Vector born and macro-parasite diseases

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I. Vector mediated transmission

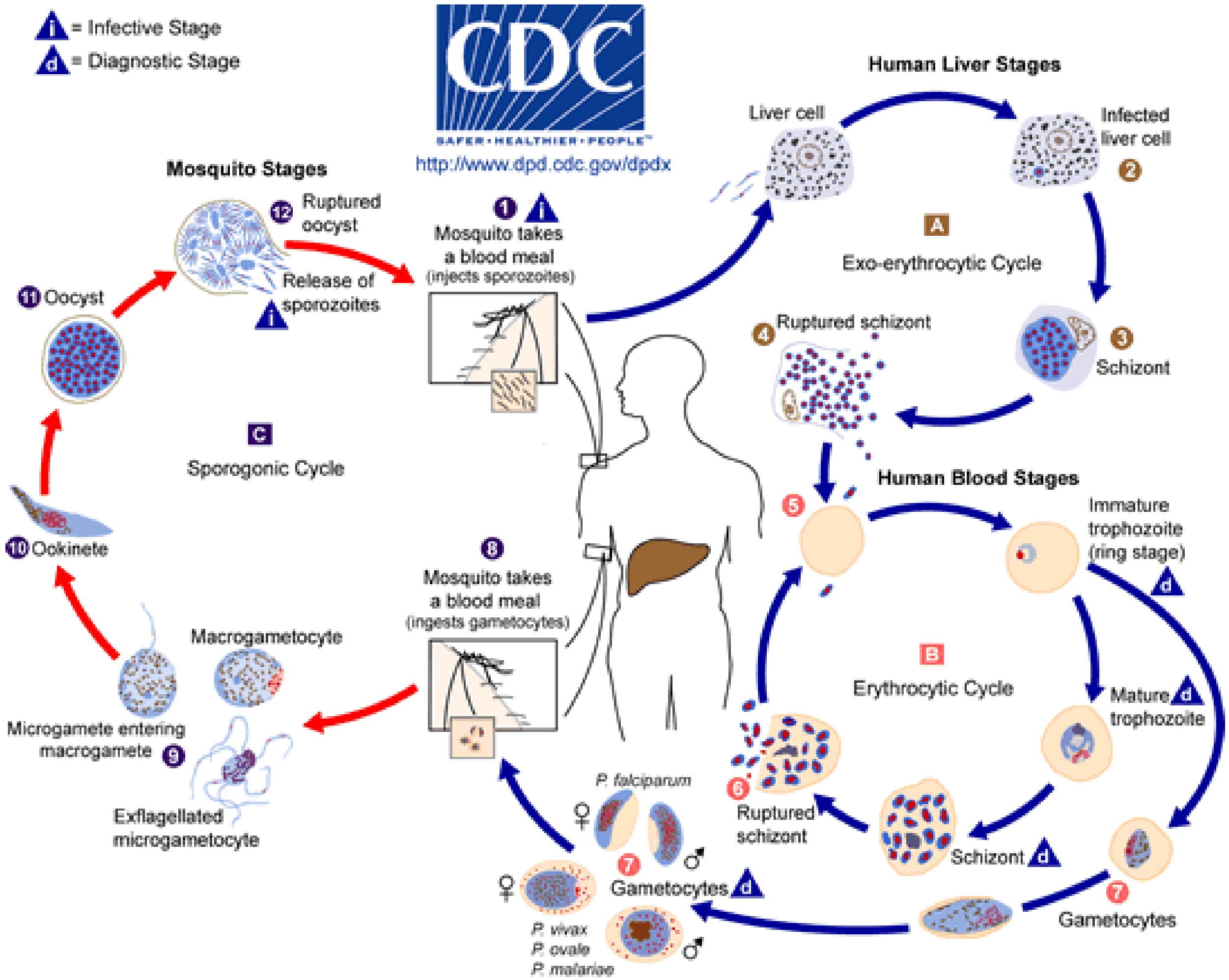
Viral: RVF, Dengue, Yellow fever,…

Protozoa: Malaria, leishmania,…

Macro-parasites (worms): Schistosomiasis,

Filariasis,…

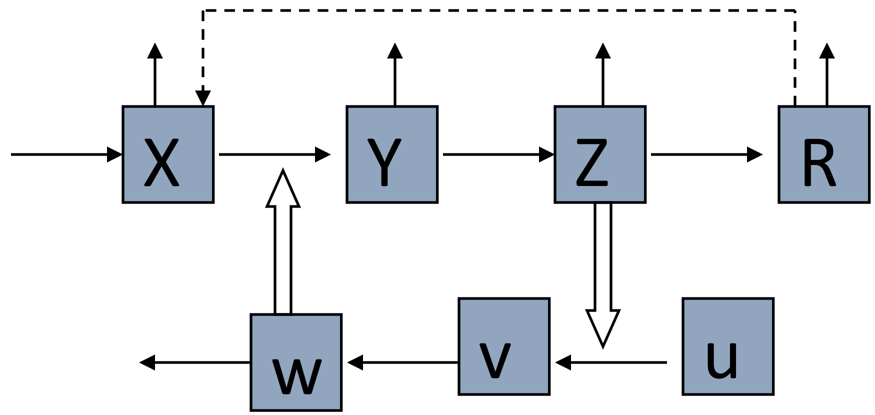
Malaria Life Cycle



Coupled “host-vector” systems

Host:

