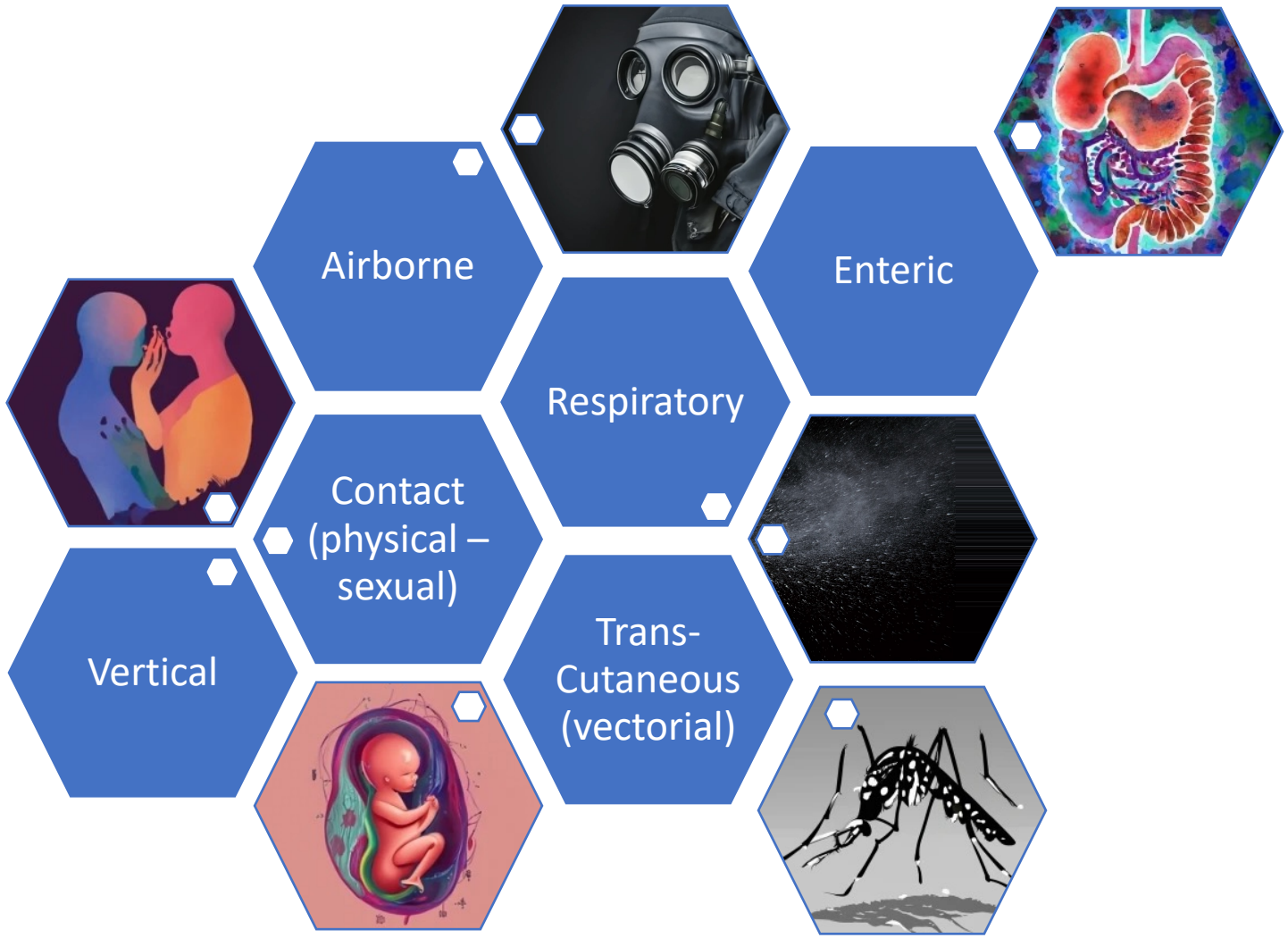
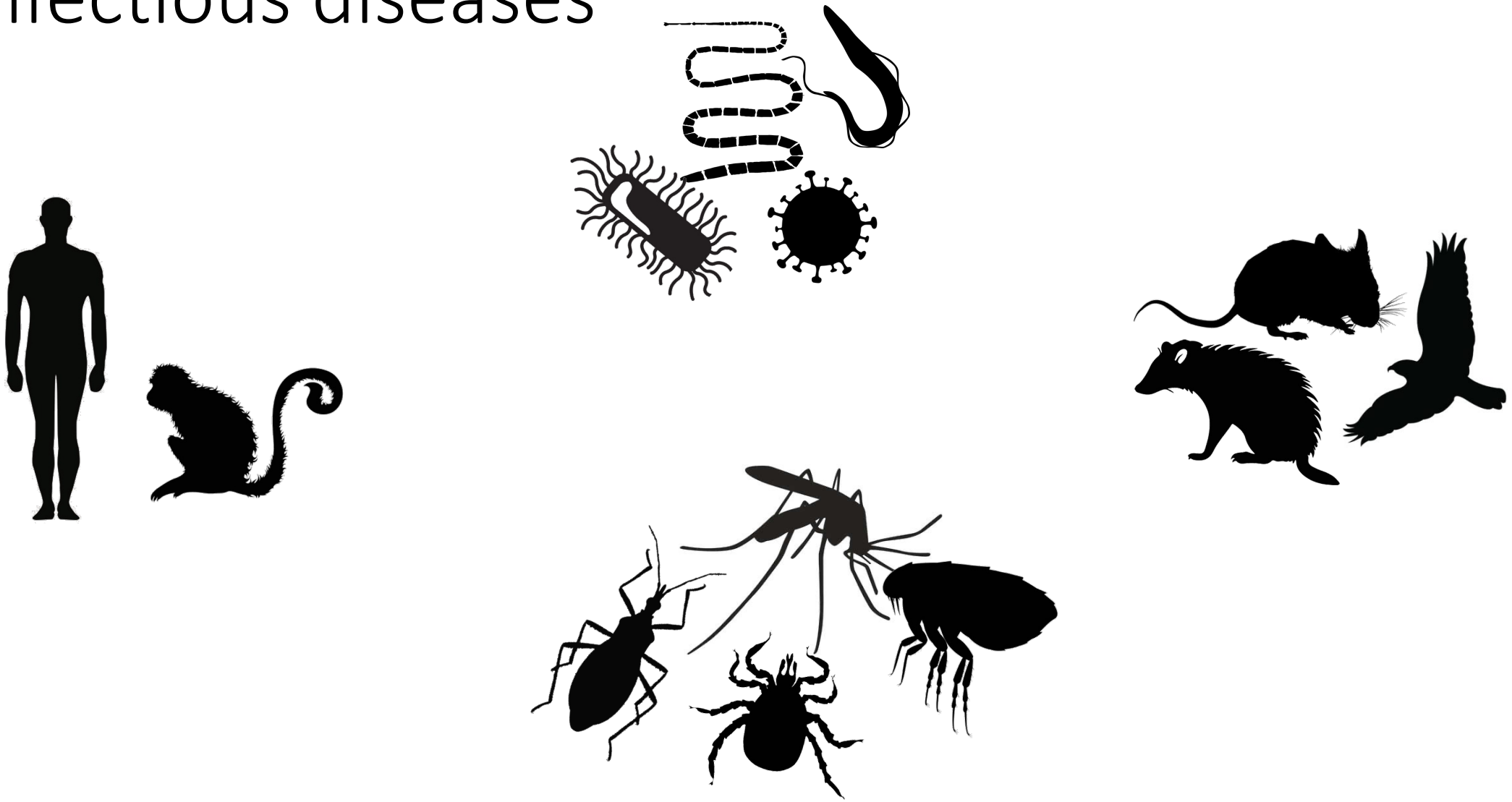
Introduction to Traits

- Define a “trait”
- Understand the role of traits (and their variation)
- Discuss how traits can be incorporated into transmission predictions

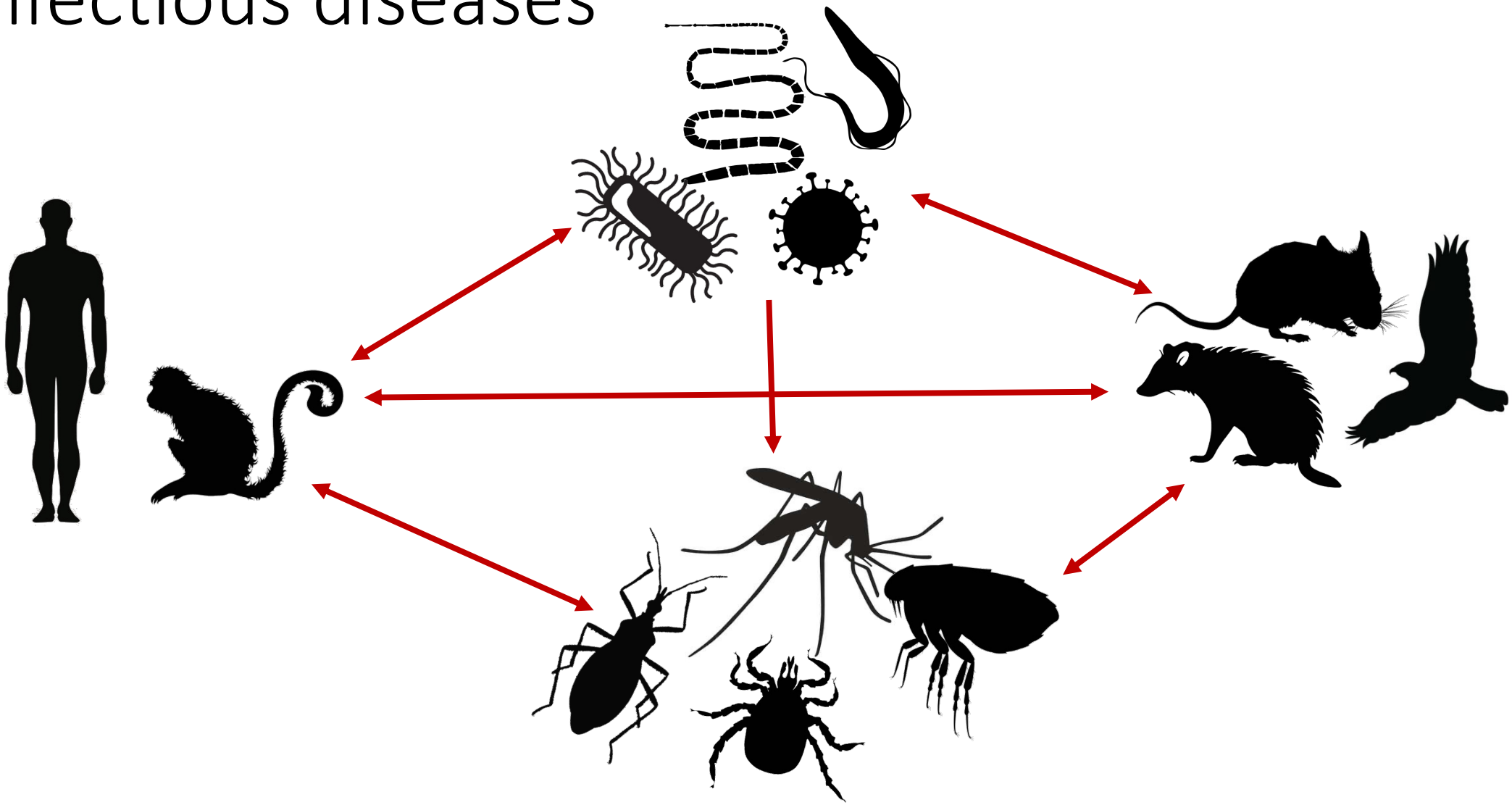
How infectious diseases are transmitted?



