The Human Ecology of West Nile Virus

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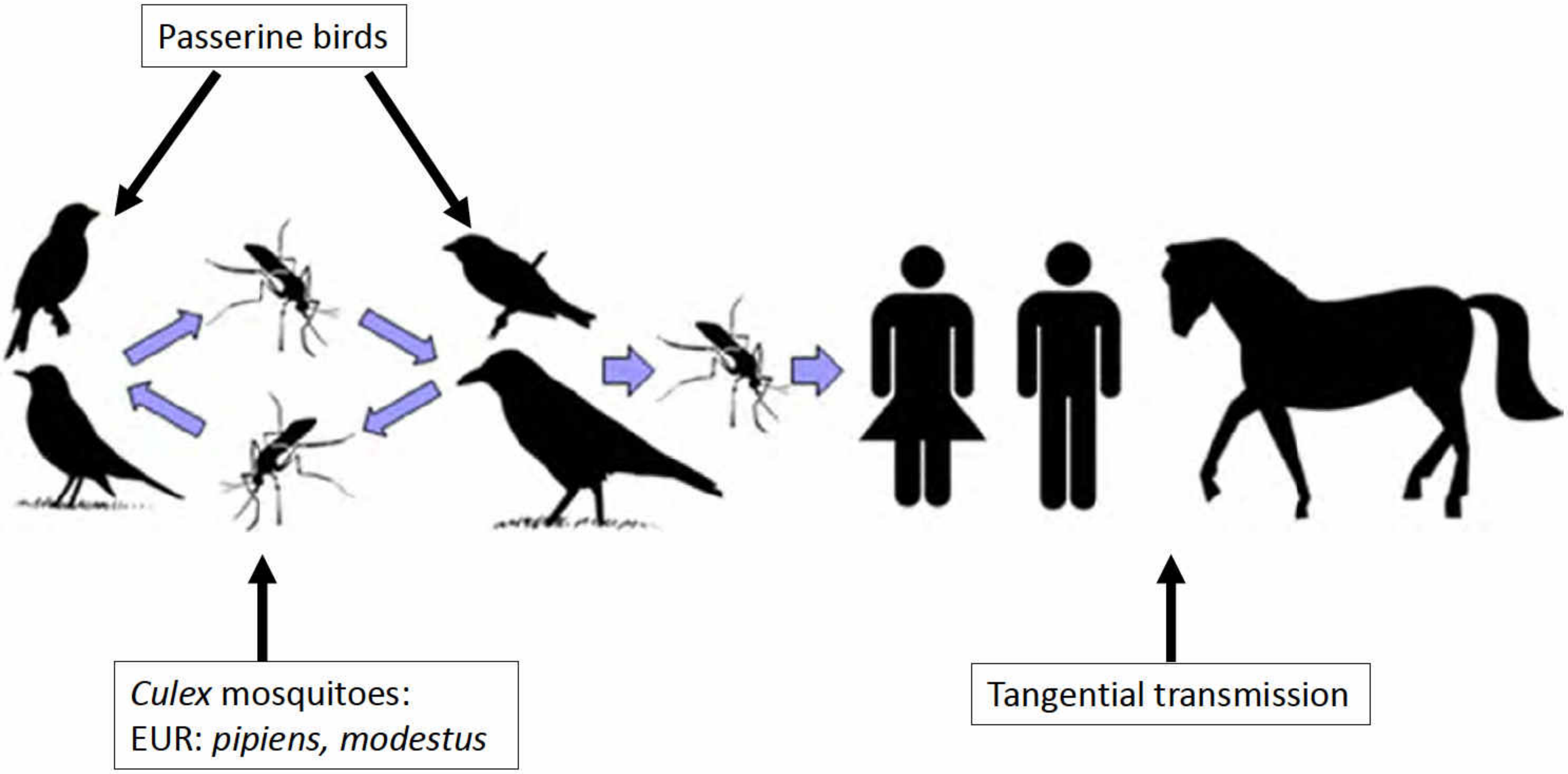
Outline