Vector:



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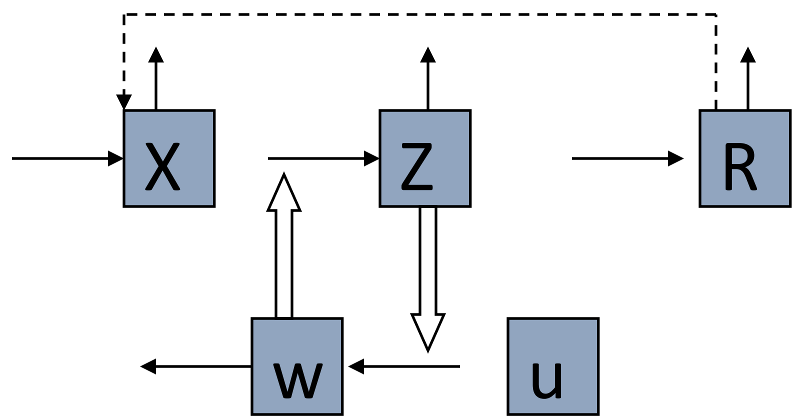
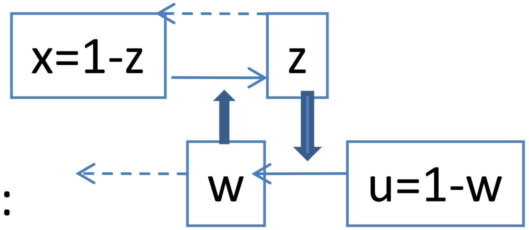


Classical Ross model of malaria (1912)

Human:

Mosquito:



Prevalence DE

$$\dot{z} = \lambda(1-z) - rz$$
$$\dot{w} = \Lambda(1-v) - \mu w$$

Parameters

r	H. recovery	μ	Mosquito mortality
b	Probability of H –infection /bite	a	Probability of M –infection /bite
m	Mosquito no/ host	ω	Mosquito biting rate

Forces of infection:

$$\lambda = bm\omega w$$
$$\Lambda = a\omega z$$

BRN: $$R_0 = \frac{abm\omega^2}{r\mu}$$

Endemic Equilibria:

$$z^* = \frac{(1 - 1/R_0)}{1 + r/b\omega m}$$
$$w^* = \frac{(1 - 1/R_0)}{1 + \mu/a\omega}$$

Mosquito control: m, ω ?

Extended “Ross” model with latency (Diezt,...)

	H	M
Latency	*L=?*	*T=10-14d*
Recovery/Mortality	*r=?*	$\mu = 4$*week*

$$\begin{cases} \dot{y} = \lambda x - e^{-rL}\left(\lambda x\right)|_L - ry; \quad x = 1 - y - z \\ \dot{z} = e^{-rL}\left(\lambda x\right)|_L - rz \end{cases}$$

$$\begin{cases} \dot{v} = \Lambda u - e^{-\mu T}\left(\Lambda u\right)|_T - \mu v; \quad u = 1 - v - w \\ \dot{w} = e^{-\mu T}\left(\Lambda u\right)|_T - \mu w \end{cases}$$

BRN:

$$R_0 = \frac{abm\omega^2}{r\mu} e^{-(\mu T + rL)}$$

Basic parameters

Model Parameters:

$$\left.\begin{array}{l} m = \dfrac{\text{mosq. \#}}{\text{host}} \\ \omega = \dfrac{\text{biting rate}}{\text{mosq}} \\ \mu = \text{mosq. mortality} \\ \tau = \text{ mosq. latency} \\ b = \dfrac{\text{prob. M-infection}}{\text{infected bite}} \\ a = \dfrac{\text{prob. H-infection}}{\text{infected bite}} \end{array}\right\} \Rightarrow \lambda_0 = \frac{abm\omega^2 e^{-\mu\tau}}{\mu} \text{ - vectorial capacity}$$