Multiple “actors” involved in transmission of infectious diseases

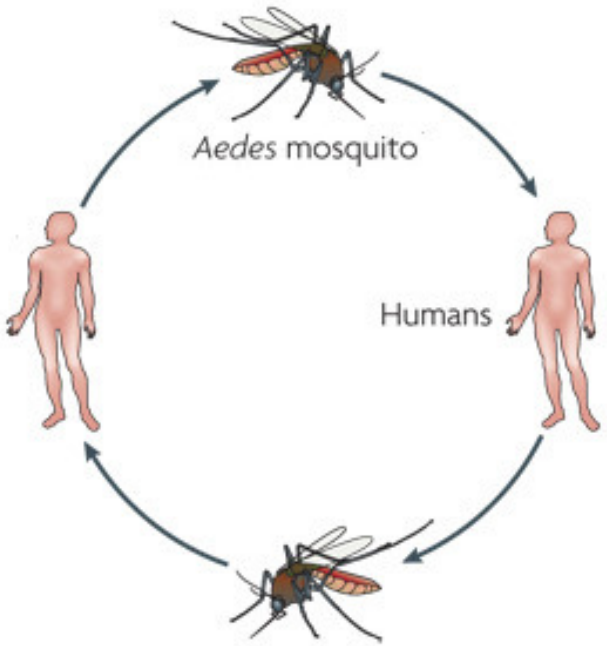


Multiple “actors” involved in transmission of infectious diseases

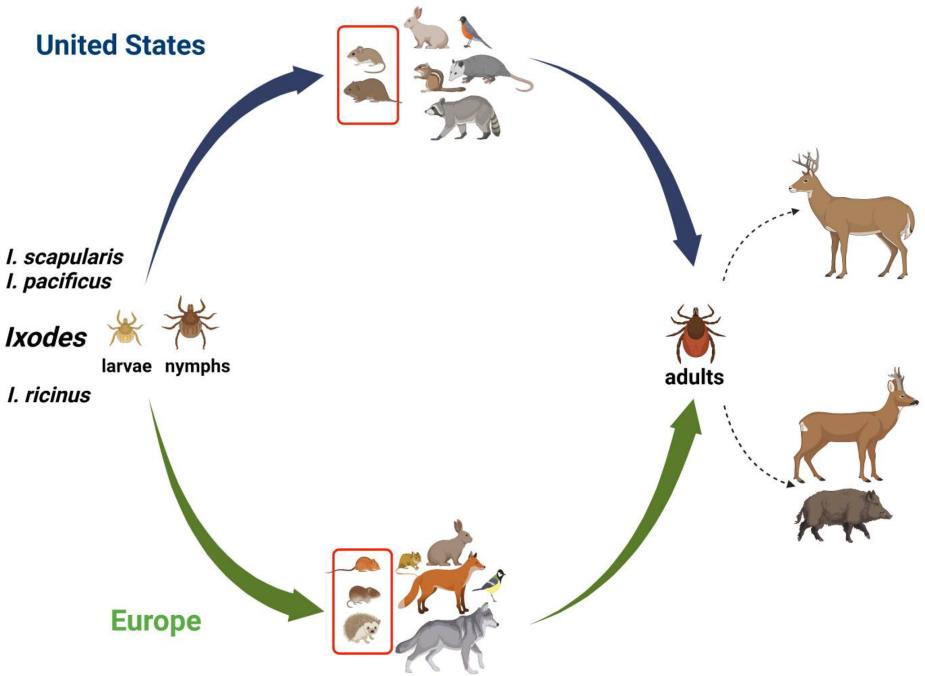


Dynamics of transmission depends of involved species

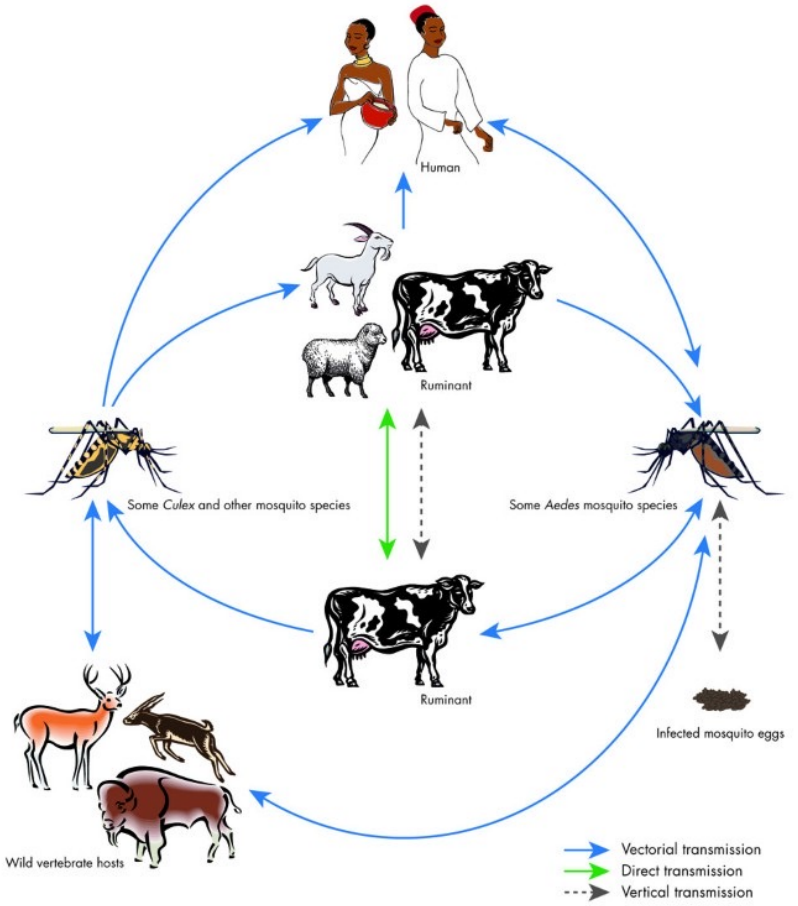
Dengue



Tick-Borne infections



Rift Valley Fever

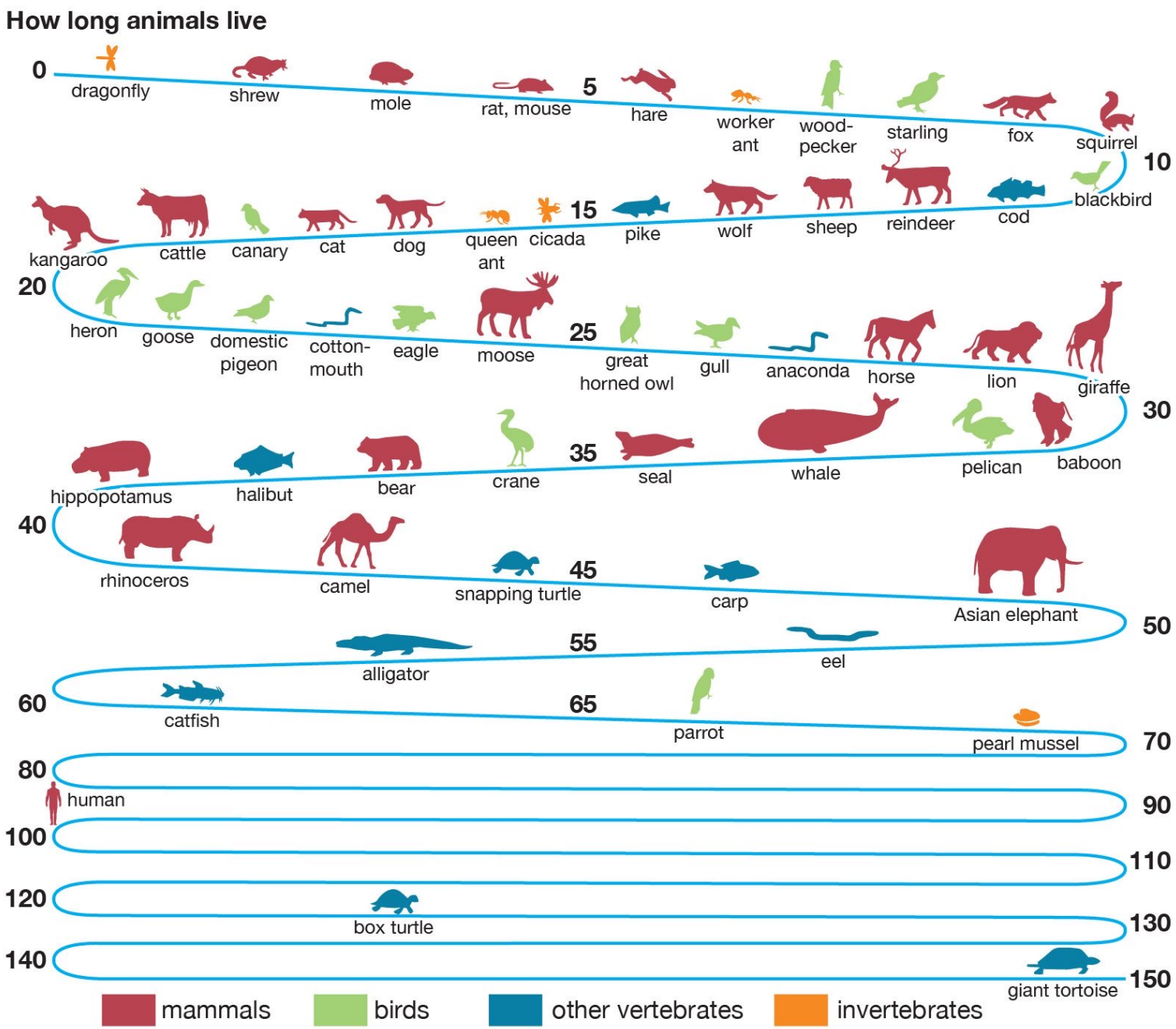


Whitehead, S. S. *et al.* Prospects for a dengue virus vaccine. *Nature Reviews Microbiology* 5, 518–528 (2007)

Rocha SC, Velásquez CV, Aquib A, Al-Nazal A, Parveen N. Transmission Cycle of Tick-Borne Infections and Co-Infections, Animal Models and Diseases. *Pathogens*. 2022; 11(11):1309

Balenghien, T., Cardinale, E., Chevalier, V. *et al.* Towards a better understanding of Rift Valley fever epidemiology in the south-west of the Indian Ocean. *Vet Res* **44**, 78 (2013).

An example on how there is variation among species: lifespan

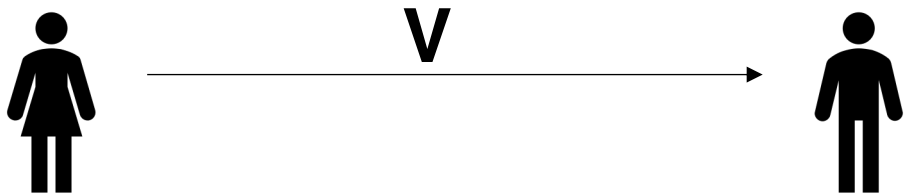


Maximum ages, in years, that certain animals may be expected to reach, based on reports of zoos and estimates of biologists. (Data from S.S. Flower, "The Duration of Life in Animals," in *Proceedings of the London Zoological Society*.)

How these variations affects transmission?

