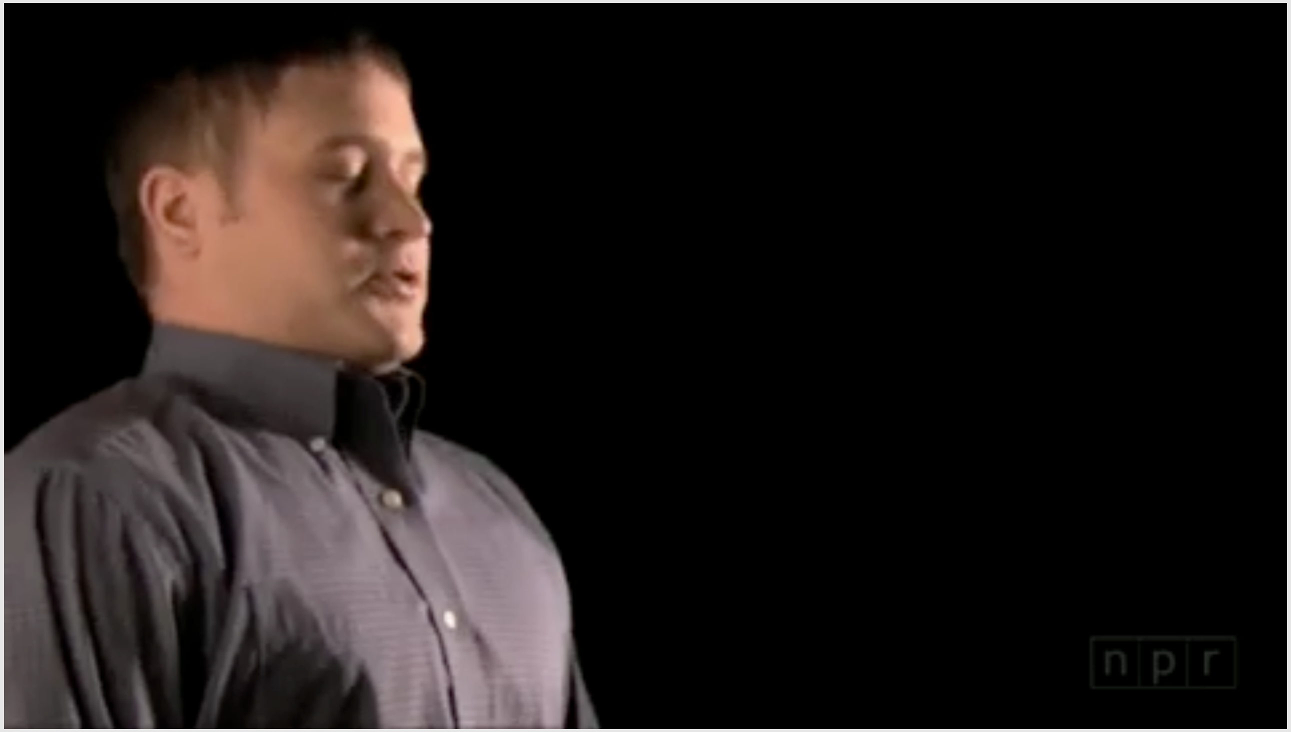
Disease evolution



http://www.youtube.com/watch?v=Rpj0emEGShQ

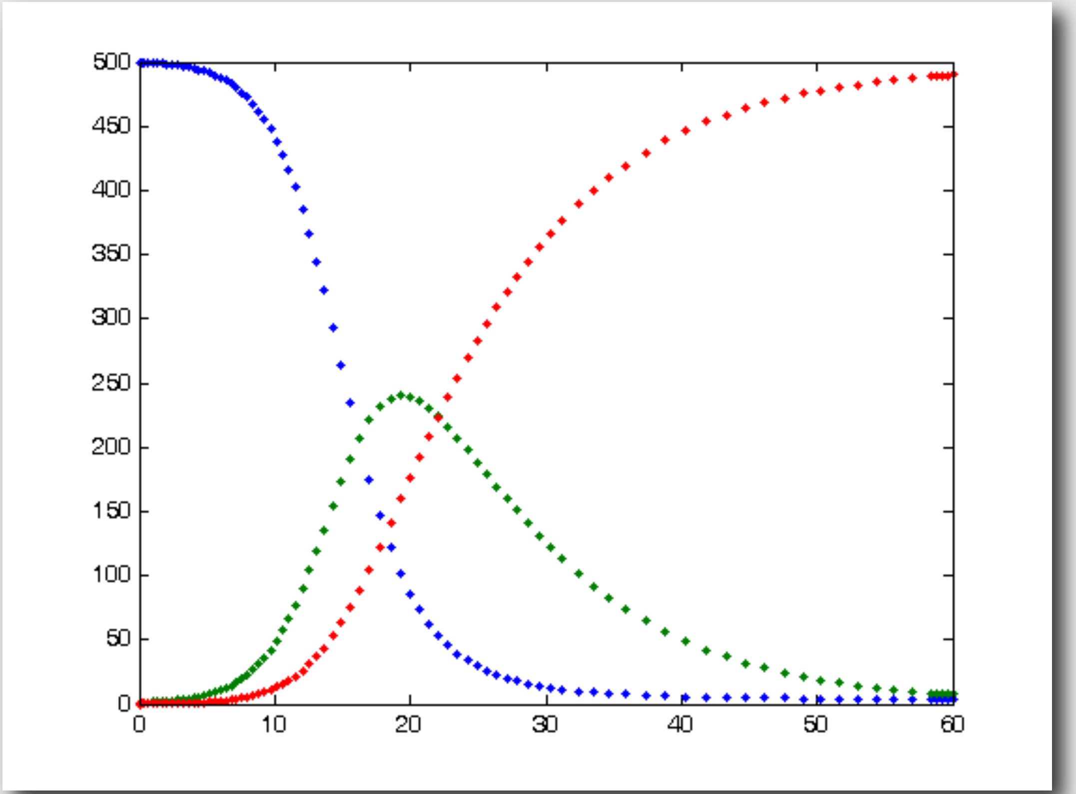
Brian O'Meara
EEB464 Fall 2019

Learning objectives

Connect ideas about symbiosis and game theory to disease evolution

Understand natural history of disease

Susceptible → Infectious → Recovered



Virus A	Virus B	Virus C
Kills host in a day	Kills host in a month	Kills host in a year

which disease will increase at the fastest rate?

Virus A	Virus B	Virus C
Kills host in a day	Kills host in a month	Kills host in a year
Each host infects 1 person on average	Each host infects 40 people on average	Each host infects 100 people on average

which disease will increase at the fastest rate?

Virus A	Virus B	Virus C
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Each host infects 1 person on average	Each host infects 40 people on average	Each host infects 100 people on average
1/1=1.0	40/30 = 1.3	100/365 = 0.3

which disease will increase at the fastest rate?

Virulence: ability of an organism to cause disease

Virus A	Virus B	Virus C
Kills host in a day	**Kills host in a month**	**Kills host in a year**
Each host infects 1 person on average	Each host infects 40 people on average	Each host infects 100 people on average
1/1=1.0	40/30 = 1.3	100/365 = 0.3

Why not just evolve to be less virulent?

