITE: absence of pigments
  - PINK/RED: Protoporphyrin
  - TURQUOISE BLUE: Biliverdin
  - GREEN: mixture of pink and turquoise pigments ?

Genetic basis of egg colour in host and parasite

- What is the influence of genetic architecture of egg coloration
  - On host and parasite egg polymorphism ?
  - On host/parasite dynamics ?

 Explore consequences of different hypothetical genetic architecture through theoretical approach

Infinite population ‘matching allele’ model

P. sublava

HOST

- Cost suffered by a host and its nest is parasitized
  - $C_p \in [0;1]$
- Depends on the frequency of parasite egg with the egg mimetic colour

A. imberbis

PARASITE

- Cost suffered by a parasite when laying in a nest where its eggs are not mimetic
  - $C_h \in [0;1]$
- Depends on the frequency of host egg with the matching colour

Llaurens & Spottiswoode in prep.

Hypothetical genetic architecture (1)

- Same autosomal architecture in host & parasite

Host

Phenotypes		Genotypes
		strict dominance between b and p
	*pink*	*pp or wp*
	*white*	*ww*
	*blue*	*bb or bp*
	*green*	-

Parasite

Phenotypes		Genotypes
		Autosomal
	*pink*	*pp or wp*
	*white*	*ww*
	*blue*	*bb or bp*

Llaurens & Spottiswoode in prep.

Model equations under hyp (1)

HOST

$$\frac{df_{xy}^{H}}{dt} = \sum_{i=1}^{i=6}\sum_{j=1}^{j=6}\{[(1 - C_p\sum_{k=1}^{k=6} R_{ik} f_k^P) + (1 - C_p\sum_{k=1}^{k=6} R_{jk} f_k^P)][qO_{ix}^H f_i^H O_{jy}^H f_j^H]\}$$

Cost of parasitism when mother is *i*

Cost of parasitism when mother is *j*

Parents *i* X *j* genotype frequencies

PARASITE

$$\frac{df_{xy}^{P}}{dt} = \sum_{i=1}^{i=6}\sum_{j=1}^{j=6}\{[(1 - (1 - C_h\sum_{k=1}^{k=6} R_{ki} f_k^H)) + (1 - (1 - C_h\sum_{k=1}^{k=6} R_{kj} f_k^P)][O_{ix}^P f_i^P O_{jy}^P f_j^P]\}$$

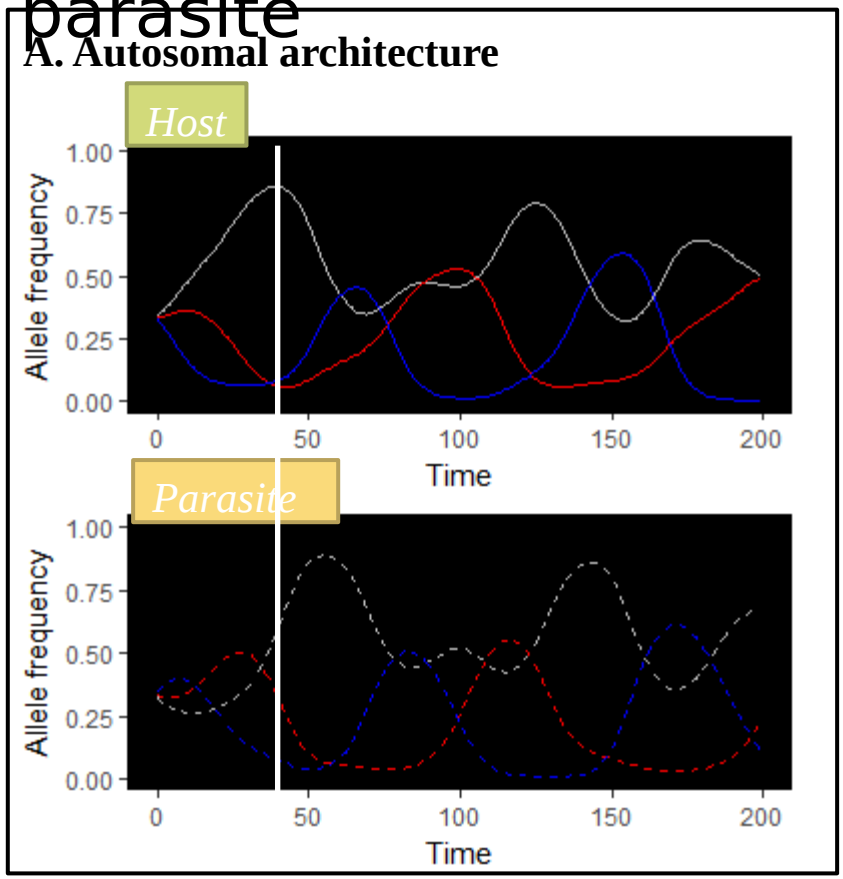
Cost of egg colour discordance when mother is *i*

