Quiz

Which of the following are likely to help a parasite to persist in a host population?

1) High host birth rate
2) Herd immunity
3) Waning immunity
4) Adaptive parasite evolution
5) $R_0<1$
6) High host recovery rate

Write down all numbers that apply

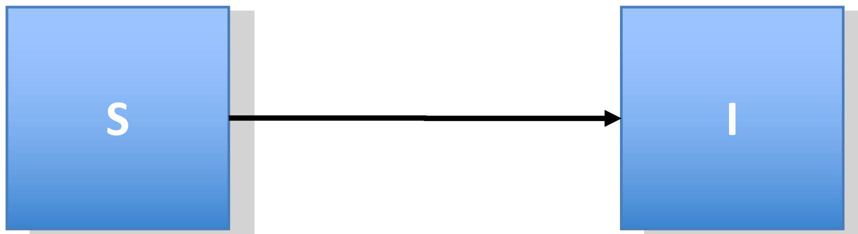
Host-parasite interactions

ECOL 4000/6000

The classic SIR model

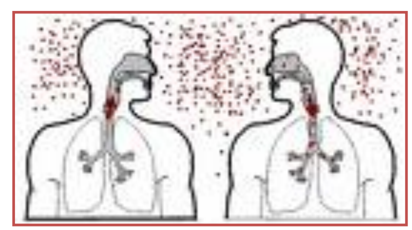
	gains	losses
S	**0**	**transmission**
I	**transmission**	**recovery**
R	**recovery**	**0**

Transmission of infection

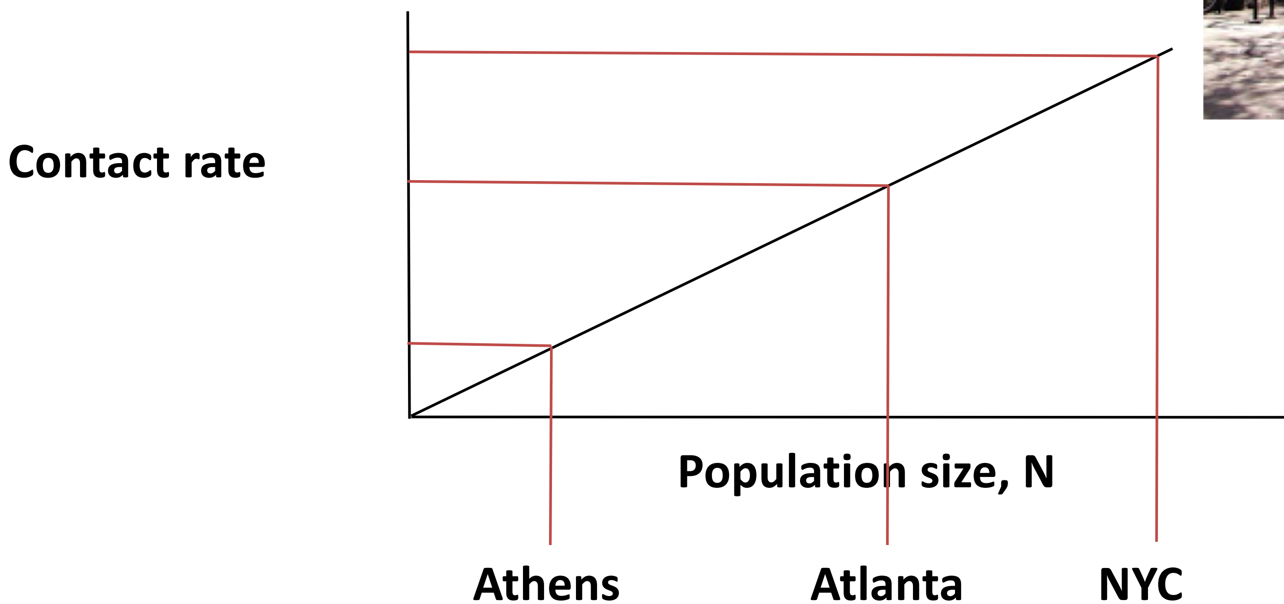


This involves susceptible and infected individuals

Note: this model assumes infected=infectious



Transmission between hosts



We often assume a linear relationship between contact rate and population size

e.g. the chances of bumping into someone on the sidewalk in different populations

Contact rate = cN

Transmission between hosts

Transmission requires:

i) Contact between individuals (cN)

ii) The ‘right’ sort of contact (between an S and an I)

iii) The parasite establishes in the new host

Transmission between hosts

For one infectious individual that makes contact with a random individual in the population, the chance that it is with a susceptible individual is S/N