1. Ecology
2. Genetic epidemiology
3. Human Disease Ecology

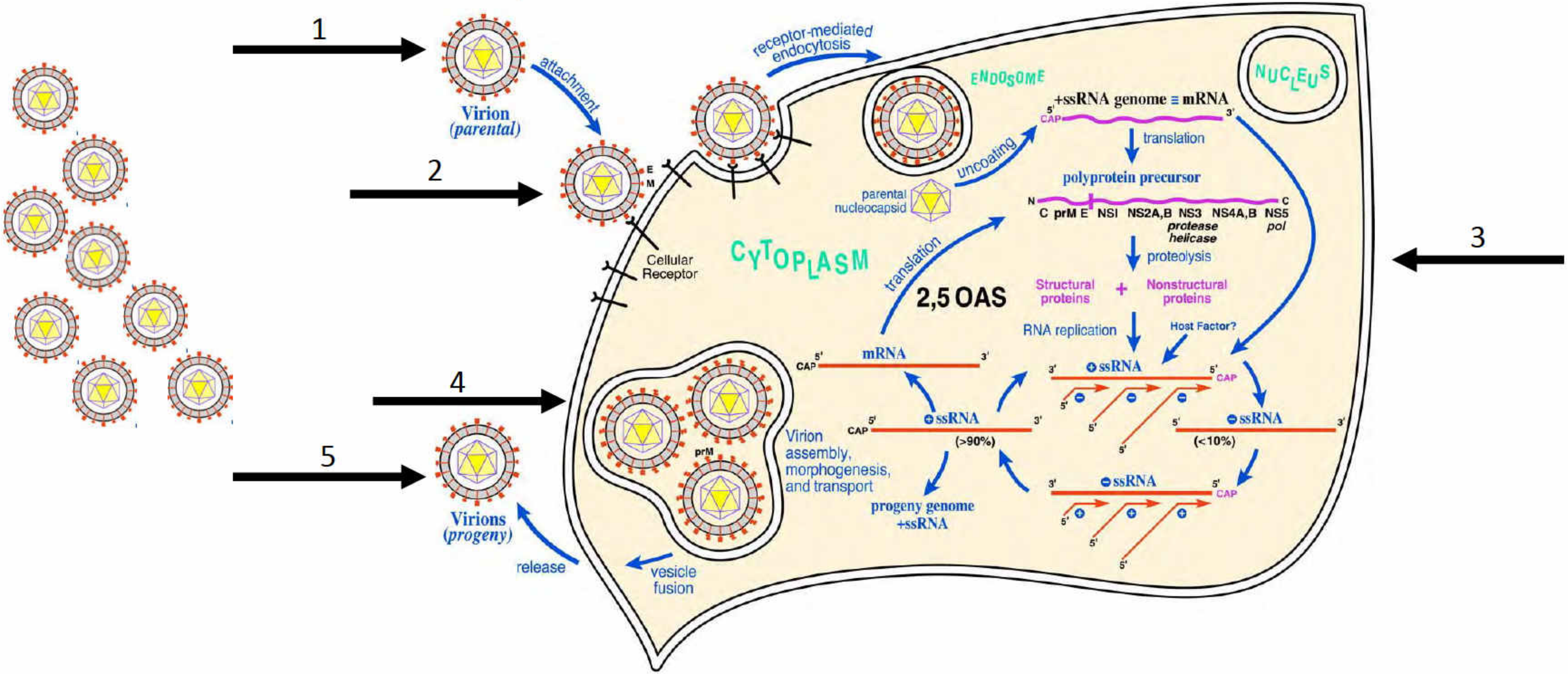
Ecology of WNV

Transmission



Hoover KC and Barker CM. 2016. West Nile virus, climate change, and circumpolar vulnerability. doi:10.1002/wcc.382