Effect on virulence of:
Change from horizontal to vertical transmission

HIV horizontal

Unprotected sex

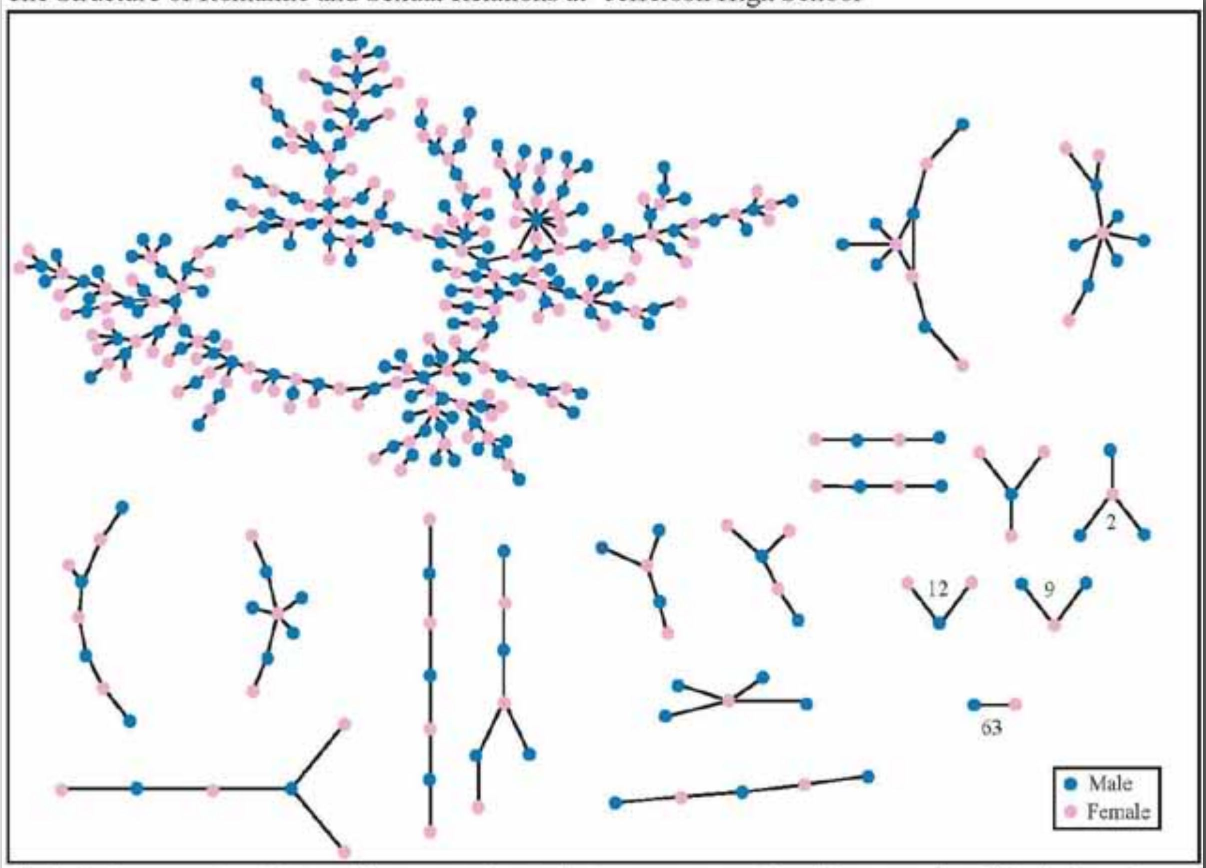
Sharing needles

HIV vertical

From parent (typically mother)

Effect on virulence of:
Increased number of sexual partners

The Structure of Romantic and Sexual Relations at "Jefferson High School"



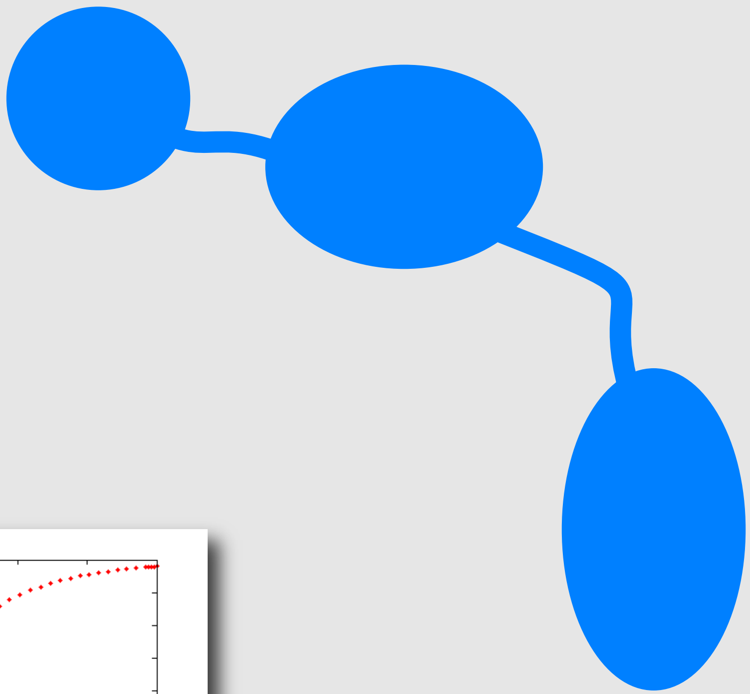
Each circle represents a student and lines connecting students represent romantic relations occuring within the 6 months preceding the interview. Numbers under the figure count the number of times that pattern was observed (i.e. we found 63 pairs unconnected to anyone else).