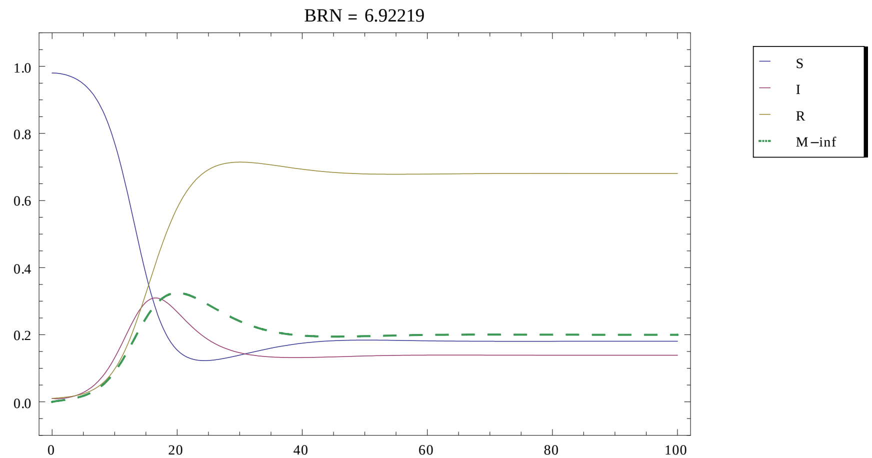
B.R.N:

$$R_0 = \frac{\lambda_0}{r+\delta} = \frac{abm\omega^2 e^{-\mu\tau}}{\mu\left(r+\delta\right)}$$

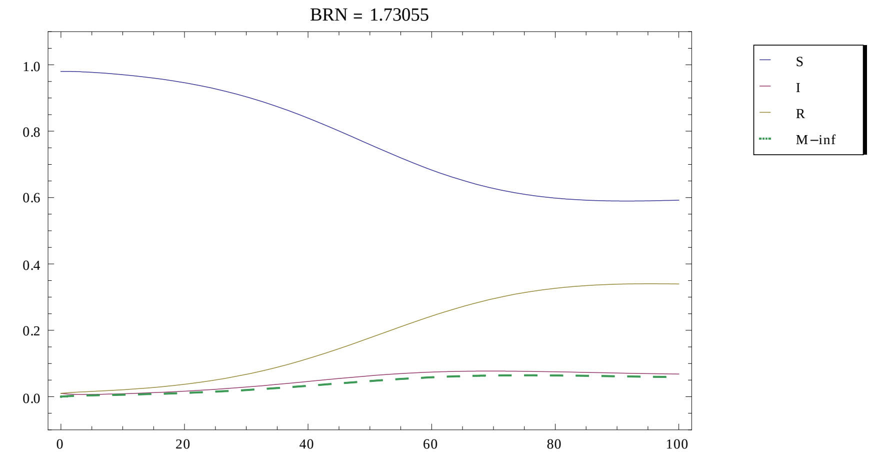
$$R_0 > 1 \Rightarrow \text{ stable (endemic) equilibrium } (y > 0)$$

$$R_0 < 1 \Rightarrow \text{ stable equilibrium } y = 0 \text{ (eradication)}$$

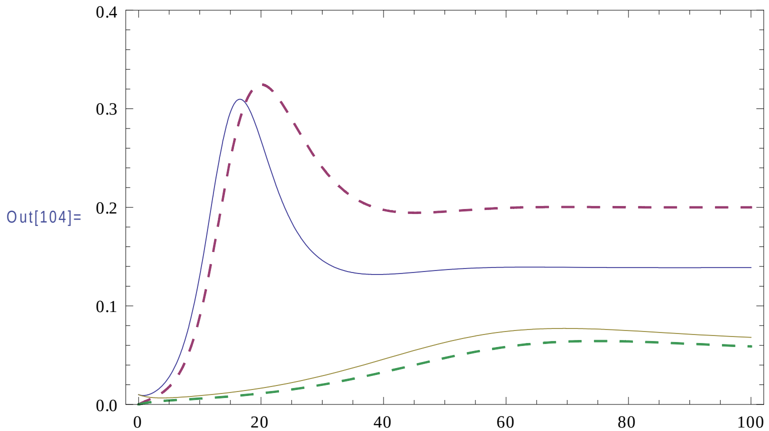
Examples of dynamic simulations with Mathematica: infection outbreak