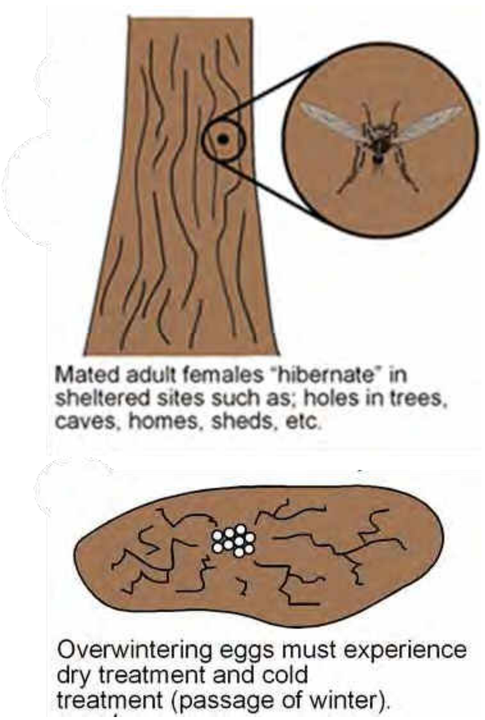
Viral Assembly



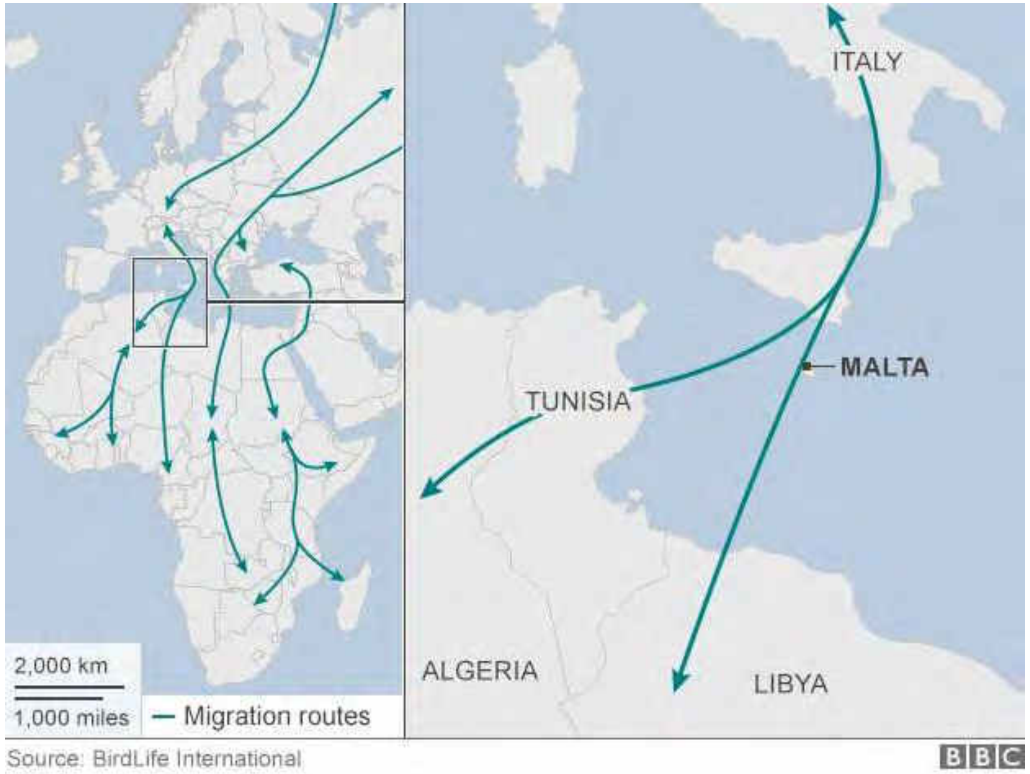
Samuel CE. 2002. Host genetic variability and West Nile virus susceptibility. Proceedings of the National Academy of Sciences doi:10.1073/pnas.202448899

Endemicity: Establishment of Disease

Overwinter



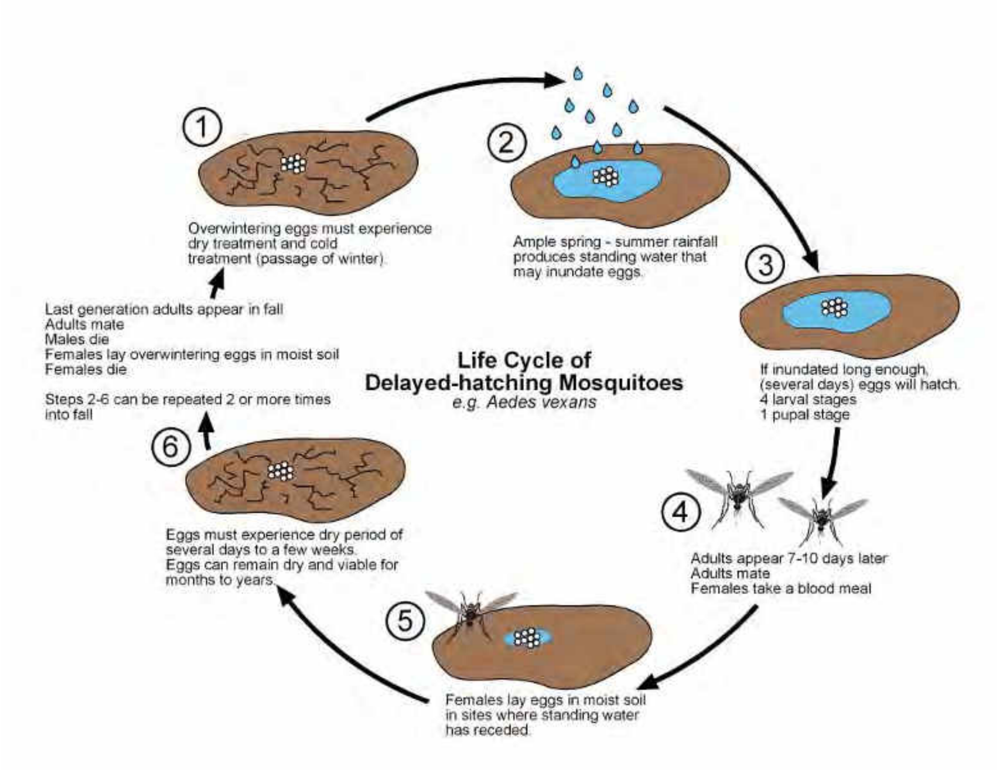
Reintroduction



Transmission season

Precipitation Dependent:

Delayed Hatch (*Aedes*)



Temperature Dependent

Direct Hatch (*Culex*)