So for "I" infectious individuals, this scales up to (S/N)*I

And we assume there is some (biologically determined) chance or rate that this sort of contact allows the parasite to establish in the new host (call this 'a')

Transmission between hosts

Transmission requires:

i) Contact between individuals (cN)

ii) The 'right' sort of contact (between an S and an I) (S/N)*I

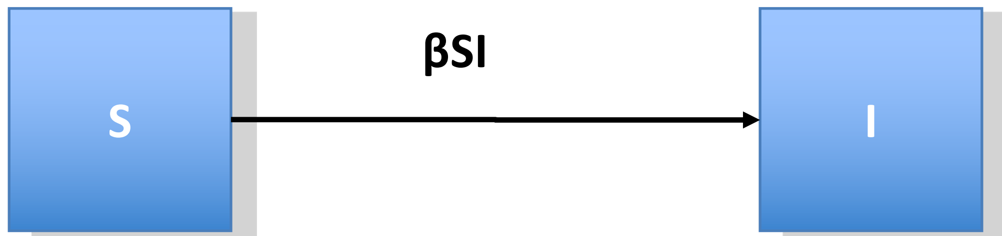
iii) The parasite establishes in the new host (a)

Expression for transmission = (cN)*(S/N)*I*a

Research papers usually make the notation simpler by replacing the constants c*a by β, which is called the transmission rate

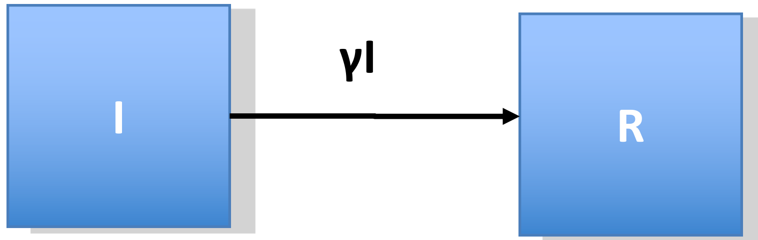
Overall expression for transmission = βSI

Transmission between hosts



Our transmission term determines how quickly individuals in the S compartment move into the I compartment

The infectious period



This is the length of time that an individual is capable of transmitting infection to susceptible individuals

Commonly, we use $1/\gamma$ for the infectious period, and rate of movement from I compartment to R compartment is γI

After this time, the host's immune system clears the virus, and this simple model assumes that hosts remain recovered

A simple "compartment" model

β = transmission rate
1/γ = infectious period

S, I and R are state variables of the model (they change over time)

β and γ are parameters of the model (in most models, these do not change over time)

A simple “compartment” model

$$\frac{dS}{dt} = -\beta SI$$

$$\frac{dI}{dt} = \beta SI - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$

	gains	losses
S	0	transmission
I	transmission	recovery
R	recovery	0

This model is a density-dependent transmission model – transmission is density-dependent because we assumed contact rate increased with N

Disease invasion (density-dependent transmission)

$$\frac{dS}{dt} = -\beta SI$$

$$\frac{dI}{dt} = \beta SI - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$

The number of infected individuals will increase if more is flowing into the "I" compartment than is flowing out (the same as saying dI/dt>0)

$$\beta SI - \gamma I > 0$$

$$\beta SI > \gamma I$$

$$\frac{\beta SI}{\gamma I} > 1$$

$$\frac{\beta S}{\gamma} > 1$$

Early on, infected individuals are rare and so S~N (the population size)

$$\frac{\beta N}{\gamma} > 1$$

R_0

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$$\frac{\beta N}{\gamma} > 1$$

R_0

What can cause large values of R0 according to this model?

Disease invasion (density-dependent transmission)

$$\frac{dS}{dt} = -\beta SI$$

$$\frac{dI}{dt} = \beta SI - \gamma I$$

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The number of infected individuals will increase if more is flowing into the "I" compartment than is flowing out (the same as saying dI/dt>0)

$$\beta SI - \gamma I > 0$$

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$$\frac{\beta SI}{\gamma I} > 1$$

$$\frac{\beta S}{\gamma} > 1$$

Early on, infected individuals are rare and so S~N (the population size)