Cost of egg colour discordance when mother is *j*

Parents *i* X *j* genotype frequencies

Hypothetical genetic architecture (1)

- Same autosomal architecture in host & parasite

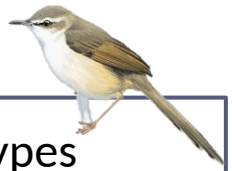


Llaurens & Spottiswoode in prep.

Hypothetical genetic architecture (2)

- W-linked in parasite

Host



Phenotypes	Genotypes
	strict dominance between b and p
 *pink*	*pp or wp*
 *white*	*ww*
 *blue*	*bb or bp*
 *green*	-

Parasite

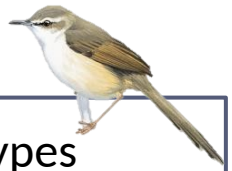
Phenotypes	Genotypes
	Autosomal
 *pink*	*pp or wp*
 *white*	*ww*
 *blue*	*bb or bp*

Llaurens & Spottiswoode in prep.

Hypothetical genetic architecture (2)

- W-linked in parasite

Host



Phenotypes	Genotypes
	strict dominance between b and p
 *pink*	*pp or wp*
 *white*	*ww*
 *blue*	*bb or bp*
 *green*	-

Parasite

Phenotypes	Genotypes	
	Autosomal	*W-linked*
 *pink*		*Wp*
 *white*		*Ww*
 *blue*		*Wp*

Llaurens & Spottiswoode in prep.

Model equations under hyp (2)

HOST

$$\frac{df_{xy}^{H}}{dt} = \sum_{i=1}^{i=6}\sum_{j=1}^{j=6}\{[(1 - C_p\sum_{k=1}^{k=3} R_{ik} f_k^P) + (1 - C_p\sum_{k=1}^{k=3} R_{jk} f_k^P)][qO_{ix}^H f_i^H O_{jy}^H f_j^H]\}$$

Cost of parasitism when mother is *i*

Cost of parasitism when mother is *j*

Parents *i* X *j* genotype frequencies

PARASITE

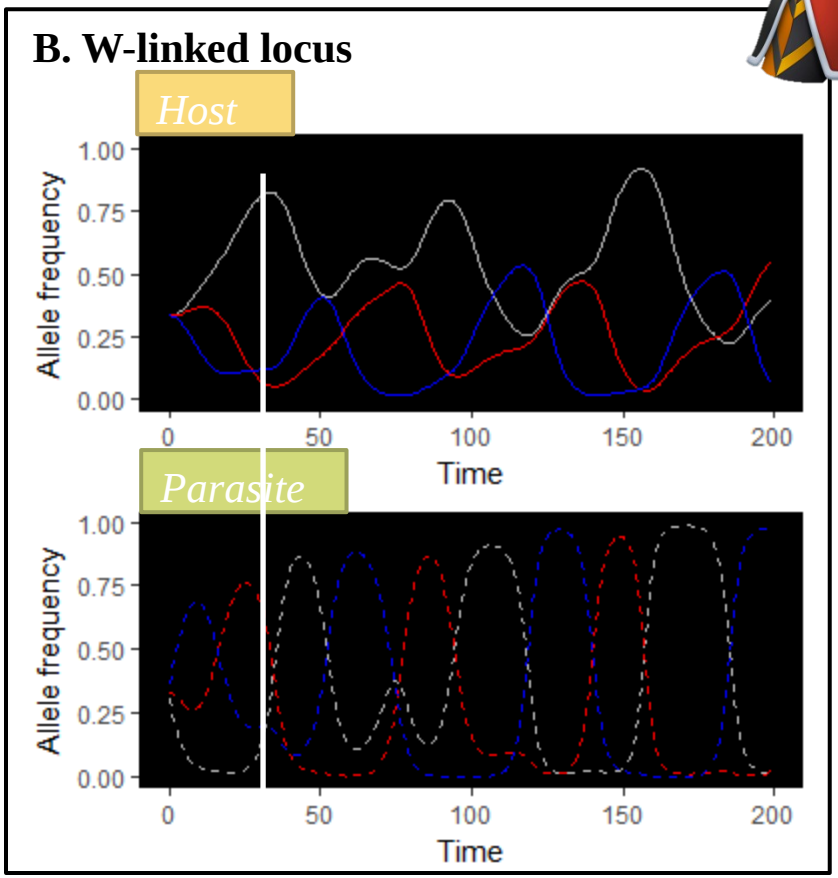
$$\frac{df_{ZW_x}^{P}}{dt} = \left(1 - (1 - C_h\sum_{k=1}^{k=6} R_{kx} f_k^H)\right) f_{ZW_x}^P$$