1. Standard outbreak

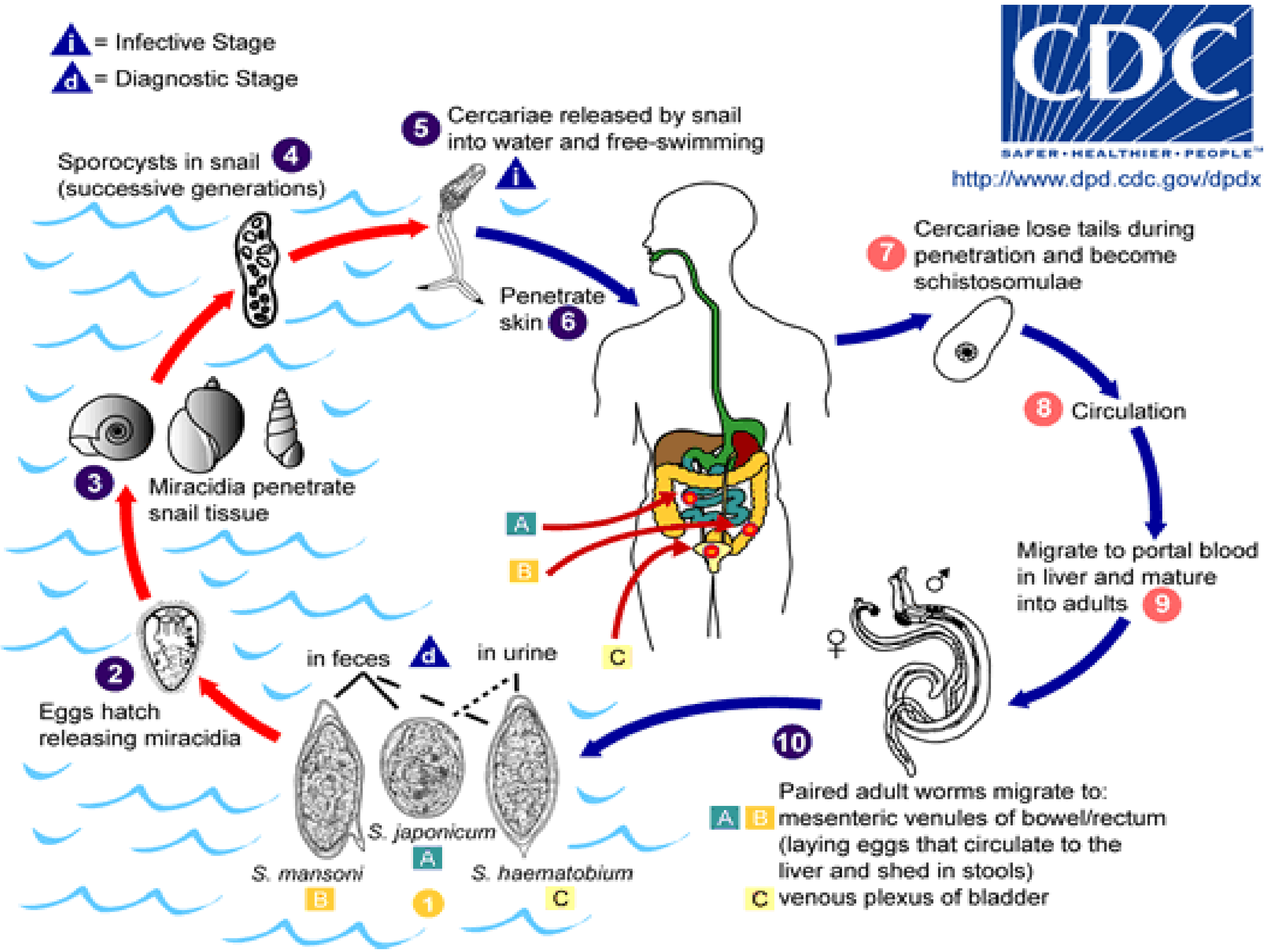


2. Reduced biting by 60% (ITN)



3. Comparison 1 and 2:
H- and M (dashed) infection prevalences

Macro-parasites: schistosome life cycle



This diagram is provided by Center for Disease Control and Prevention (CDC).

“Mean burden” (host) + prevalence (“vector”)

For macro-parasites ***infection intensity*** (burden) is more important than ***prevalence***!

Macdonald (1965)

$$\frac{dw}{dt} = (\alpha\eta N)y - \gamma w = Ay - \gamma w$$

$$\frac{dy}{dt} = (\beta\eta H)w(1-y) - \mu y = Bw(1-y) - \mu y$$

w=mean worm burden of H population;
y=prevalence of shedding snail
A,B – transmission coefficients:
“snail->human” and “human -> snail”

α	Worm establishment probability per contact per shedding snail
β	Contamination rate per susceptible snail per contact per adult worm
η	Human-snail contact rate
γ	Mortality of worm in human host
μ	Mortality of shedding snail

Premises:
- Steady snail population and environment
- Homogeneous human population, and transmission patterns (contact /contamination rates, worm establishment ets)

BRN: $$R_0 = \frac{AB}{\gamma\mu}$$ => equilibria, analysis and control