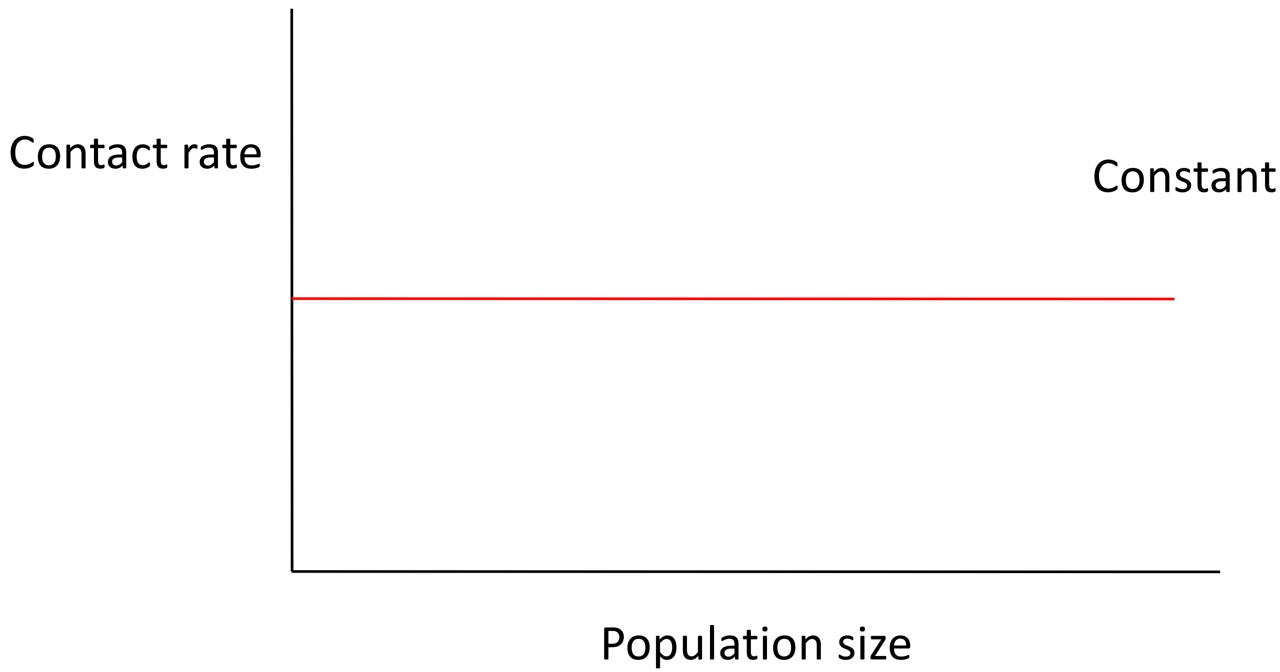
$$\frac{\beta N}{\gamma} > 1 \qquad N_T > \frac{\gamma}{\beta}$$

R_0

This model has a threshold population size which must be exceeded for a disease to invade

Density-independent transmission:

Alternative to density-dependent transmission



Density-independent transmission:

Transmission requires:

i) Contact between individuals (c)

ii) The 'right' sort of contact (between an S and an I) (S/N)*I

iii) The parasite establishes in the new host (a)

Expression for transmission = (c)*(S/N)*I*a

Research papers usually make the notation simpler by replacing the constants c*a by β, which is called the transmission rate

Expression for transmission = βSI/N

Disease invasion (density-**in**dependent transmission)

$$\frac{dS}{dt} = -\frac{\beta SI}{N}$$

$$\frac{dI}{dt} = \frac{\beta SI}{N} - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$

The number of infected individuals will increase if more is flowing into the "I" compartment than is flowing out (the same as saying dI/dt>0)

$$\frac{\beta SI}{N} - \gamma I > 0$$

$$\frac{\beta SI}{N} > \gamma I$$

$$\frac{\beta SI}{\gamma IN} > 1$$

$$\frac{\beta S}{N\gamma} > 1$$

Early on, infected individuals are rare and so S~N (the population size)