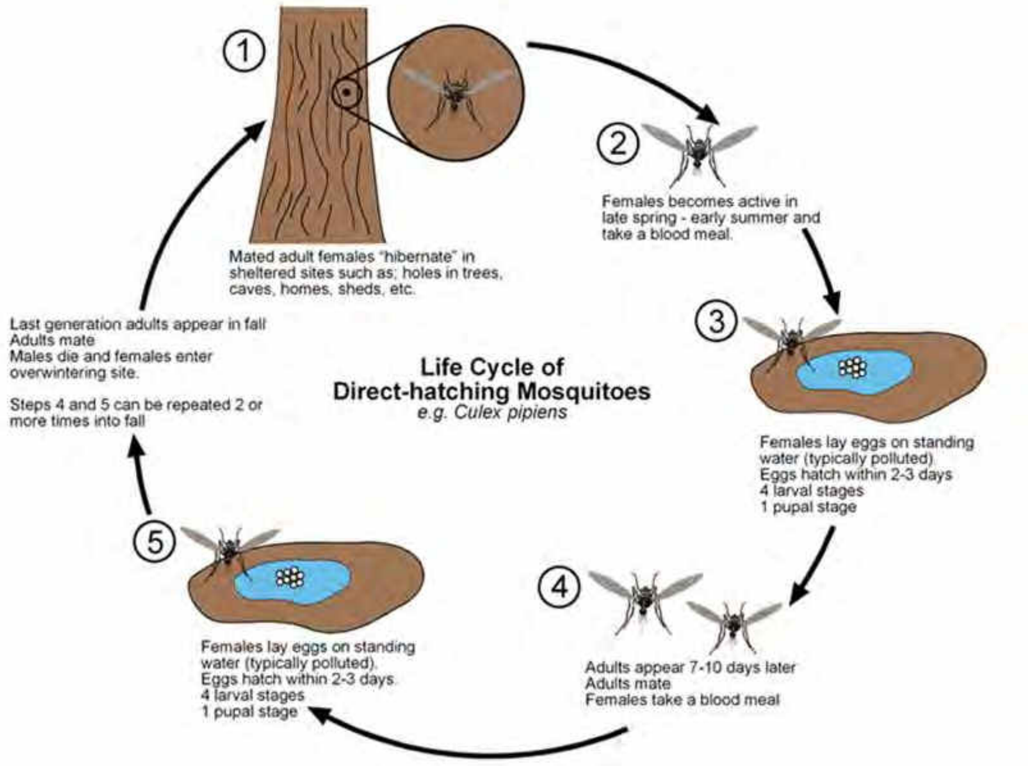
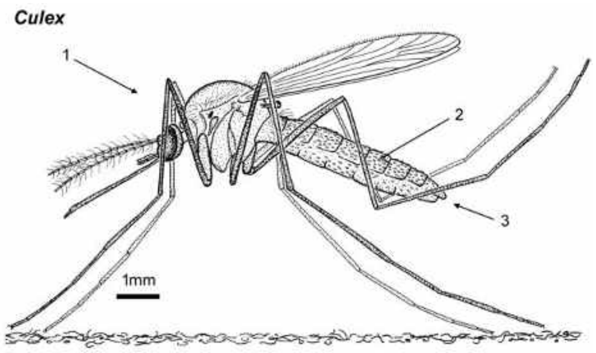
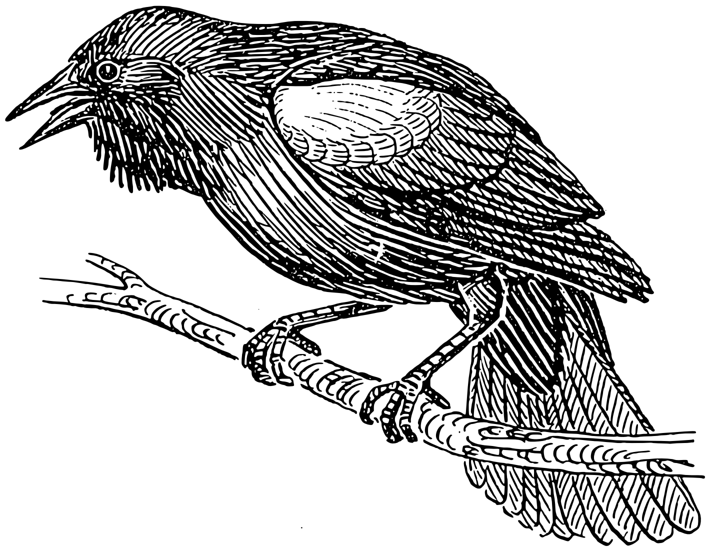
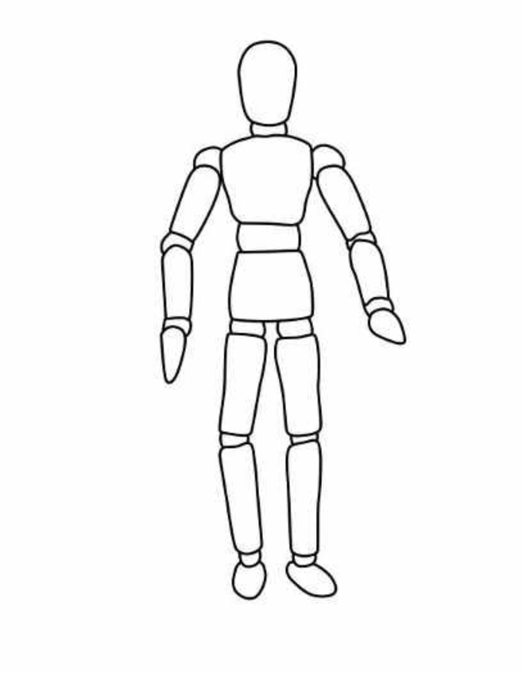