Cost of discordance in egg colour when mother is *i*

Mother *Wk* genotype frequencies

Hypothetical genetic architecture (2)

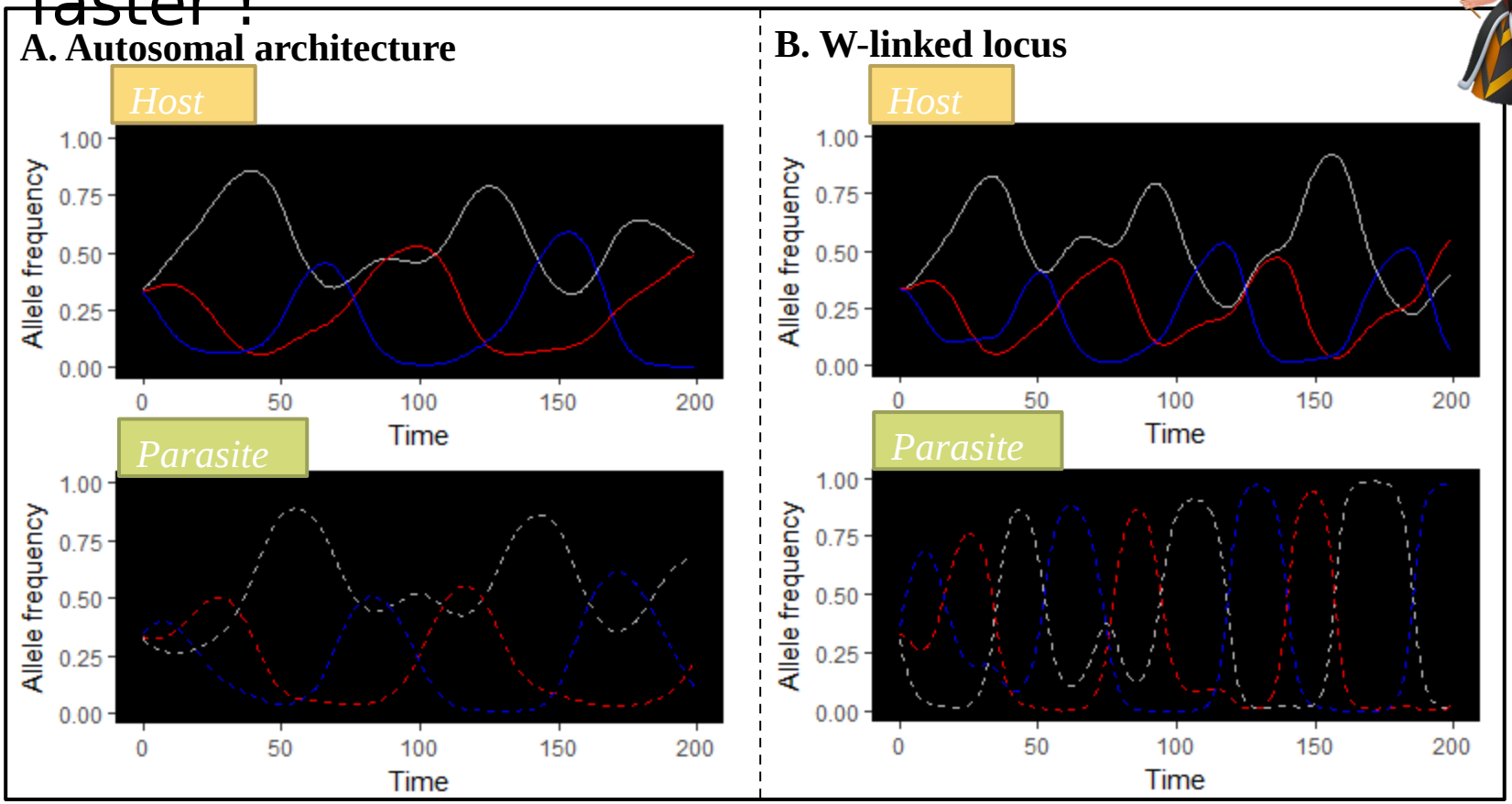
- W-linked in parasite



Llaurens & Spottiswoode in prep.