$$\frac{\beta}{\gamma} > 1$$

R_0

Herd immunity

We want an average individual in the population to give rise to an $R_0 < 1$

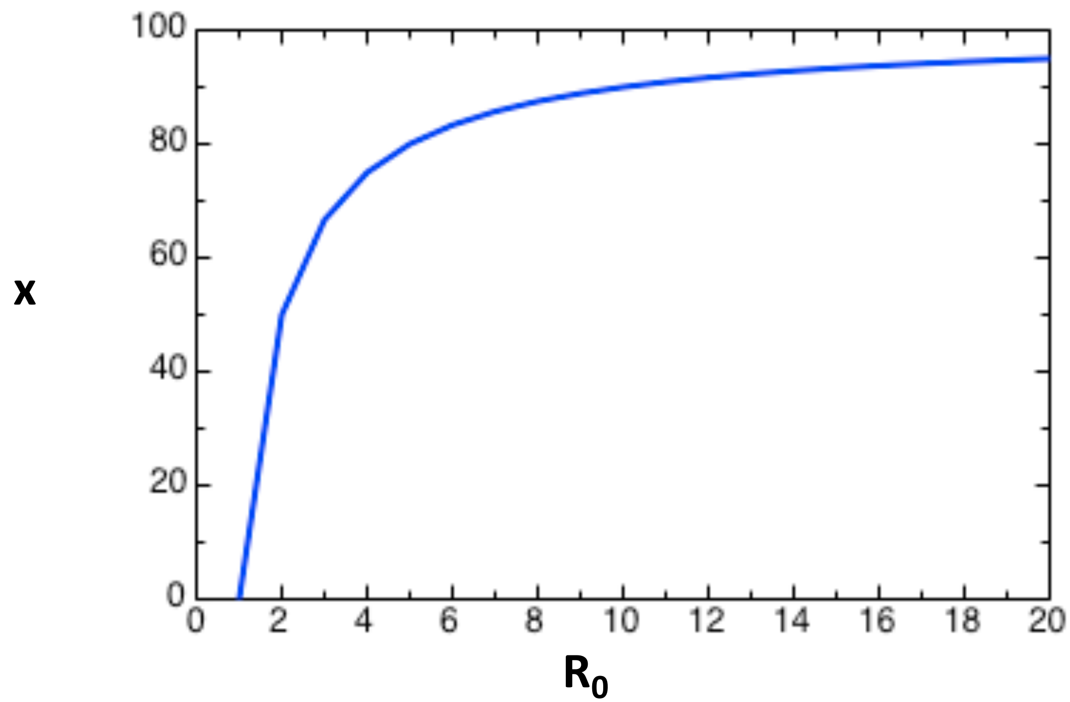
If we vaccinate a proportion of the population, x, with a perfect vaccine then we have two types of individual:

Type	Proportion	Basic reproductive number
protected	x	0
susceptible	1-x	R_0

Then we require $(1-x)*R_0<1$ which tells us that, at least, we need to vaccinate a proportion $x>1-1/R_0$