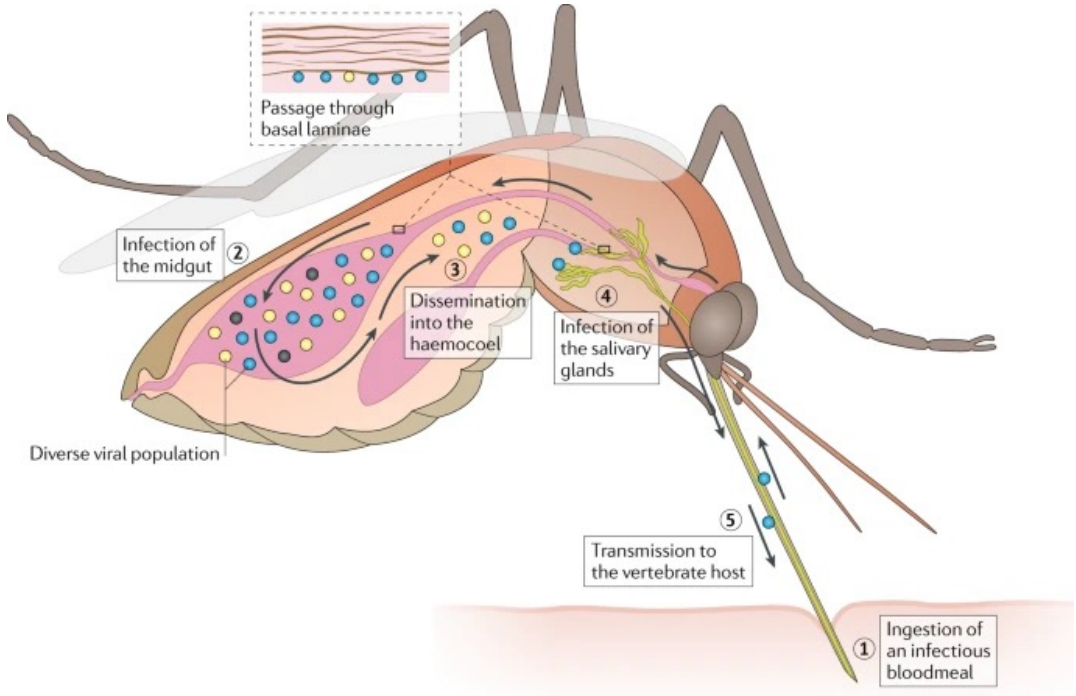
The case of vector-borne diseases

- any agent which carries and transmits an infectious agent between hosts → Vector