Illustration by: Scott Charlesworth, Purdue University
From: https://extension.entm.purdue.edu/publichealth/insects/mosquito.html

Timeline







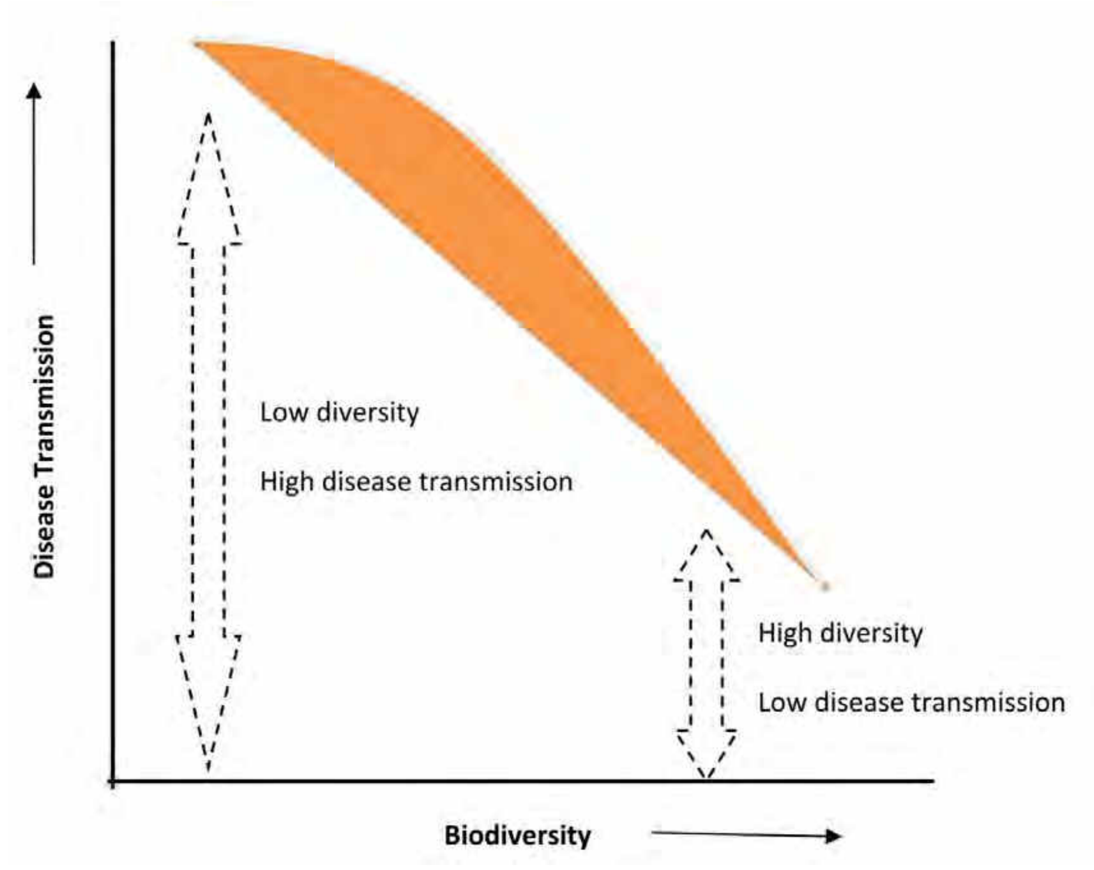
16-25 days → 5-6 days → 2-6 days →

From: Wikimedia Commons, CY-BY-SA-4.0

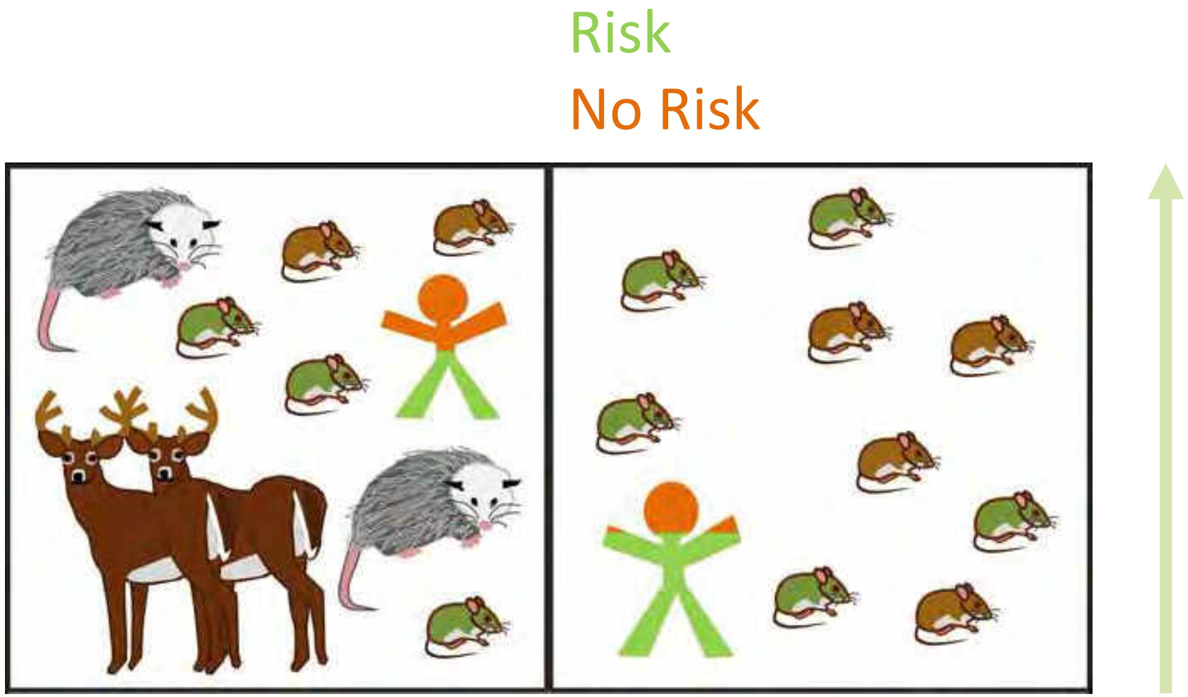