Hypothetical genetic architecture (2)

- W-linked in parasite : parasites are running faster !

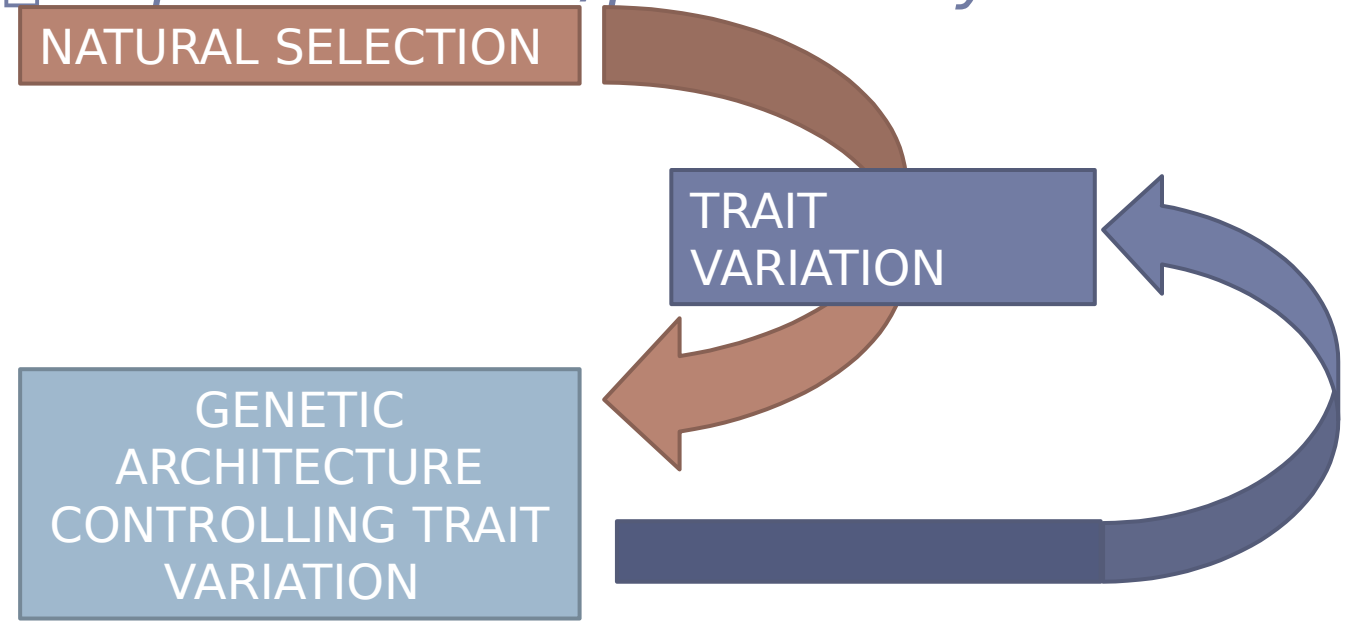


Llaurens & Spottiswoode in prep.

Genetic architecture & polymorphism

- Location of locus controlling egg colour variations

- *Impact on host/parasite dynamics*

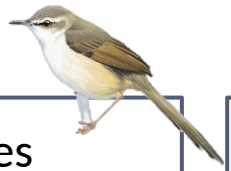


Llaurens & Spottiswoode in prep.

Hypothetical genetic architecture (3)

- Co-dominance in host allowing ‘green’ egg colour.

Host



Phenotypes		Genotypes *strict dominance between b and p*
	*pink*	*pp or wp*
	*white*	*ww*
	*blue*	*bb or bp*
	*green*	-

Parasite

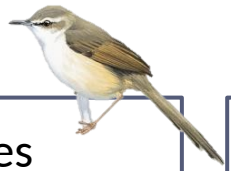
Phenotypes		Genotypes	
		Autosomal	*W-linked*
	*pink*		*Wp*
	*white*		*Ww*
	*blue*		*Wp*

Llaurens & Spottiswoode in prep.