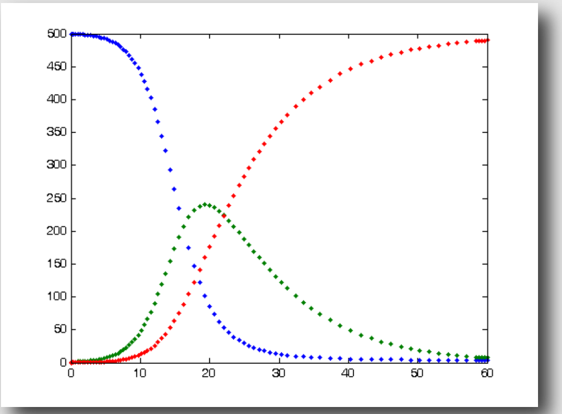
Bearman et al 2004

Effect on virulence of:
Spatial structure

Unstructured

Structured





Effect on virulence of: Vaccination

Effect on virulence of: Vaccination

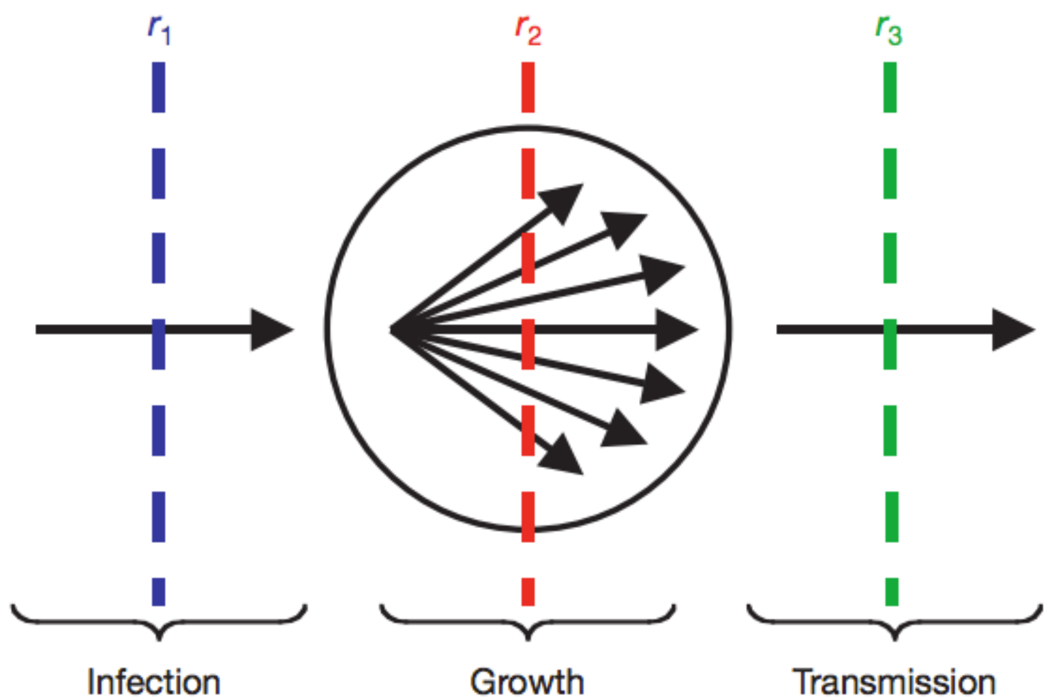
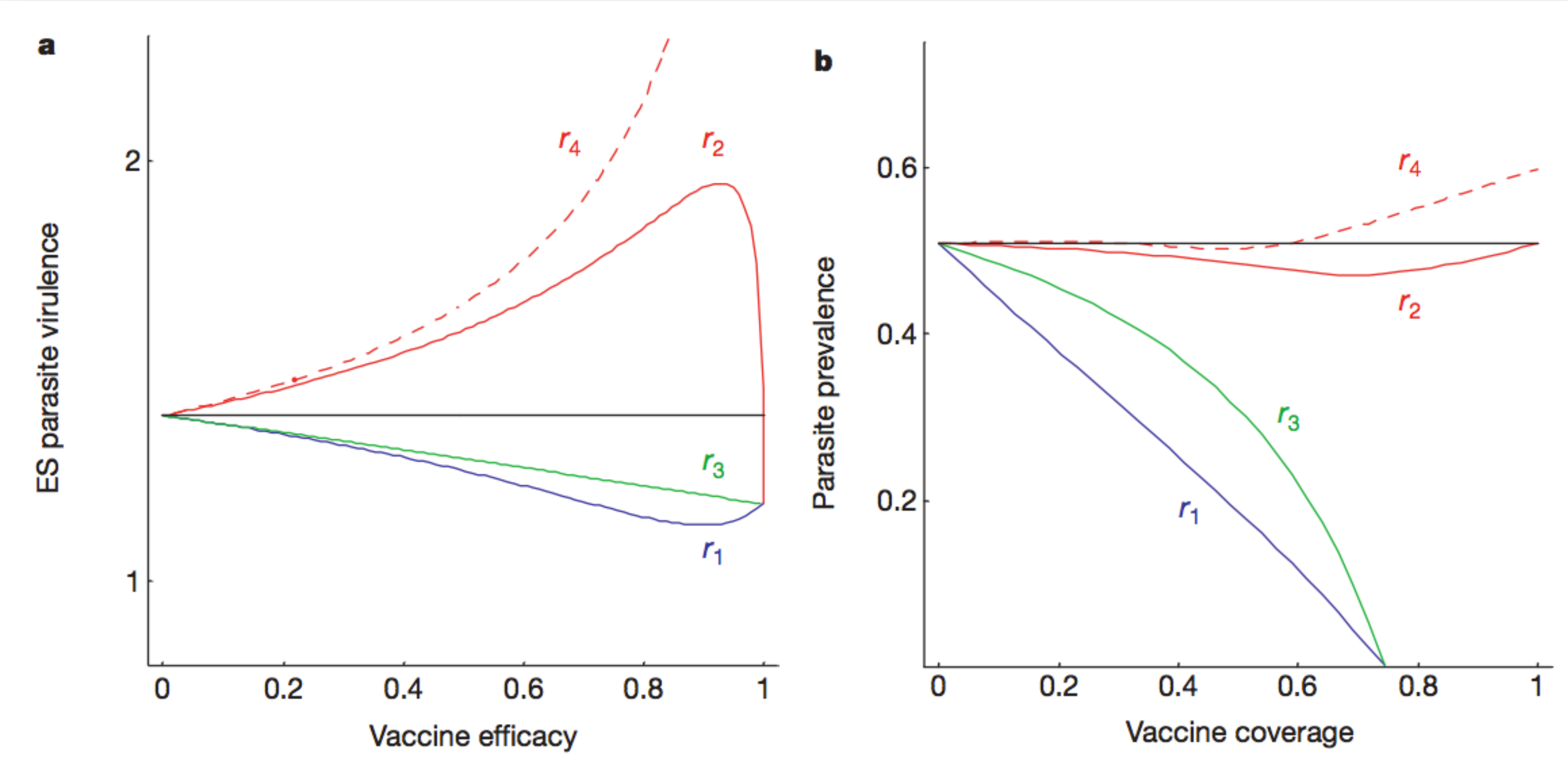
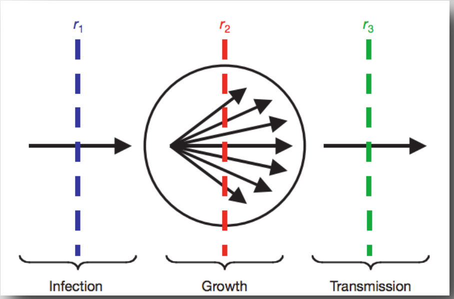