From Openclipart.com, CCZero 1.0

From pluspng.com, Body Outline #1660381

Biodiversity & the Dilution Effect



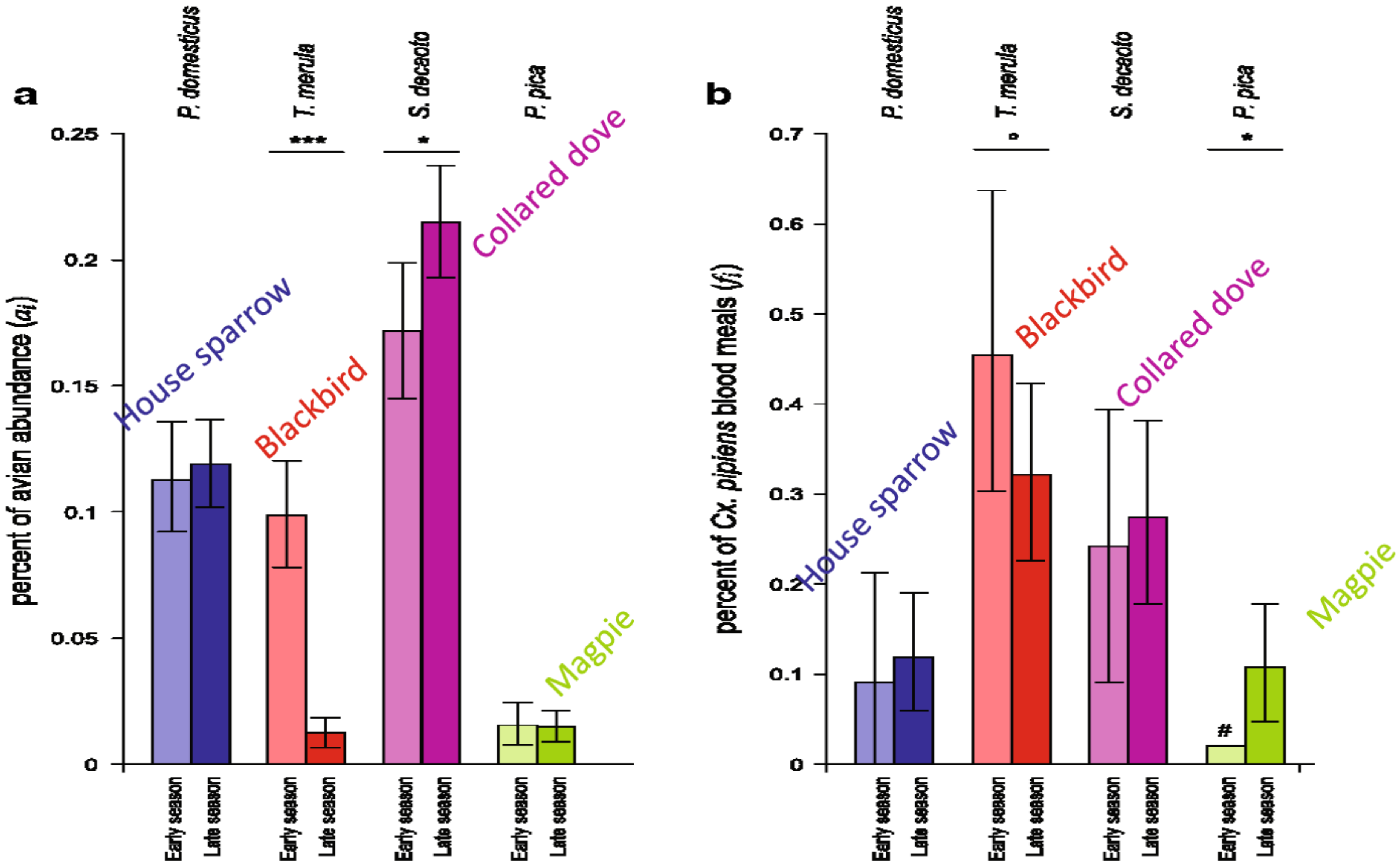
Zargar UR. 2015. Does alteration in biodiversity really affect disease outcome? doi: 10.1016/j.sjbs.2014.05.004