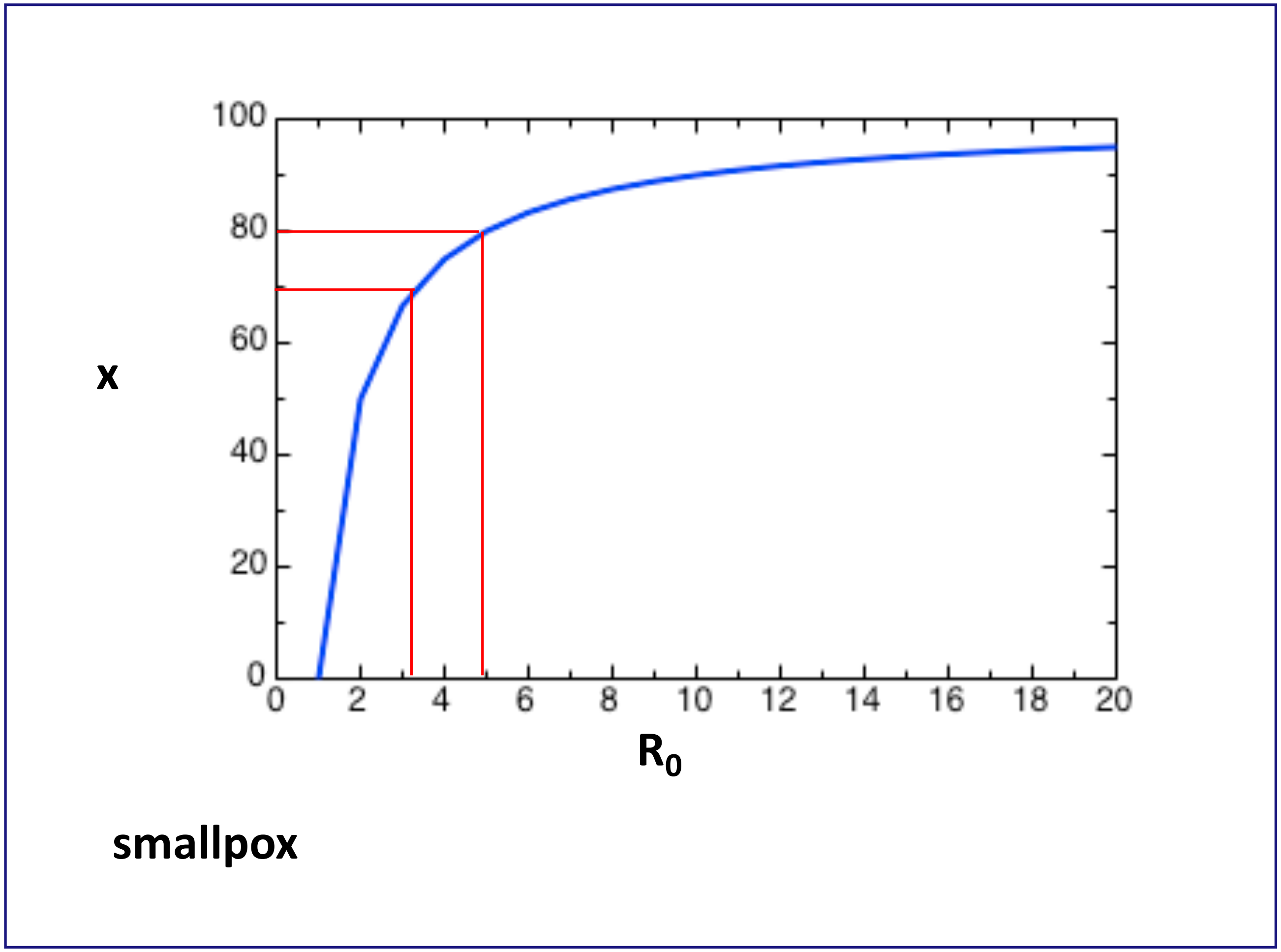
Herd immunity

Minimum target percentage to immunize



Herd immunity

Minimum target percentage to immunize



Herd immunity

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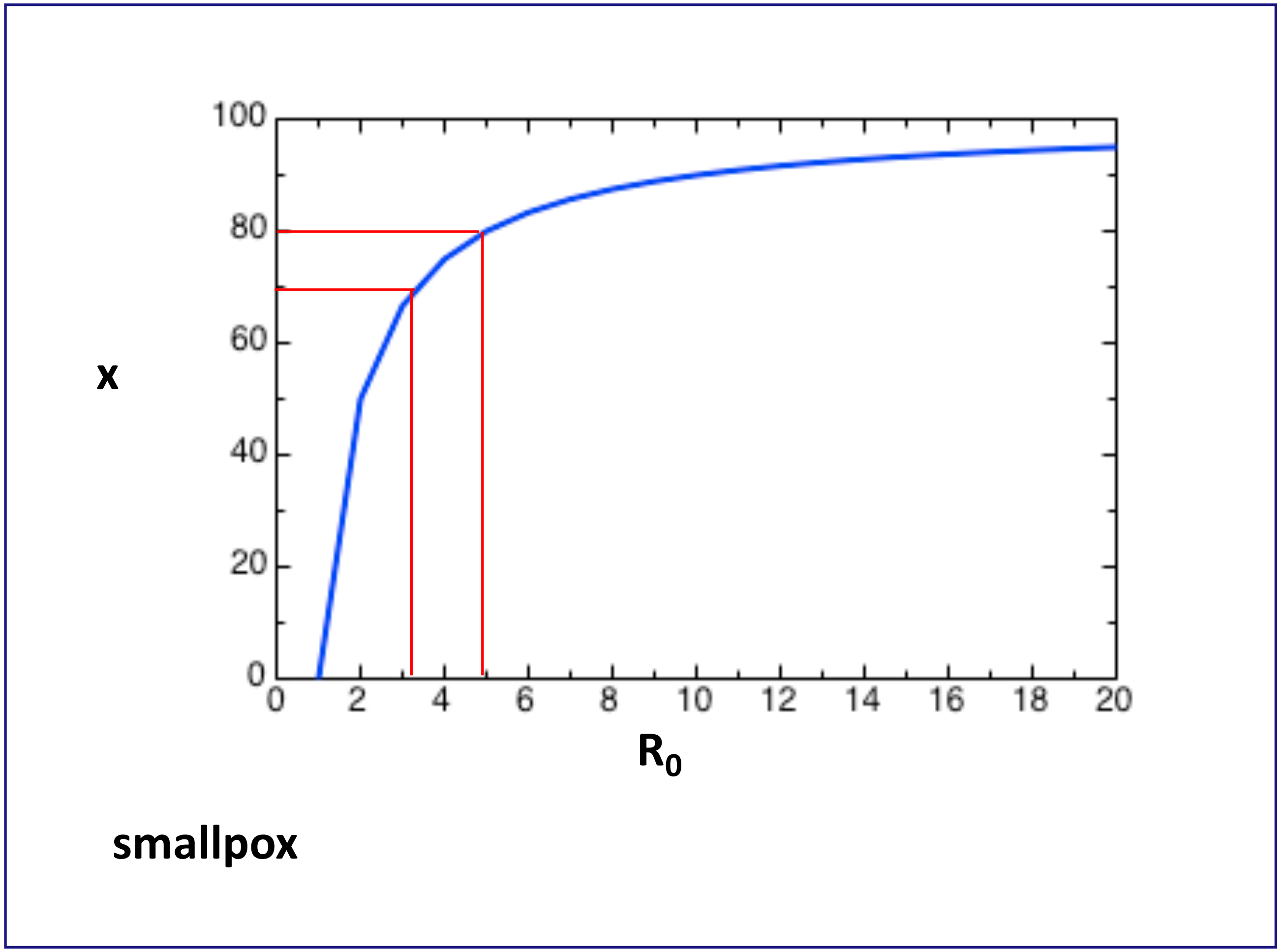
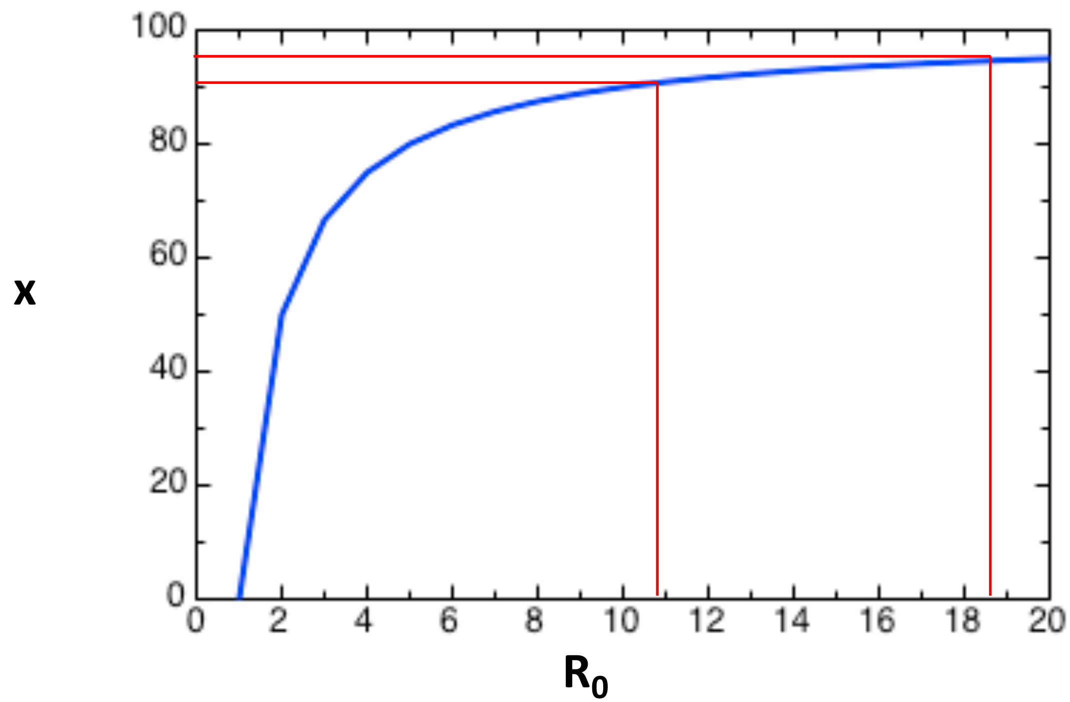


1968-73: coverage in Africa & Indian subcontinent ranged from 77-95%

Herd immunity

Minimum target percentage to immunize



measles

Summary

- SIR model assumes all individuals belong to one compartment (S, I or R) at any time
- Transmission may be density-dependent or density-independent
- (Only) Density-dependent transmission has a threshold population size for parasite invasion
- R0 determines the proportion of the population that must be immunized to protect the population (herd immunity concept)