Figure 1 Schematic representation of the action of different types of host resistance at different stages of the pathogen's life cycle. r_1, anti-infection resistance; r_2, anti-growth-rate resistance; r_3, transmission-blocking resistance. A fourth type of resistance—anti-toxin resistance, r_4—is not shown because it only acts upon host death rates.

Gandon et al. 2001 *Nature*

Effect on virulence of: Vaccination

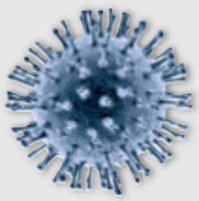


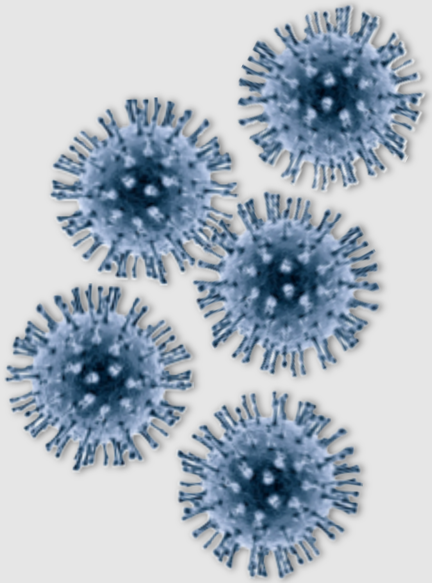


Gandon et al. 2001 *Nature*

Blue = anti-infection vaccine
Green = transmission-blocking vaccine
Red solid = anti-growth rate vaccine (slow parasite growth)
Red dashed = anti-toxin immunity (make parasite less harmful w/o affecting transmission and growth rates)

Effect on virulence of:
Number of innocula





How do we then get pandemics?