Hypothetical genetic architecture (3)

- Co-dominance in host allowing ‘green’ egg colour.

Host



Phenotypes		Genotypes	
		strict dominance between b and p	*co-dominance between b and p*
	*pink*		*pp or wp*
	*white*		*ww*
	*blue*		*bb or wb*
	*green*		*bp*

Parasite

Phenotypes		Genotypes	
		Autosomal	*W-linked*
	*pink*		*Wp*
	*white*		*Ww*
	*blue*		*Wp*

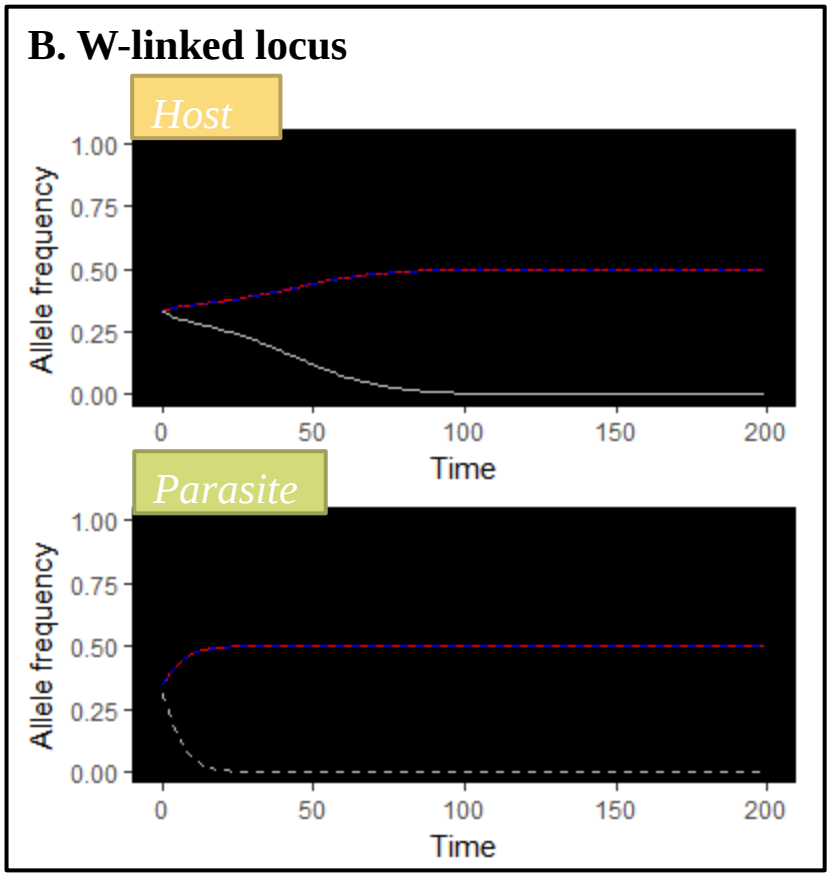
Llaurens & Spottiswoode in prep.

Hypothetical genetic architecture (3)

- Co-dominance in host allowing ‘green’ egg colour.

 Loss of red queen dynamics due to heterozygote advantage associated with green eggs.