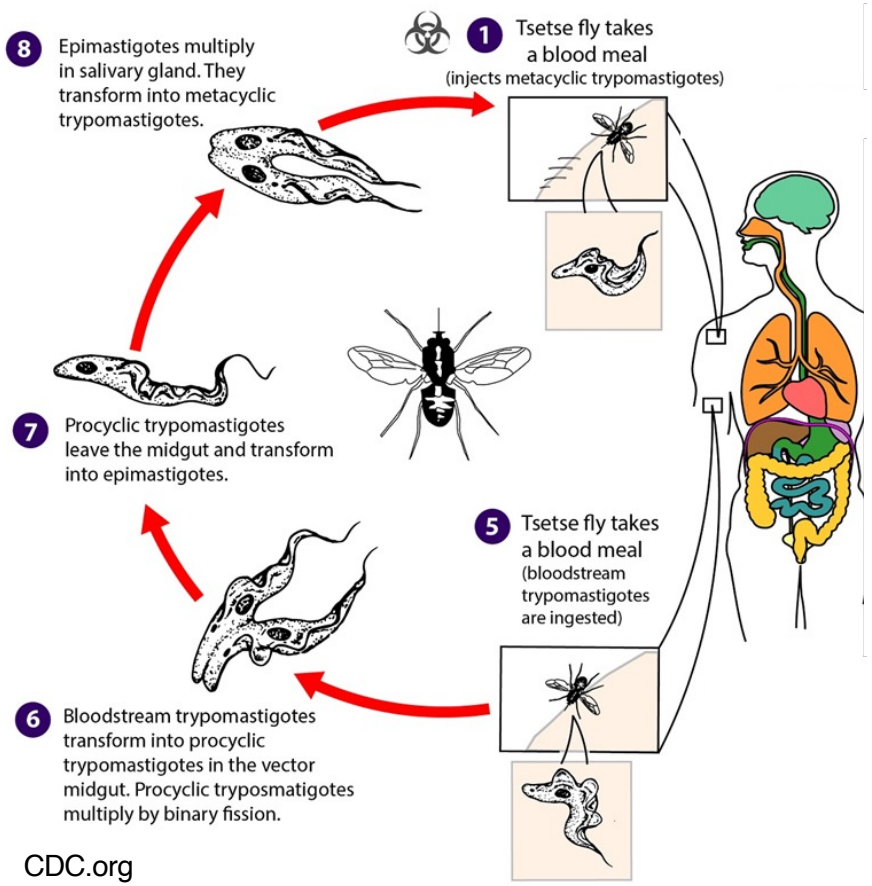


Overview of VBD Transmission

- Biological transmission

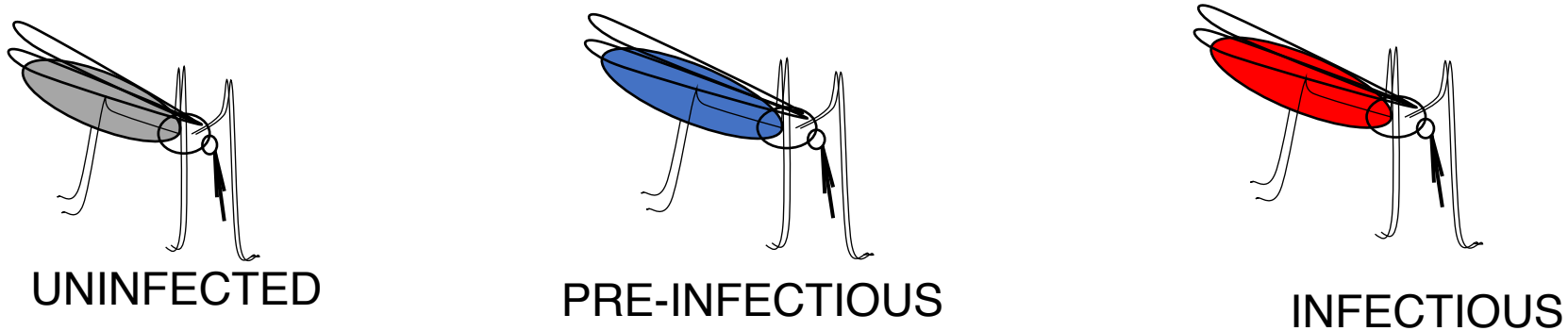


Weaver et al. 2021 *Nature Reviews Microbiology*

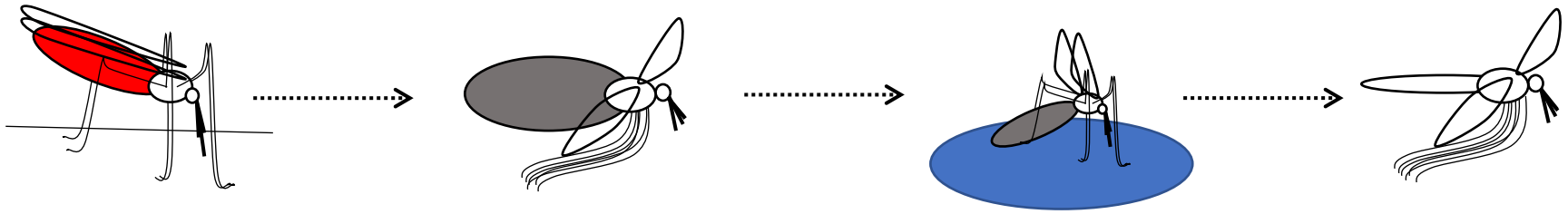


CDC.org

Pathogens undergo obligate development in the mosquito

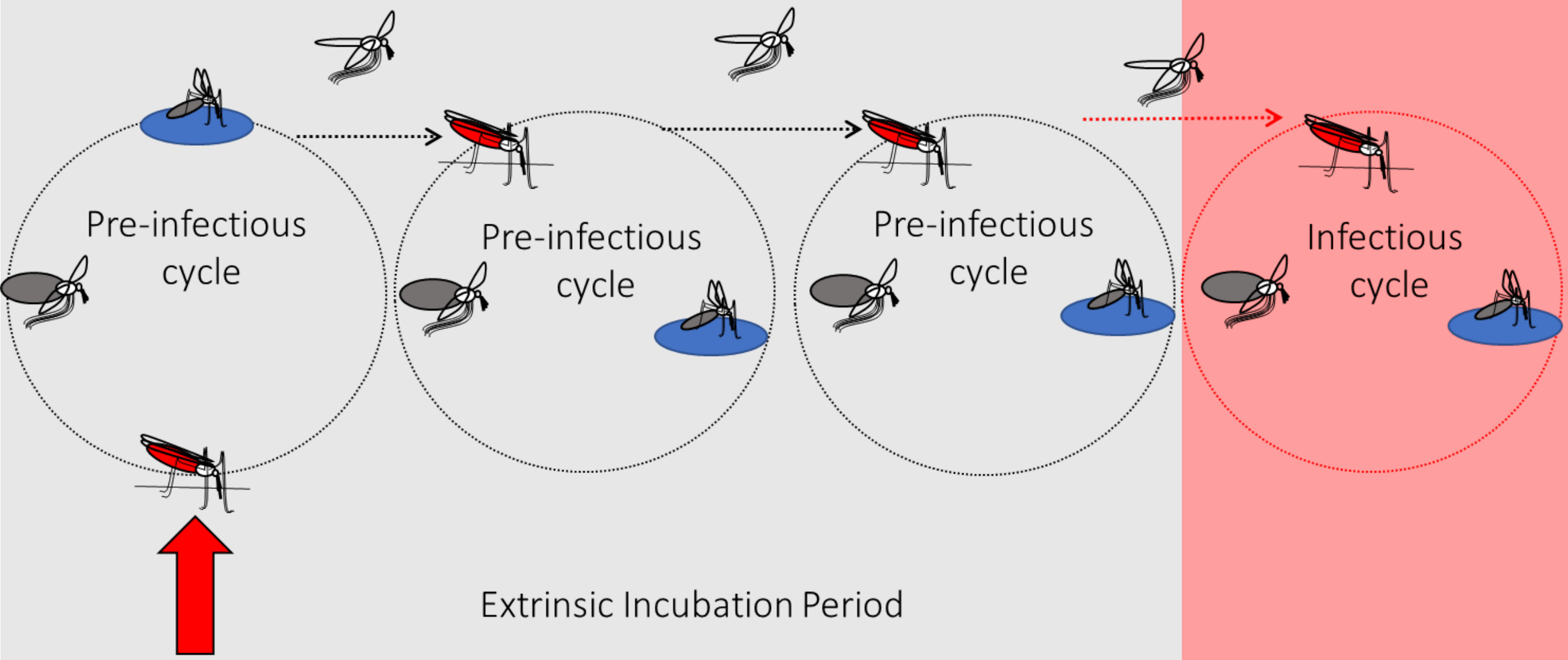


Extrinsic Incubation Period
(EIP)
Malaria: 10-12 Days
Dengue: 3-10 Days

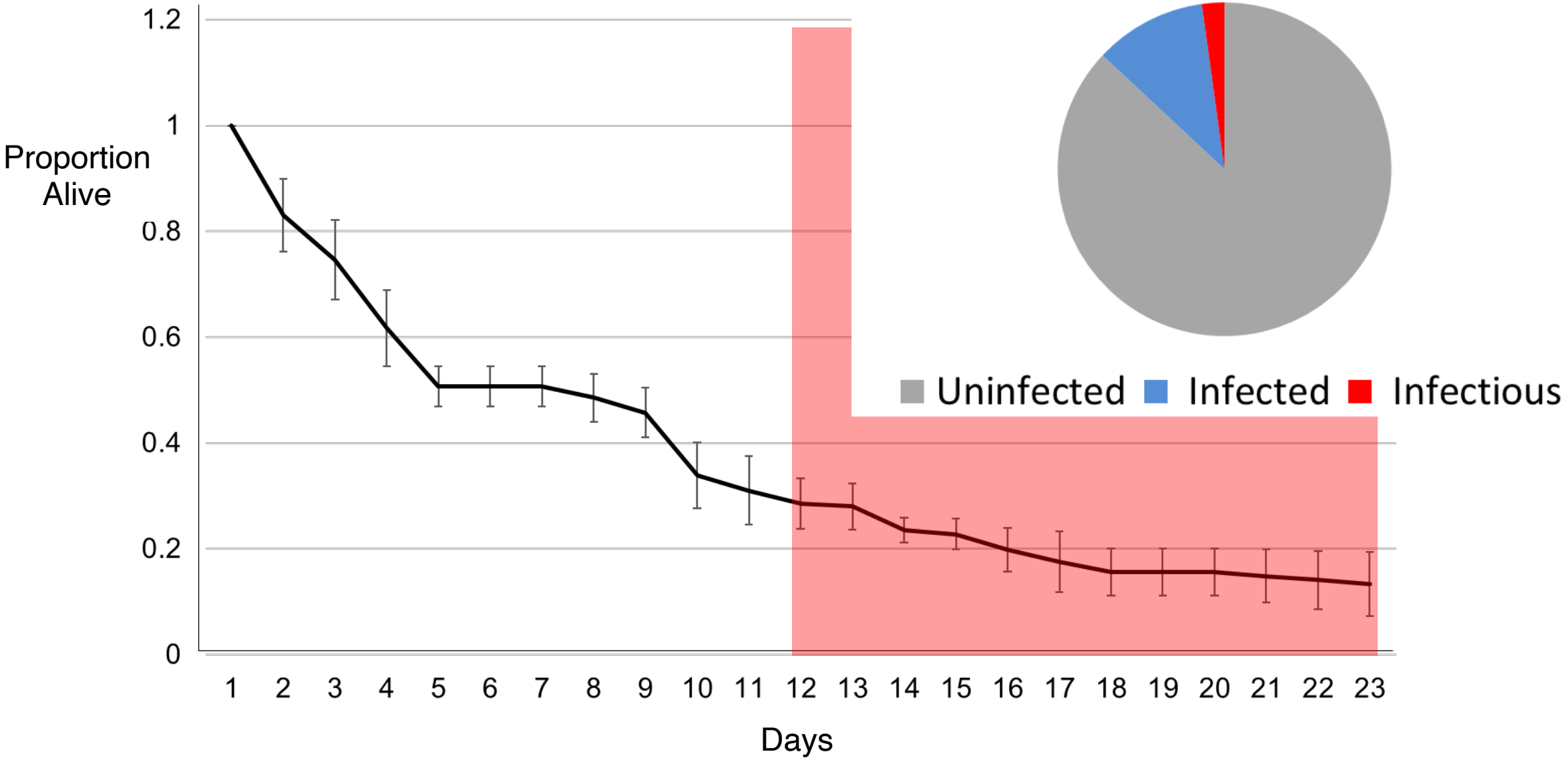


Gonotrophic Cycle
3-4 Days

Transmission is at the intersection of two cycles:

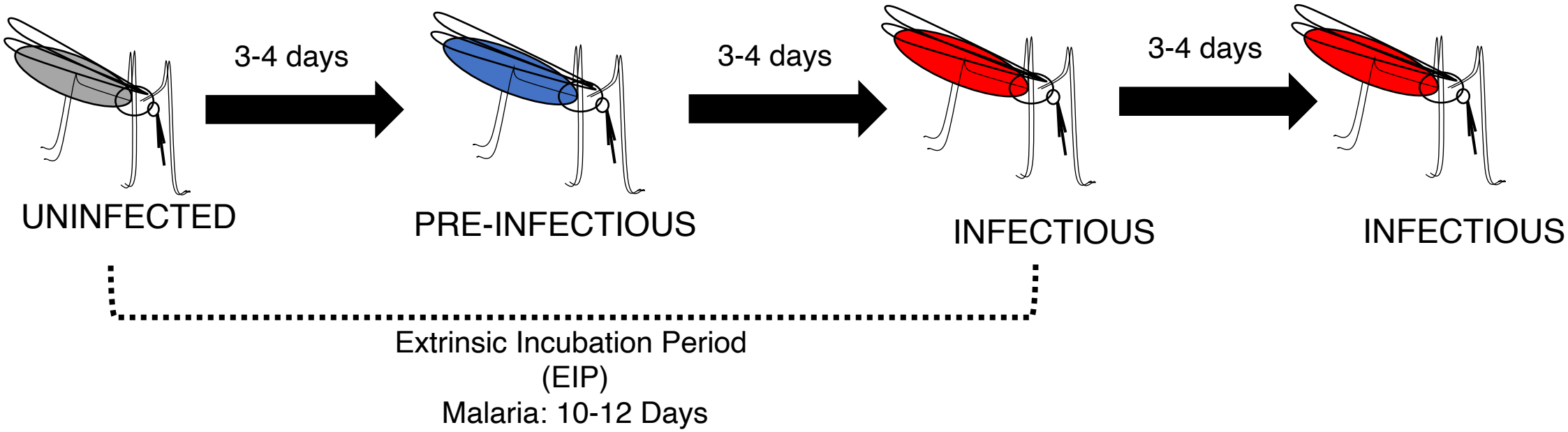


Overview of VBD Transmission- Survival



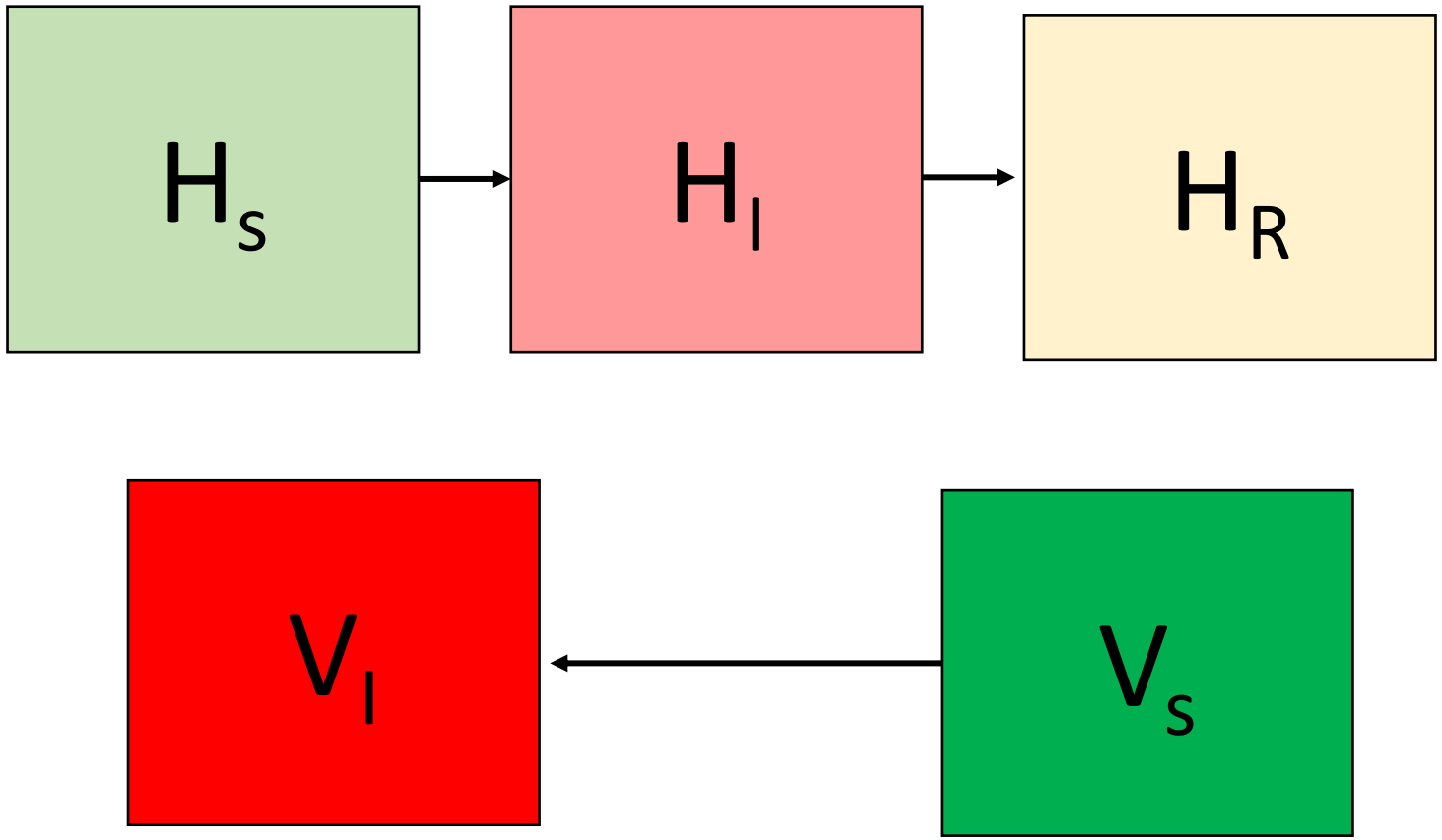
Ohm et al. 2016

Overview of VBD Transmission



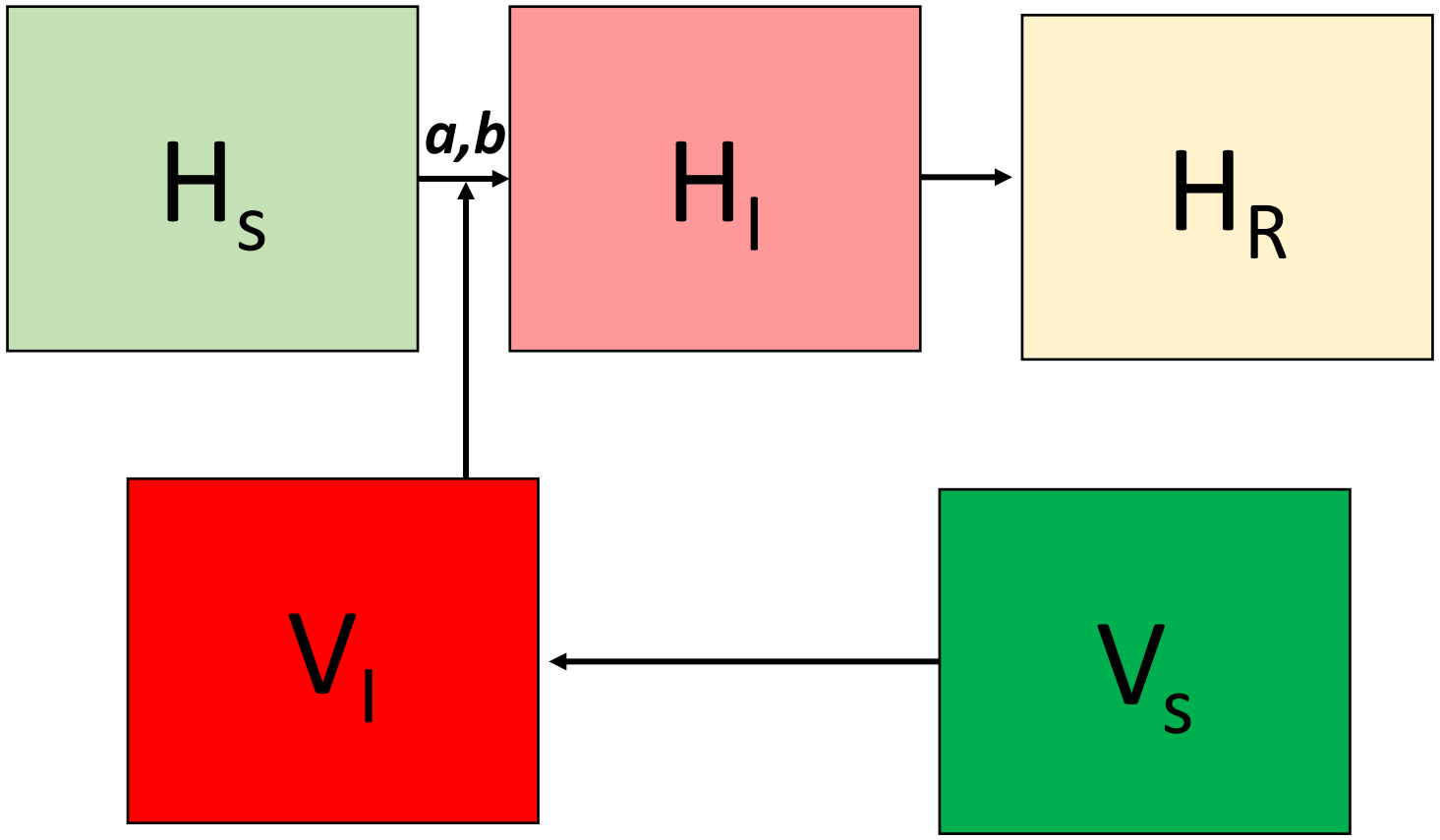
What are the elements we need to include?