http://www.christinatonges.com

SUMMARY TABLE 35.2 **The Diversity of Viral Genomes**

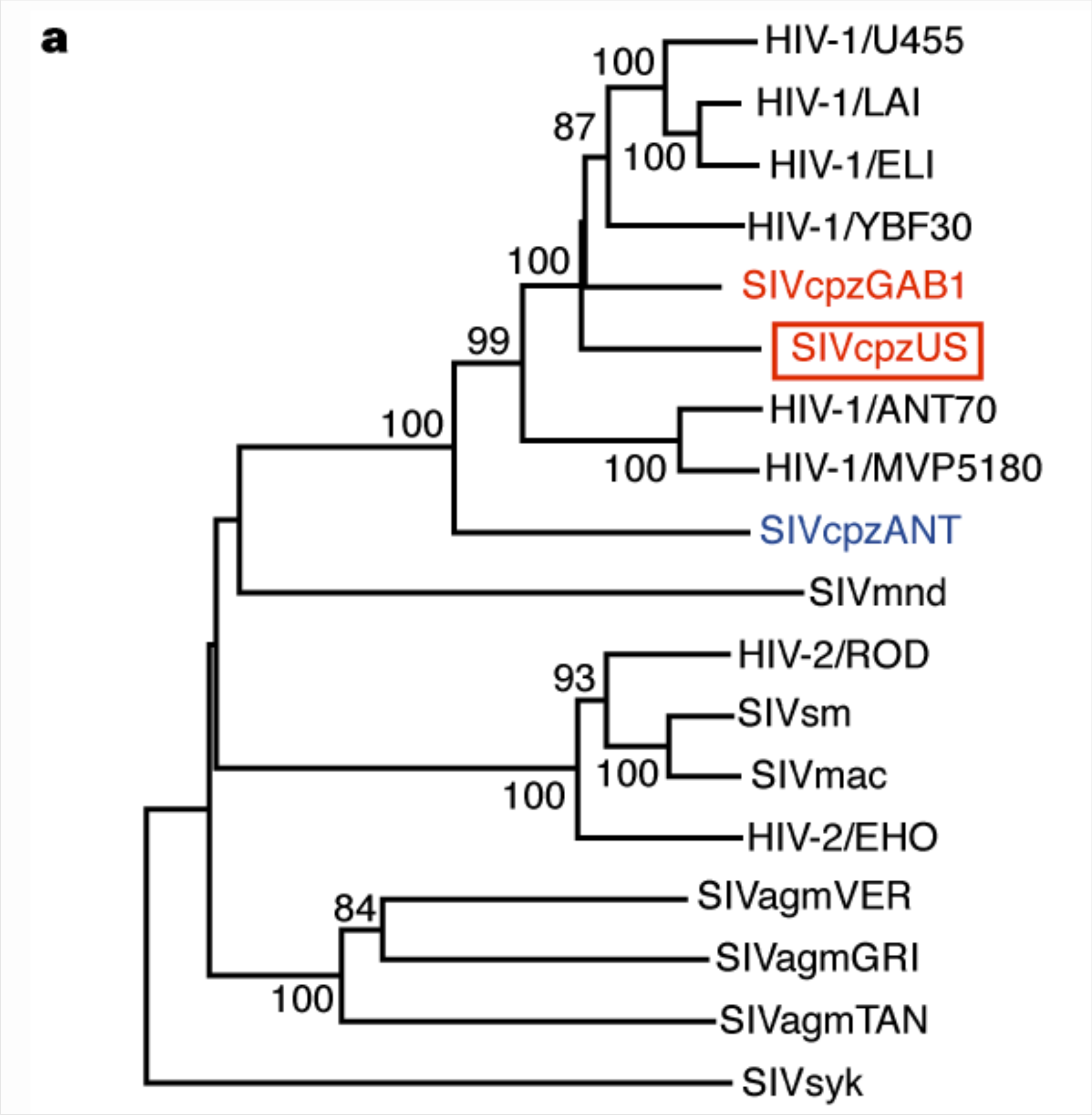
Key: ss = single stranded; ds = double stranded; (+) = positive sense (genome sequence is the same as viral mRNA); (−) = negative sense (genome sequence is complementary to viral mRNA)

Genome		Example(s)	Host	Result of Infection	Notes
(+)ssRNA	+	TMV	Tobacco plants	Tobacco mosaic disease (leaf wilting)	TMV was the first RNA virus to be discovered.
(−)ssRNA	−	Influenza	Many mammal and bird species	Influenza	The negative-sense ssRNA viruses transcribe their genomes to mRNA via RNA replicase.
dsRNA	+ / −	Phytovirus	Rice, corn, and other crop species	Dwarfing	Double-stranded RNA viruses are transmitted from plant to plant by insects. Many can also replicate in their insect hosts.
ssRNA that requires reverse transcription for replication	+	Rous sarcoma virus	Chickens	Sarcoma (cancer of connective tissue)	These are called retroviruses. Rous sarcoma virus was identified as a cancer-causing agent in 1911—decades before any virus was seen.
ssDNA—can be (+), (−), or (+) and (−)	+ or −	φX174	Bacteria	Death of host cell	The genome for φX174 is circular and was the first complete genome ever sequenced.
dsDNA that is replicated through an RNA intermediate	+ / −	Hepatitis B virus	Humans	Hepatitis	These are called "reversiviruses."
dsDNA that is replicated by DNA polymerase	+ / −	Baculovirus Smallpox Bacteriophage	Insects Humans Bacteria	Death Smallpox Death	These include the largest viruses in terms of genome size and overall size.