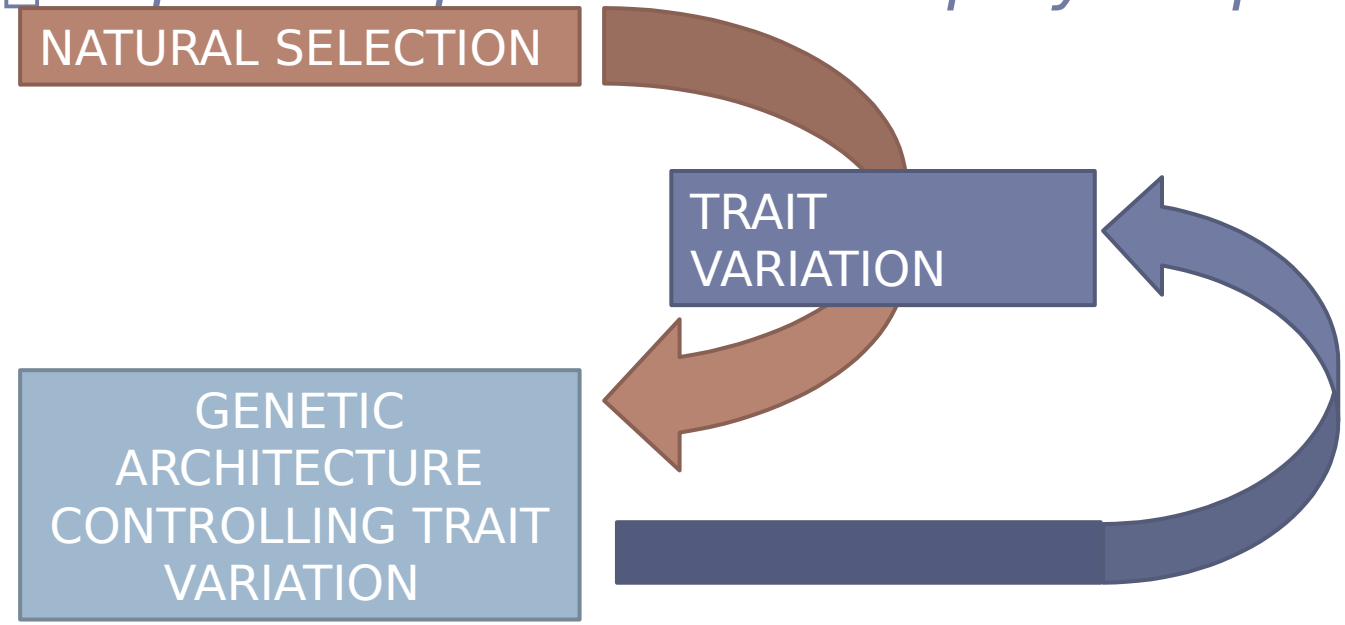
 Loss of ‘white’ allele in both host & parasite



Llaurens & Spottiswoode in prep.

Genetic architecture & polymorphism

- Dominance of alleles controlling egg colour variations
- *Impact on persistence of polymorphism*

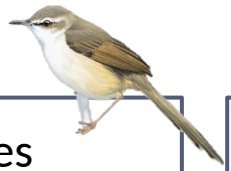


Llaurens & Spottiswoode in prep.

Hypothetical genetic architecture (4)

- Co-dominance in host allowing ‘green’ egg colour.

Host



Phenotypes		Genotypes	
		strict dominance between b and p	*co-dominance between b and p*
	*pink*		*pp or wp*
	*white*		*ww*
	*blue*		*bb or wb*
	*green*		*bp*

Parasite

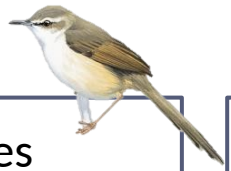
Phenotypes		Genotypes	
		Autosomal	*W-linked*
	*pink*		*Wp*
	*white*		*Ww*
	*blue*		*Wp*

Llaurens & Spottiswoode in prep.

Hypothetical genetic architecture (4)

- Co-dominance in host allowing ‘green’ egg colour.

Host



Phenotypes		Genotypes	
		strict dominance between b and p	*co-dominance between b and p*
	*pink*		*pp or wp*
	*white*		*ww*
	*blue*		*bb or wb*
	*green*		*bp*