Vector-borne Disease Modelling



H= Host, V=Vector $_s$=susceptible, $_I$=infected, $_r$=recovered,

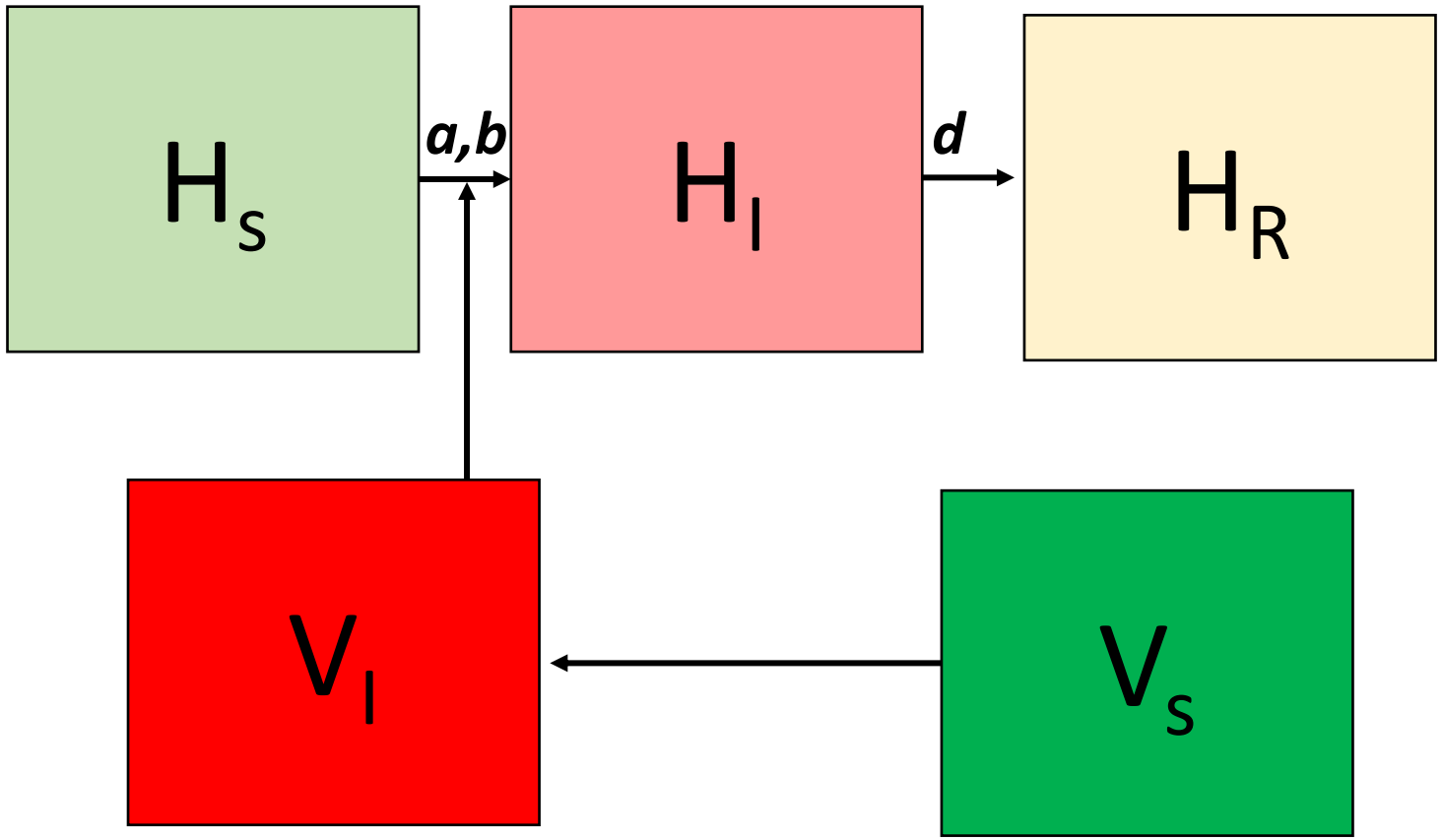
Vector-borne Disease Modelling



H= Host, V=Vector $_s$=susceptible, $_I$=infected, $_r$=recovered, $_e$=exposed

a= per-vector biting rate, *b*=vector->host transmission success (proportion of bites)

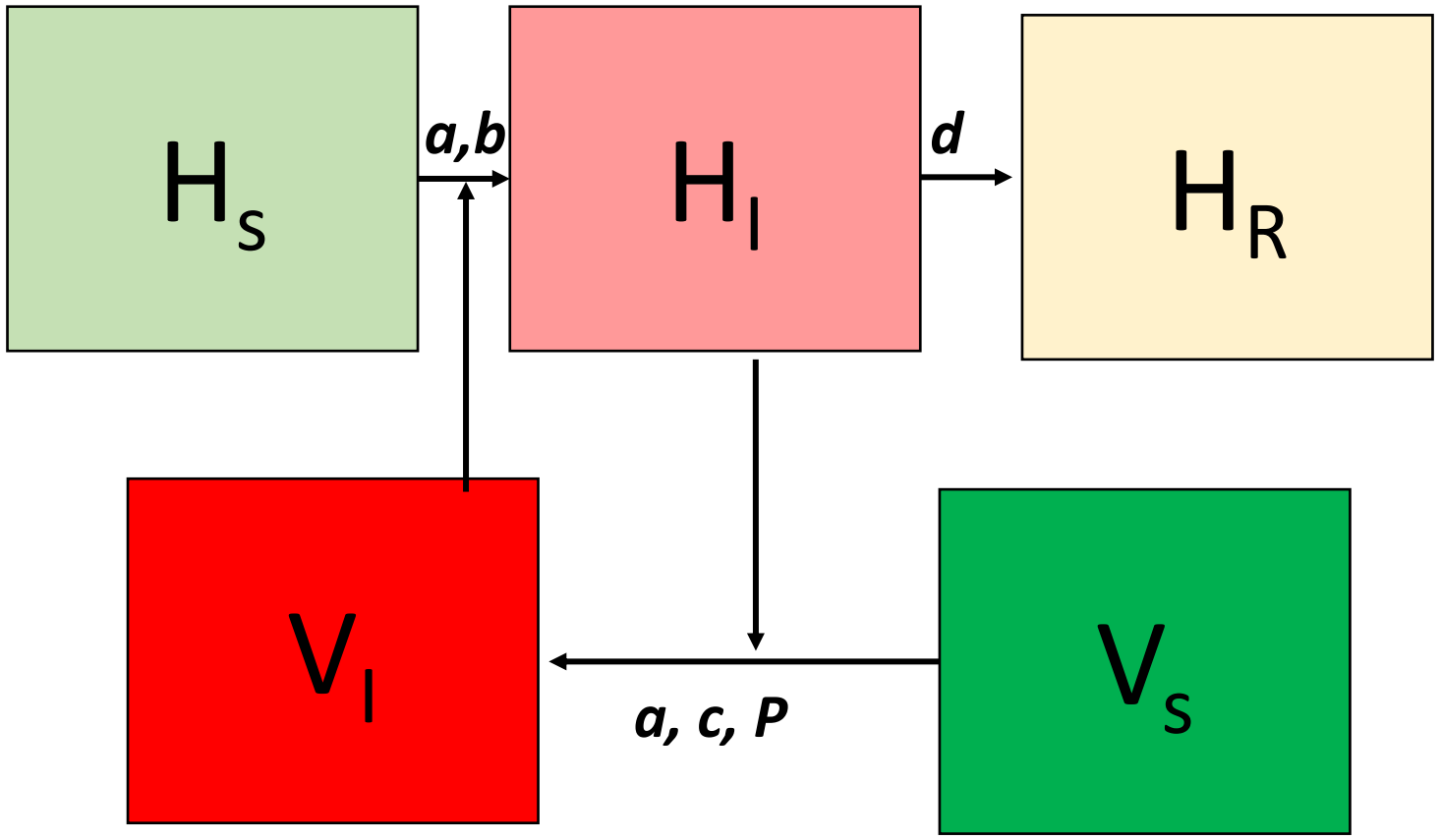
Vector-borne Disease Modelling



H= Host, V=Vector $_s$=susceptible, $_I$=infected, $_r$=recovered, $_e$=exposed

a= per-vector biting rate, *b*=vector->host transmission success (proportion of bites), *d*=recovery