Origins of virus

Origins of a particular virus (SARS, HIV, flu)

Origins of viruses as a biological entity



Gao et al. 1999

Origins of viruses as a biological entity
Three hypotheses

Virus-first

Reduction

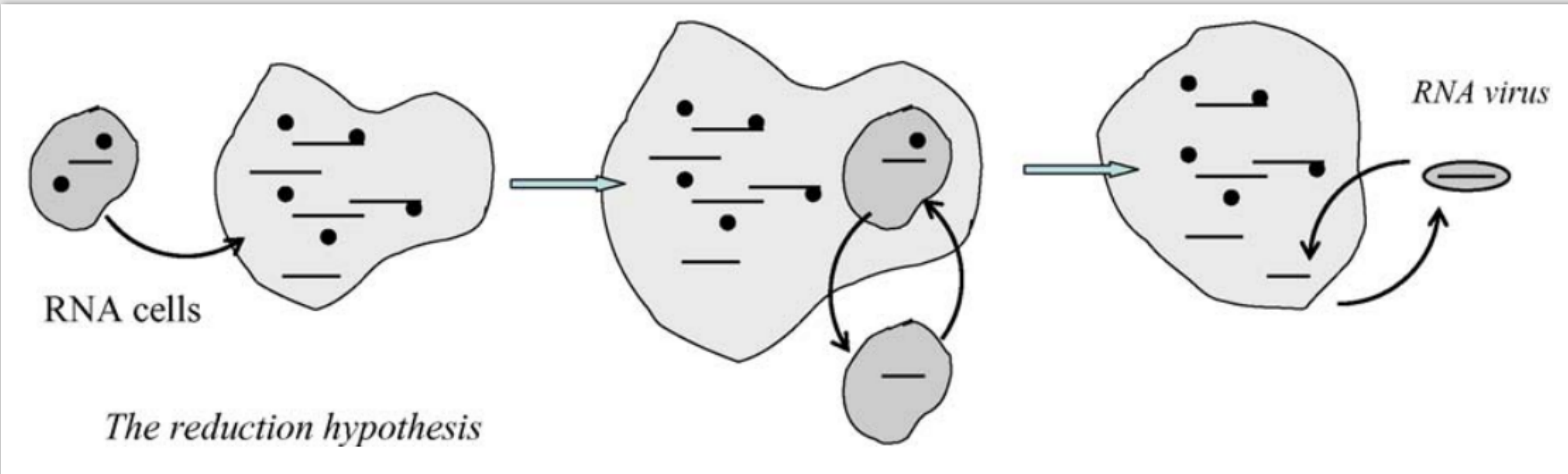
Escape

Forterre 2006

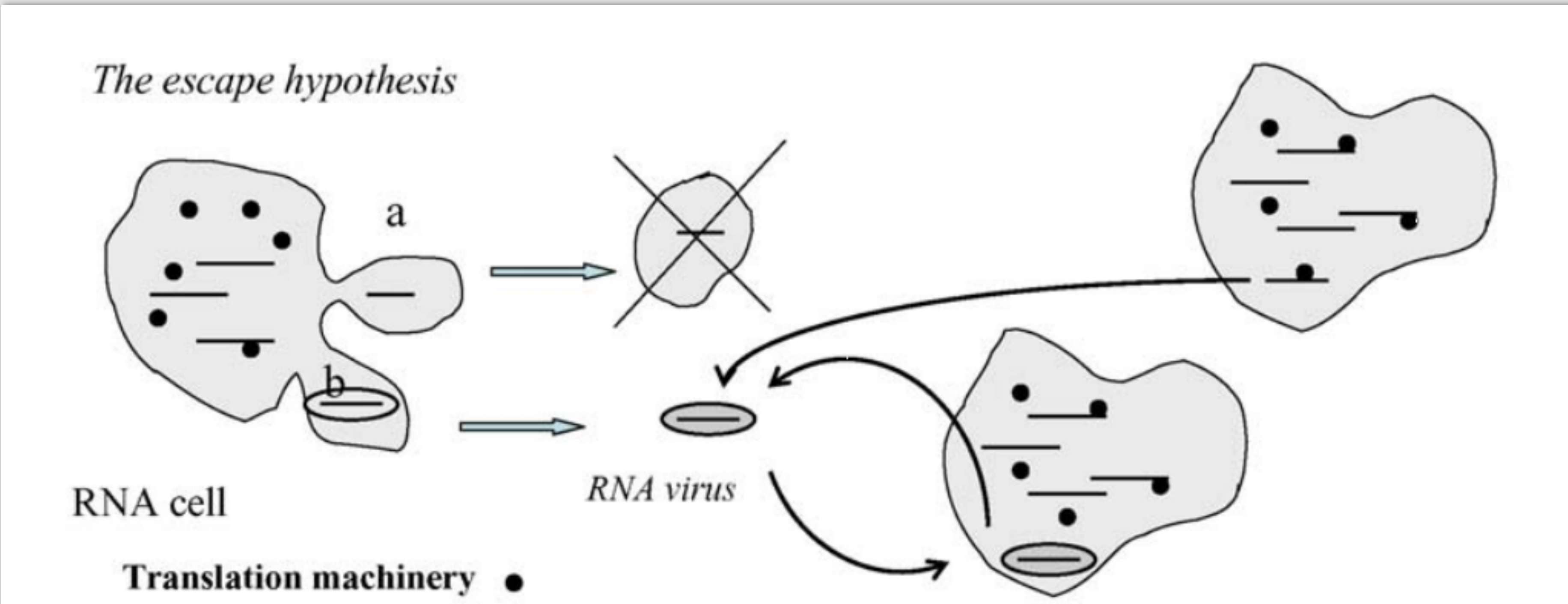
Virus-first: Viruses evolve, use the prebiotic soup for replication, later parasitize cells