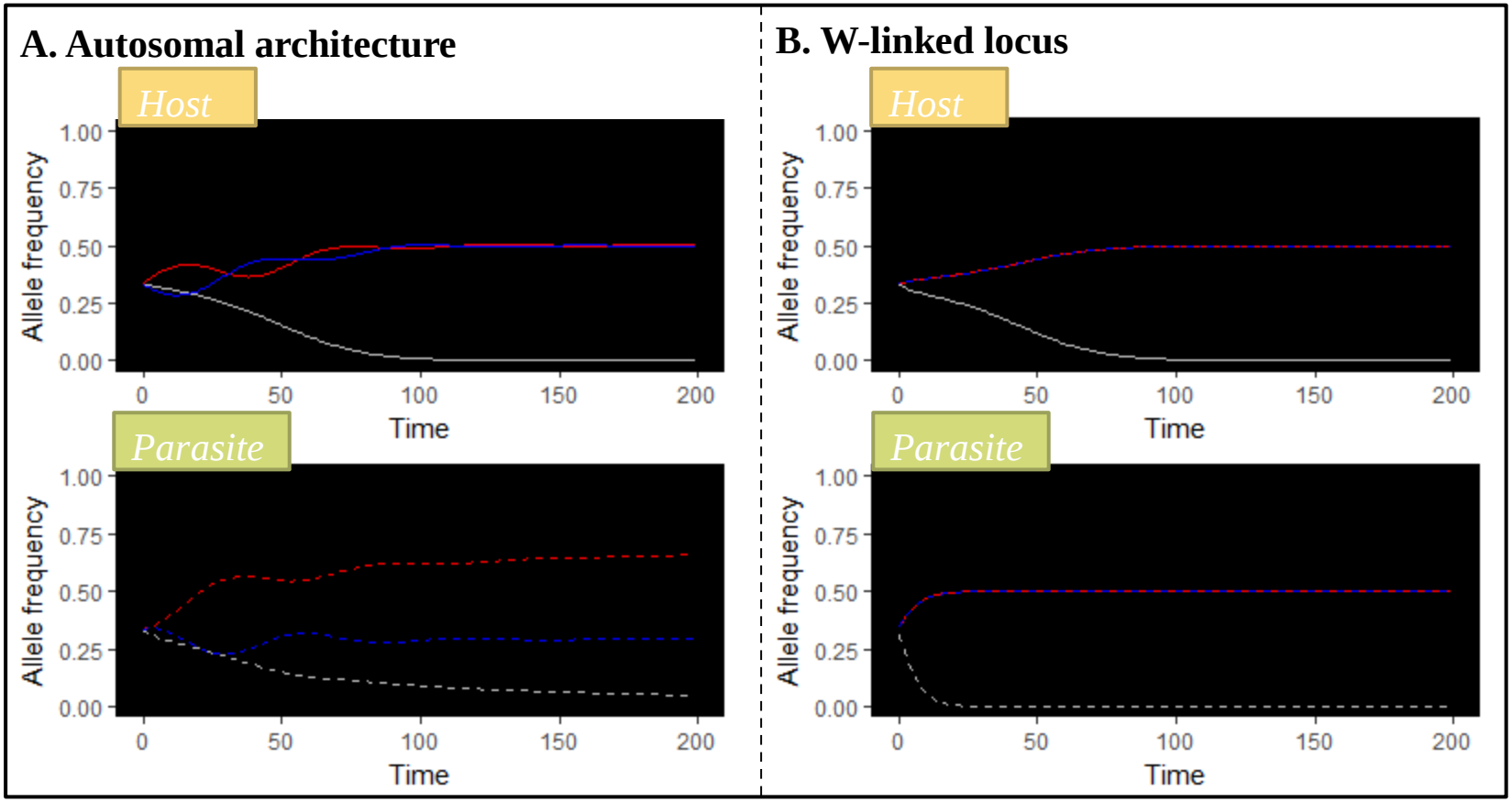
Parasite

Phenotypes		Genotypes	
		Autosomal	*W-linked*
	*pink*	*pp or wp*	
	*white*	*ww*	
	*blue*	*bb or bp*	

Llaurens & Spottiswoode in prep.

Hypothetical genetic architecture (4)

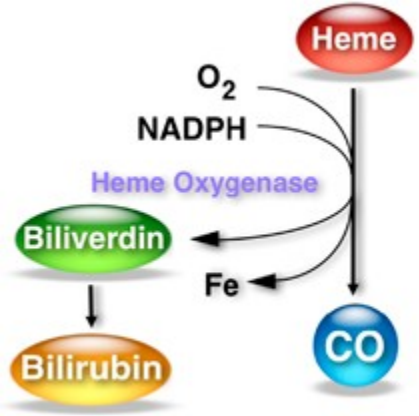
- Co-dominance in host allowing ‘green’ egg colour when both autosomal.



Llaurens & Spottiswoode in prep.

Perspectives

- Explore host and parasite costs parameters space
- Add pigmentation cost ?



- Quantitative variations at locus *N (reflecting colour diversity found in natural population)*

- Finite populations model

Take home message

- Balancing selection & persistence of polymorphism
- Importance of dominance
  - Significant differences between diploid and haploid model
  - (Smadi, Leman & Llaurens JTB 2018)
- Interactions between genetic architecture and selection regime

Thank you for your attention !

Many thanks to Claire Spottiswoode !!