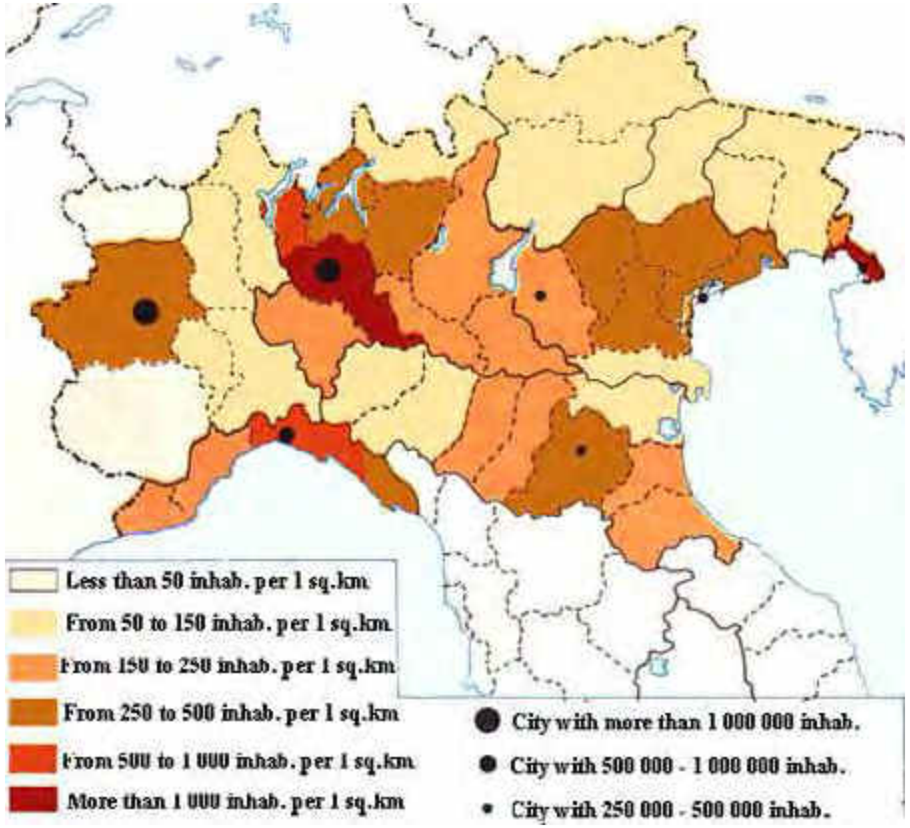
The Dilution Effect-Numbers Densities and Prevalences . https://parasiteecology.wordpress.com/page/29/?wref=bif

Feeding Preference & Host Switching

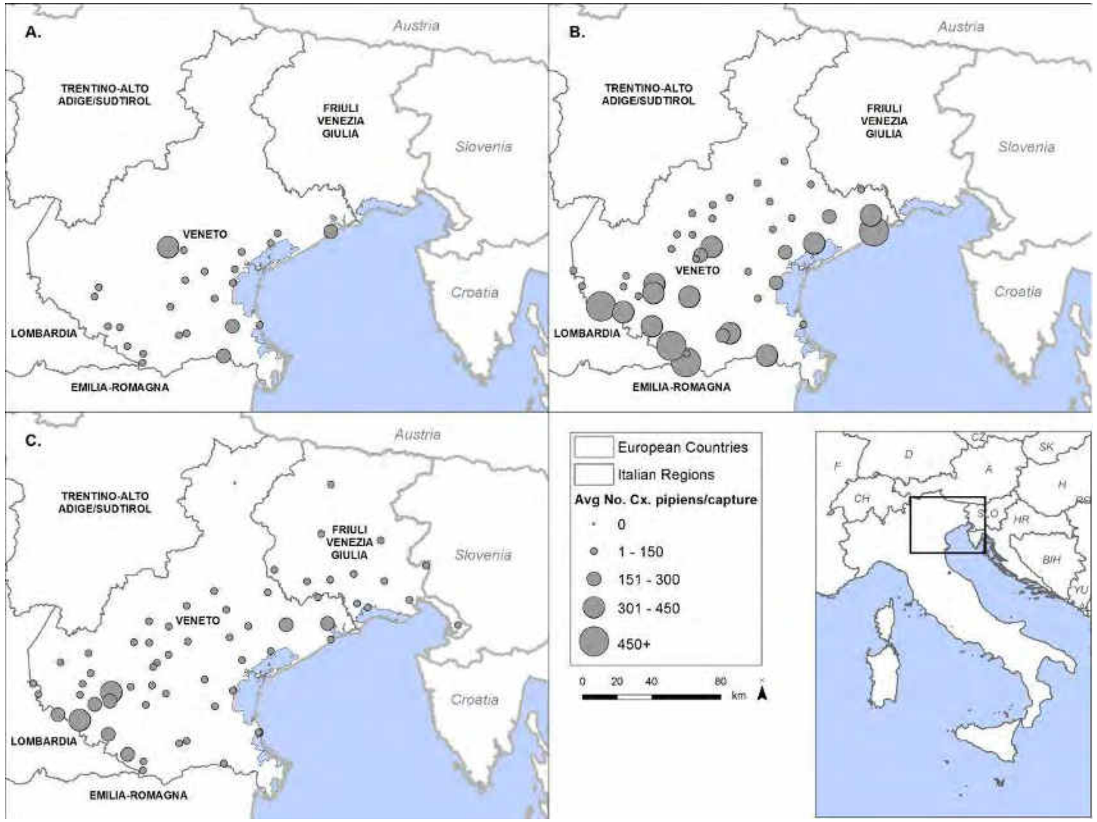
Rizzoli A. et al., 2015. Understanding WNV ecology in Europe: *Culex pipiens* host feeding preference in a hotspot of virus emergence. doi:10.1186/s13071-015-0831-4.http://creativecommons.org/licenses/by/4.0