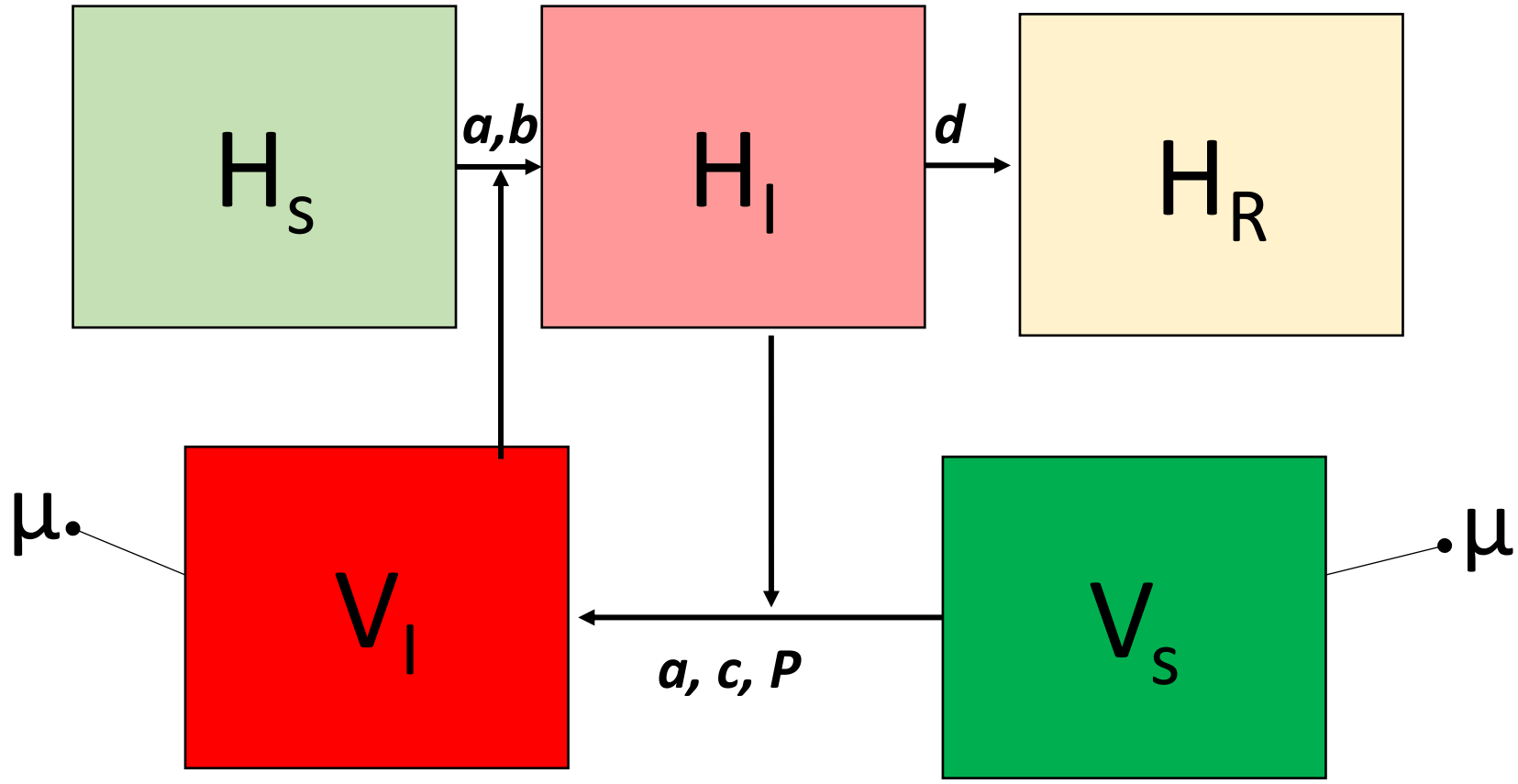
Vector-borne Disease Modelling



H= Host, V=Vector $_s$=susceptible, $_I$=infected, $_r$=recovered, $_e$=exposed

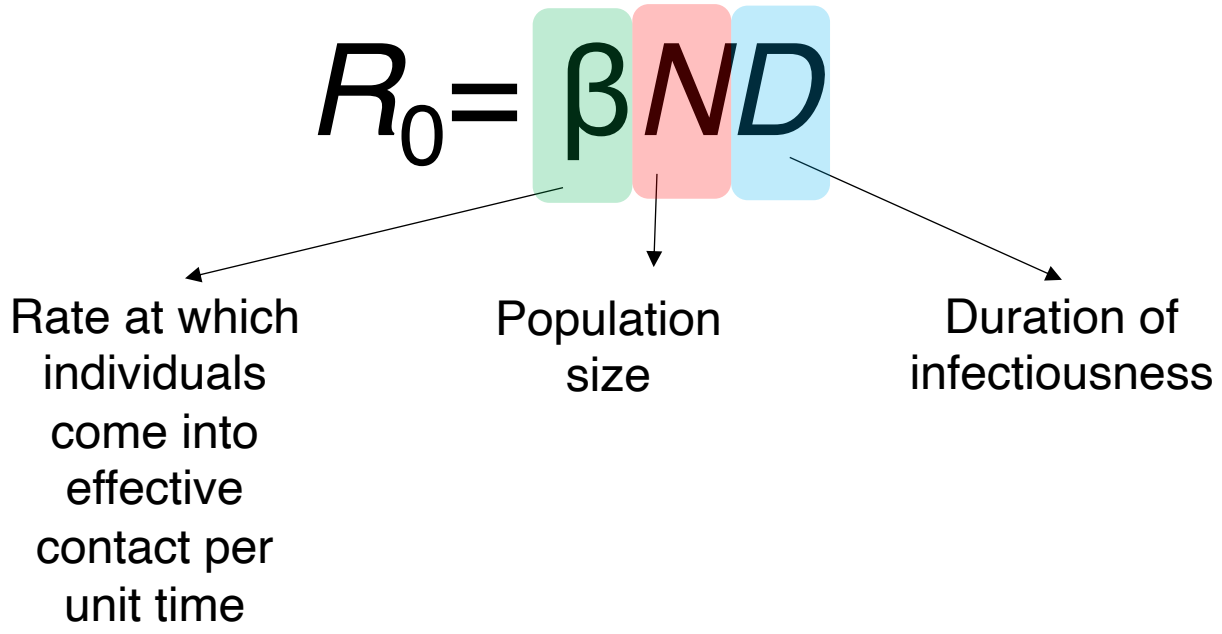
a= per-vector biting rate, *b*=vector->host transmission success (proportion of bites), *c*= host-> vector transmission success (proportion of bites), *d*=recovery, rate, *P*= extrinsic incubation period

Vector-borne Disease Modelling



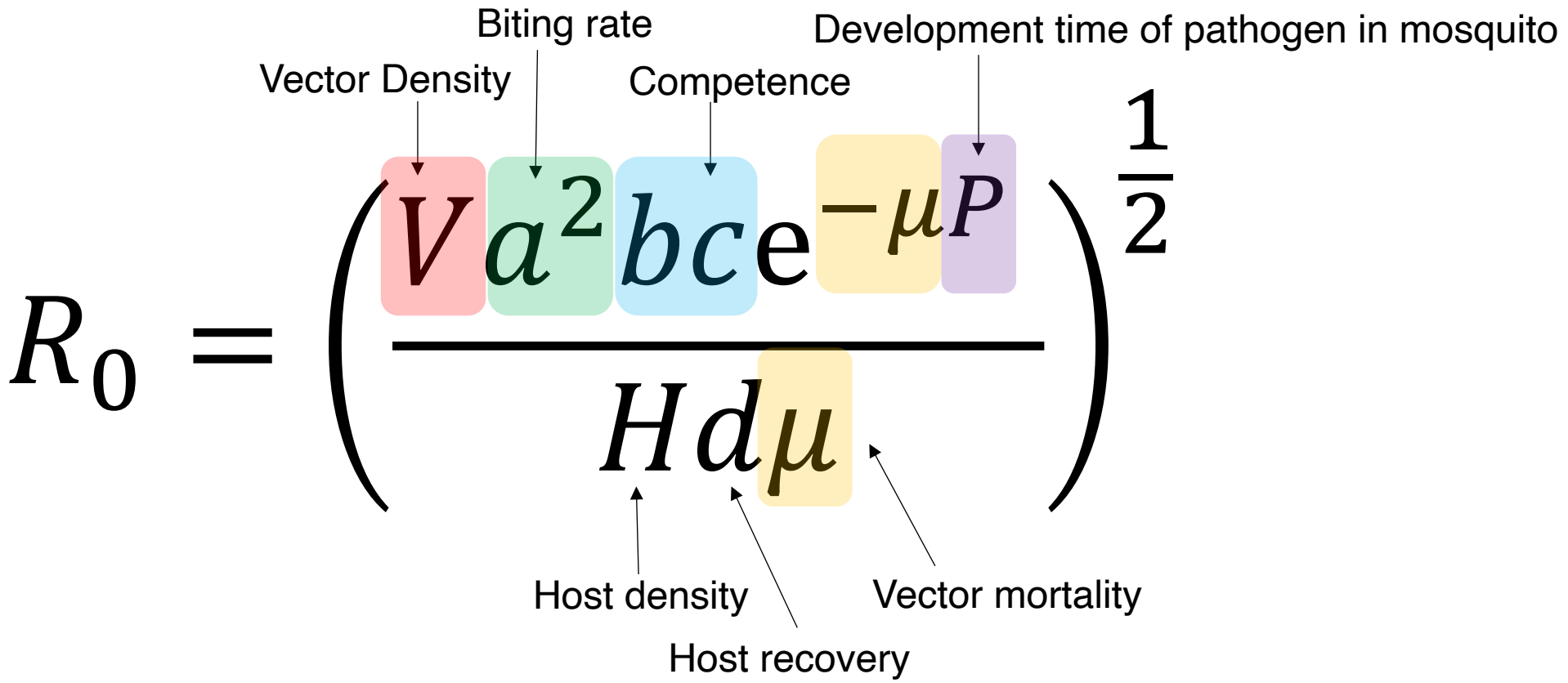
H= Host, V=Vector $_s$=susceptible, $_I$=infected, $_r$=recovered, $_e$=exposed, *a*= per-vector biting rate, *b*=vector->host transmission success (proportion of bites), *c*= host-> vector transmission success (proportion of bites), *d*=recovery, rate, *P*= extrinsic incubation period, μ= adult vector mortality rate

R_0 for a Directly-Transmitted Pathogen



The higher the contact rate, population size, and infectious period the greater the R0.