Not favored: requires ribosomes (protein synthesis for coats), other complex structures, need Darwinian evolution for that

Forterre 2006

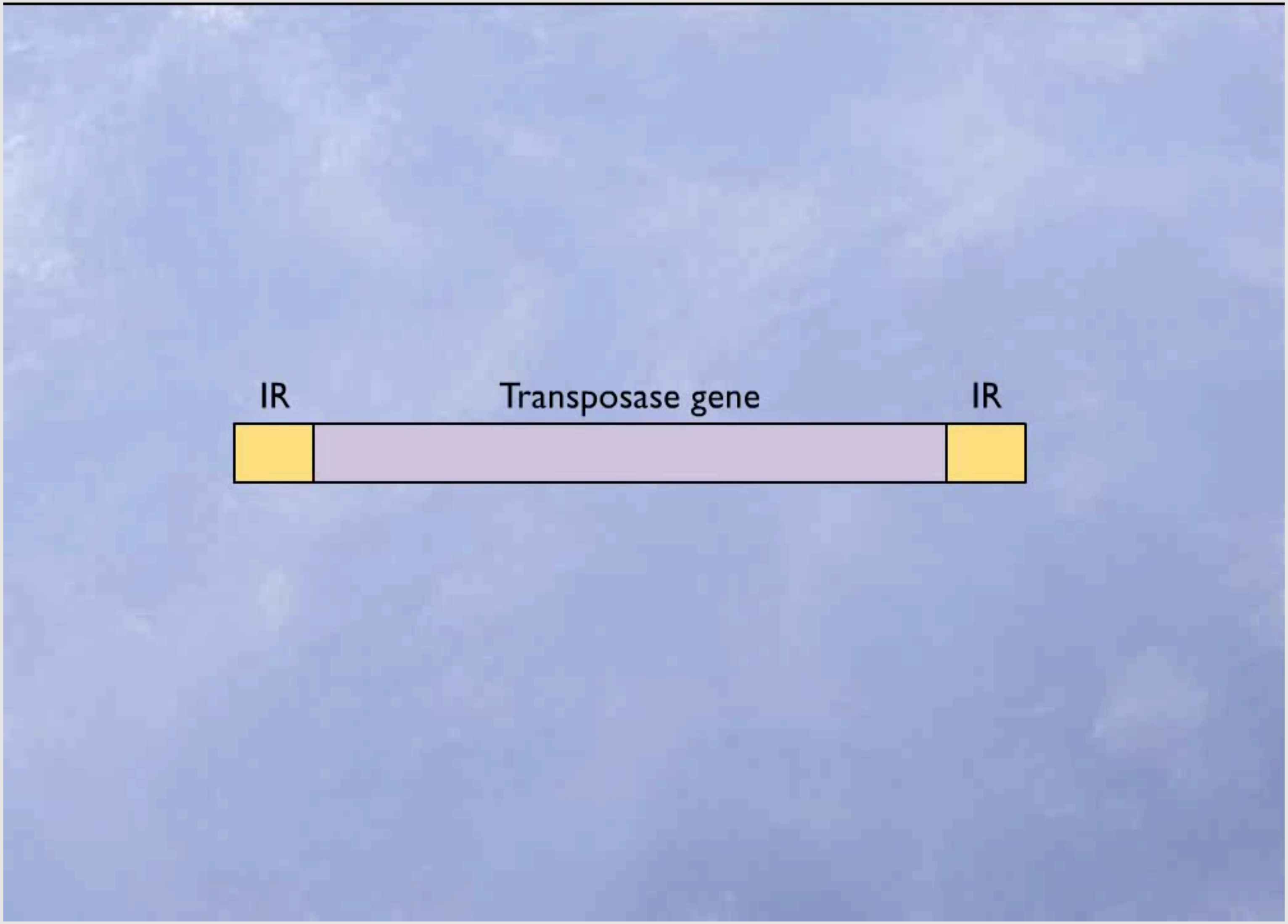


Forterre 2006



Forterre 2006

Transposons



McGraw-Hill. https://www.youtube.com/watch?v=ul8BmgqN2YY (it's less than 2 minutes long. It *feels* longer, but it's worth it.


SERIES
2003
A


SERIES
2003
A

- Cows (Bovine spongiform encephalopathy, aka “mad cow”)
- Sheep (Scrapie)
- Mink
- Cats
- Deer (chronic wasting disease)
- Humans (kuru; variant Creutzfeldt-Jakob Disease (vCJD))