R_0 for a Vector-Borne Disease



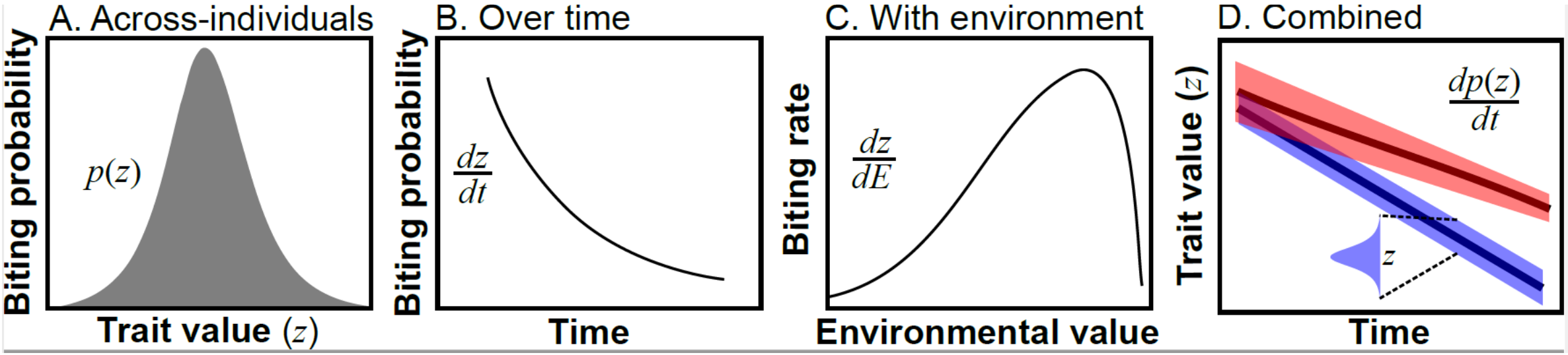
Trait

any measurable feature of an individual organism

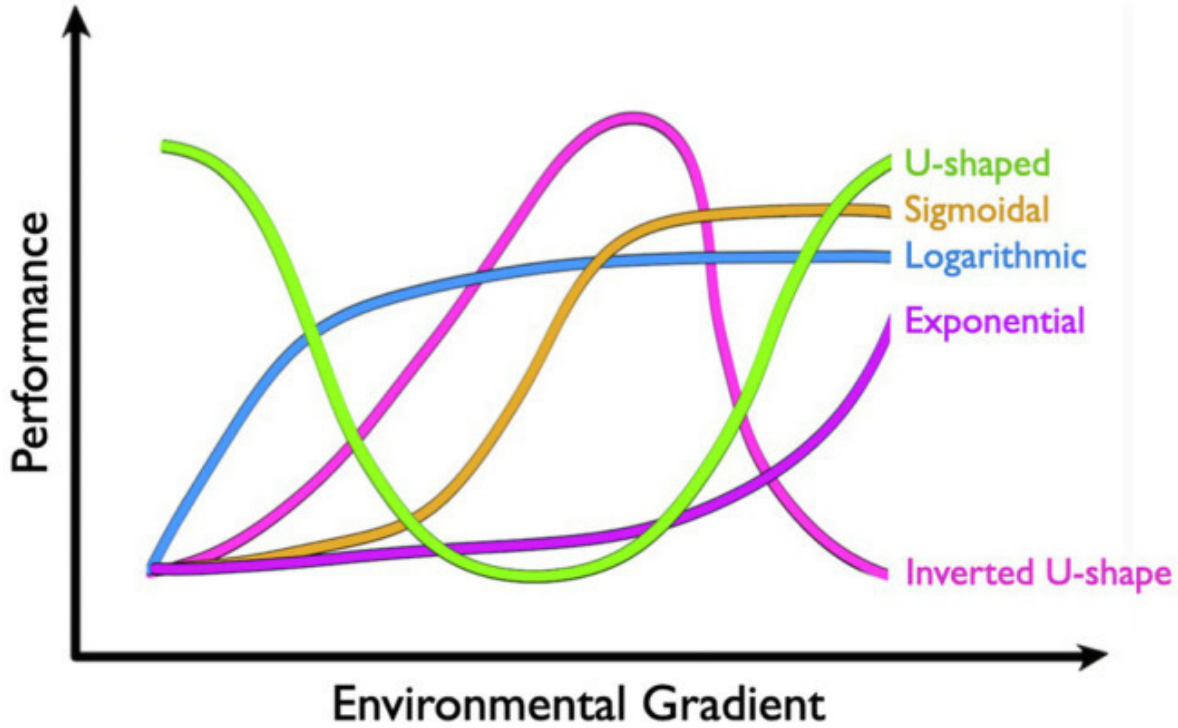
Functional trait

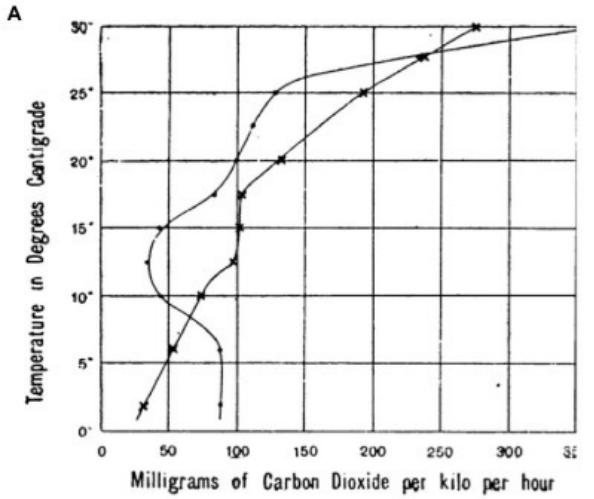
feeding rate, size, metabolic rate, eggs per day

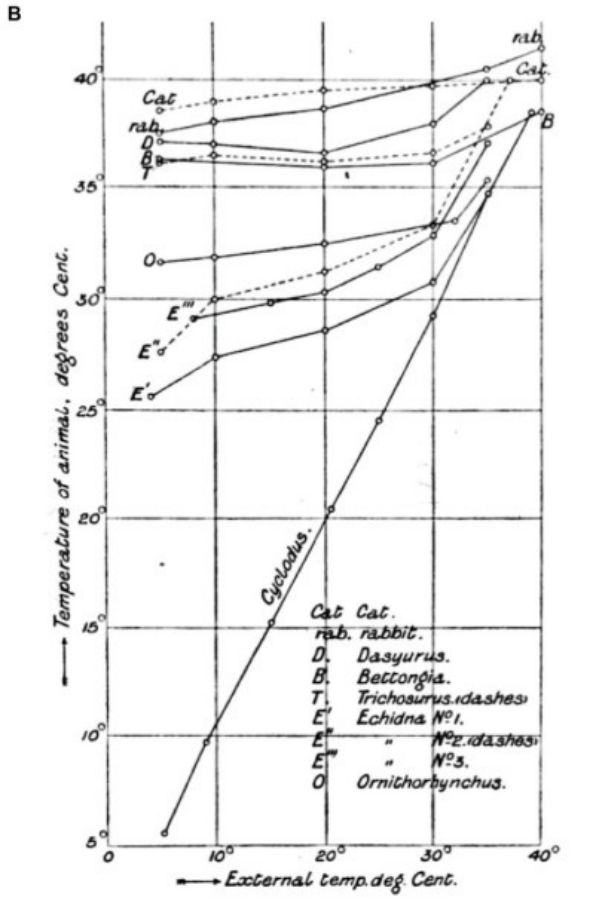
Some traits respond to environment, the environment changes, so traits vary:

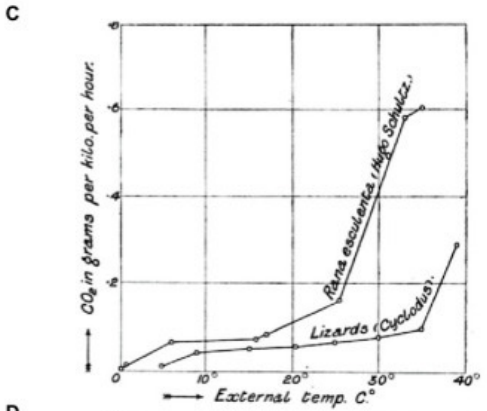


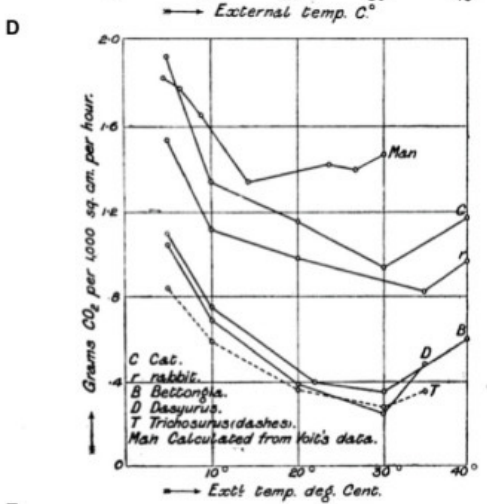
Traits vary:

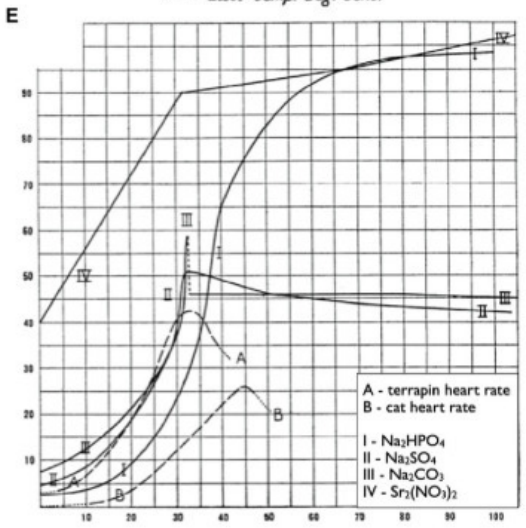




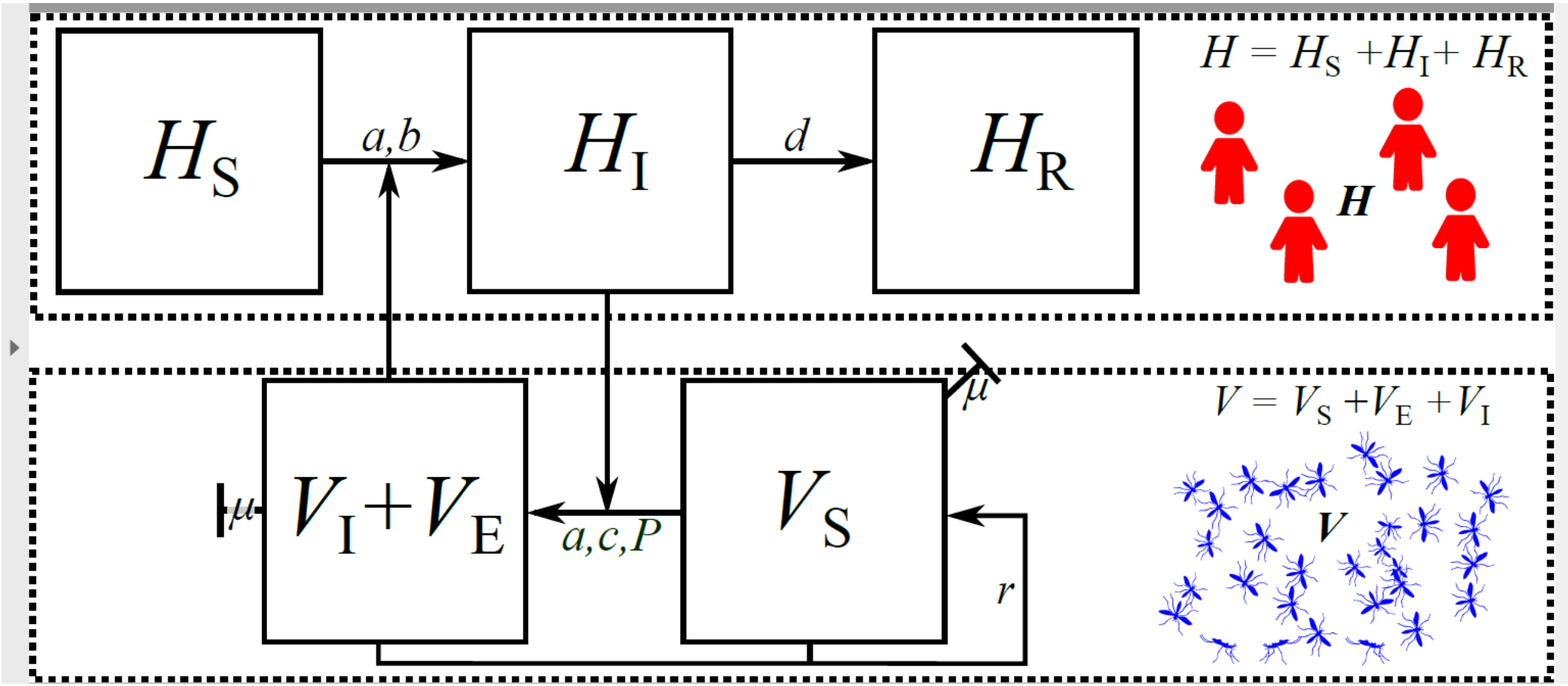


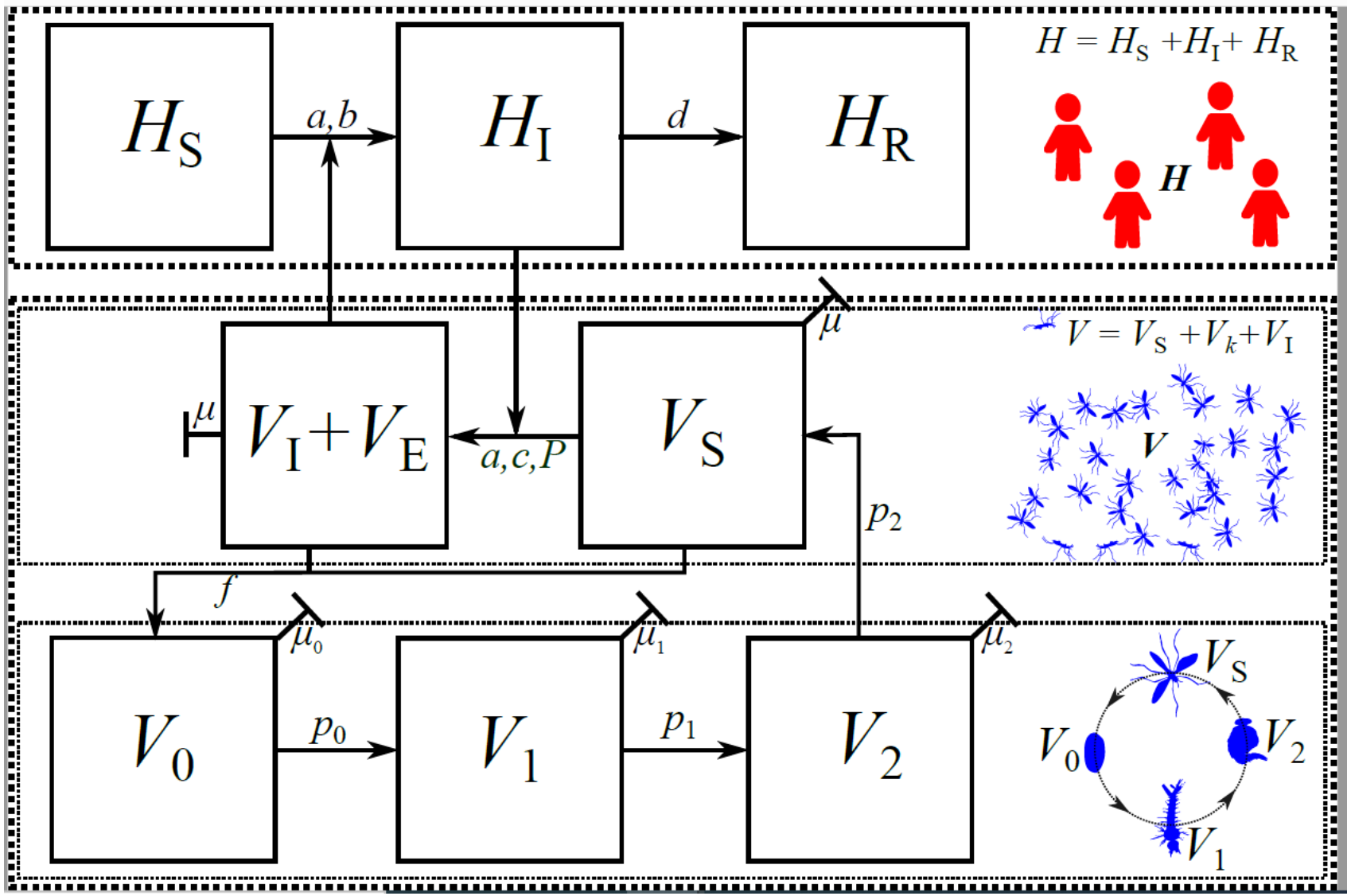


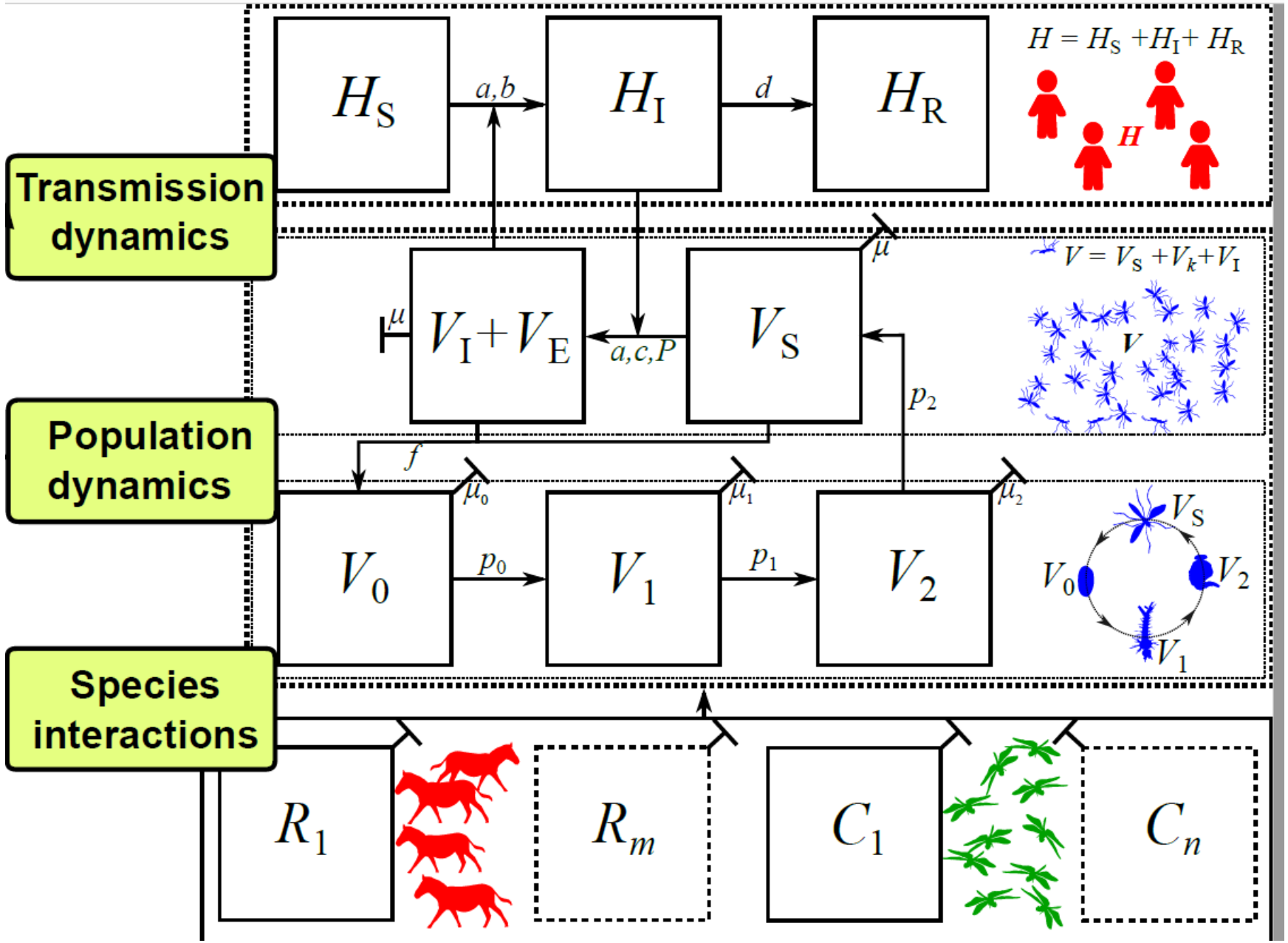


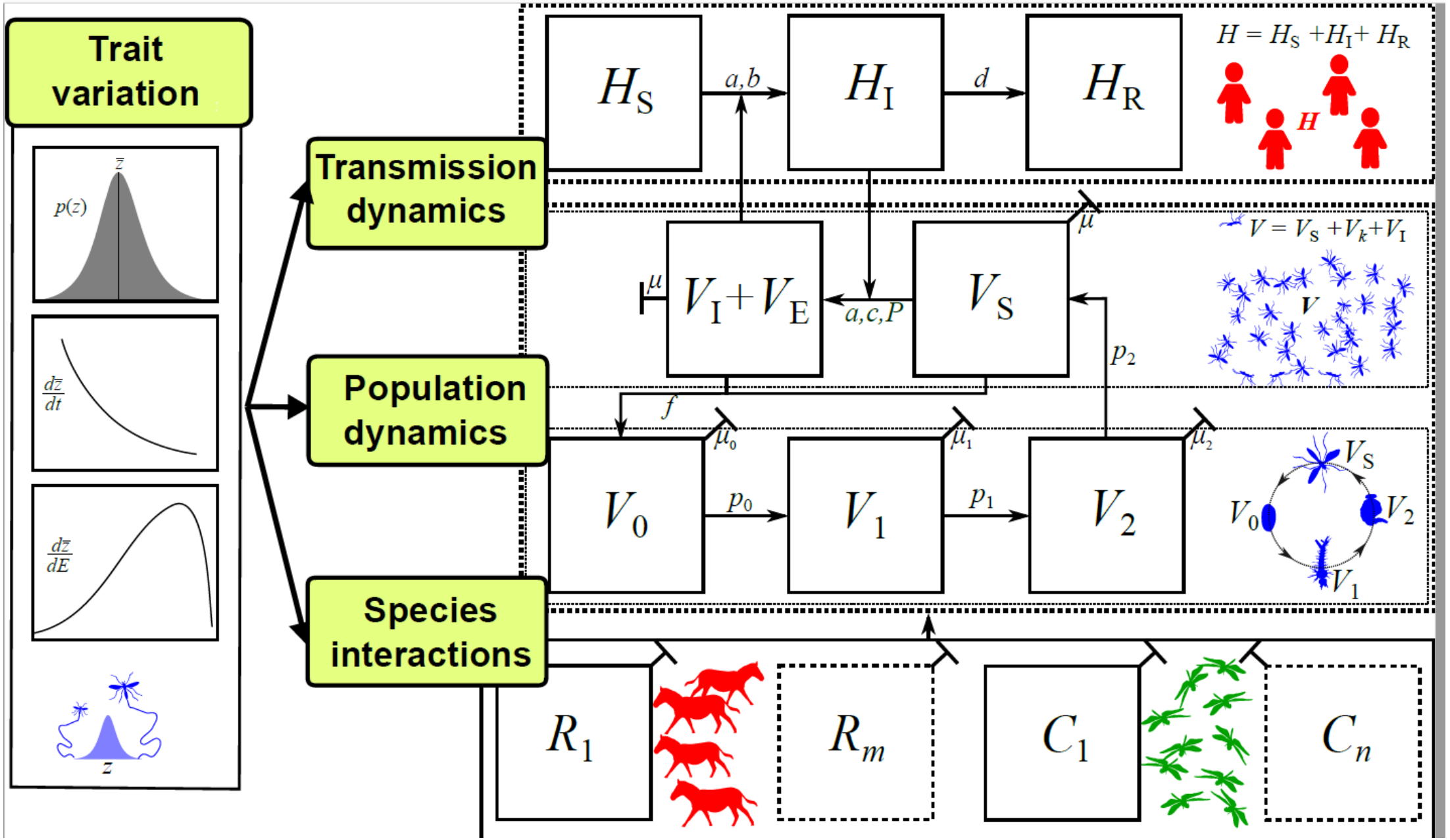


Little AG, Seebacher F. Physiological Performance Curves: When Are They Useful? Front Physiol. 2021 Dec 2;12:805102


H_S
a,b
H_I
d
H_R
$H = H_S + H_I + H_R$
H
μ
$V_I + V_E$
a,c,P
V_S
μ
r
$V = V_S + V_E + V_I$
V


H_S
a,b
H_I
d
H_R
$H = H_S + H_I + H_R$
H
μ
$V_I + V_E$
a,c,P
V_S
$V = V_S + V_k + V_I$
V
p_2
f
μ_0
μ_1
μ_2
V_0
p_0
V_1
p_1
V_2
V_S
V_0
V_2
V_1


Transmission dynamics
Population dynamics
Species interactions
H_S
a,b
H_I
d
H_R
$H = H_S + H_I + H_R$
H
μ
$V_I + V_E$
a,c,P
V_S
$V = V_S + V_k + V_I$
V
p_2
f
μ_0
μ_1
μ_2
V_0
p_0
V_1
p_1
V_2
V_S
V_0
V_2
V_1
R_1
R_m
C_1
C_n


Trait variation
$\bar{z}$
$p(z)$
$\frac{d\bar{z}}{dt}$
$\frac{d\bar{z}}{dE}$
z
Transmission dynamics
Population dynamics
Species interactions
H_S
a,b
H_I
d
H_R
$H = H_S + H_I + H_R$
H
μ
$V_I + V_E$
a,c,P
V_S
$V = V_S + V_k + V_I$
V
p_2
f
μ_0
μ_1
μ_2
V_0
p_0
V_1
p_1
V_2
V_S
V_0
V_2
V_1
R_1
R_m
C_1
C_n