Population Density: Human Infection



rometour.org

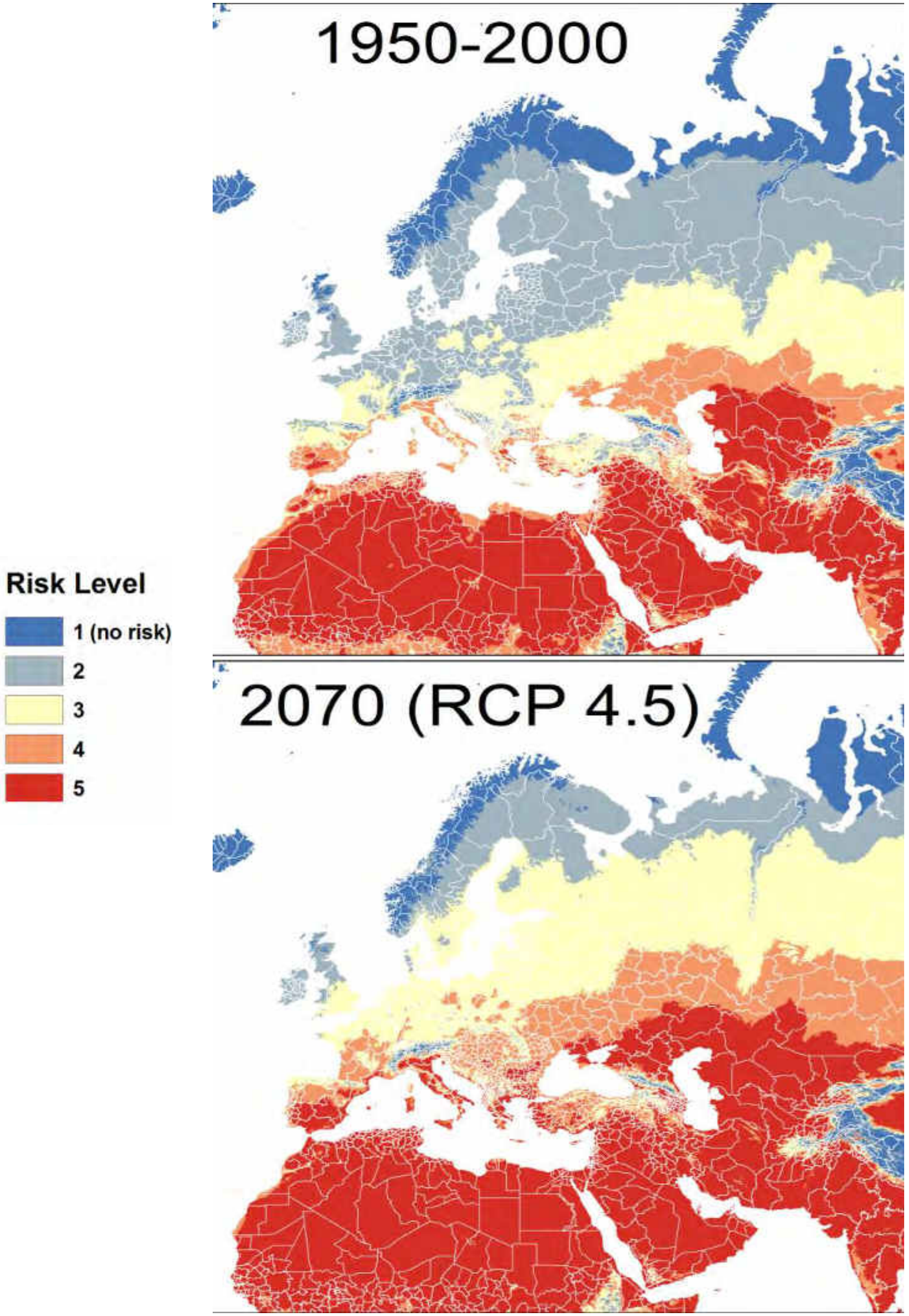


Mulatti P et al. 2013. Determinants of the population growth of the West Nile virus mosquito vector *Culex pipiens* in a repeatedly affected area in Italy. doi: 10.1186/1756-3305-7-26

Temperature Projections

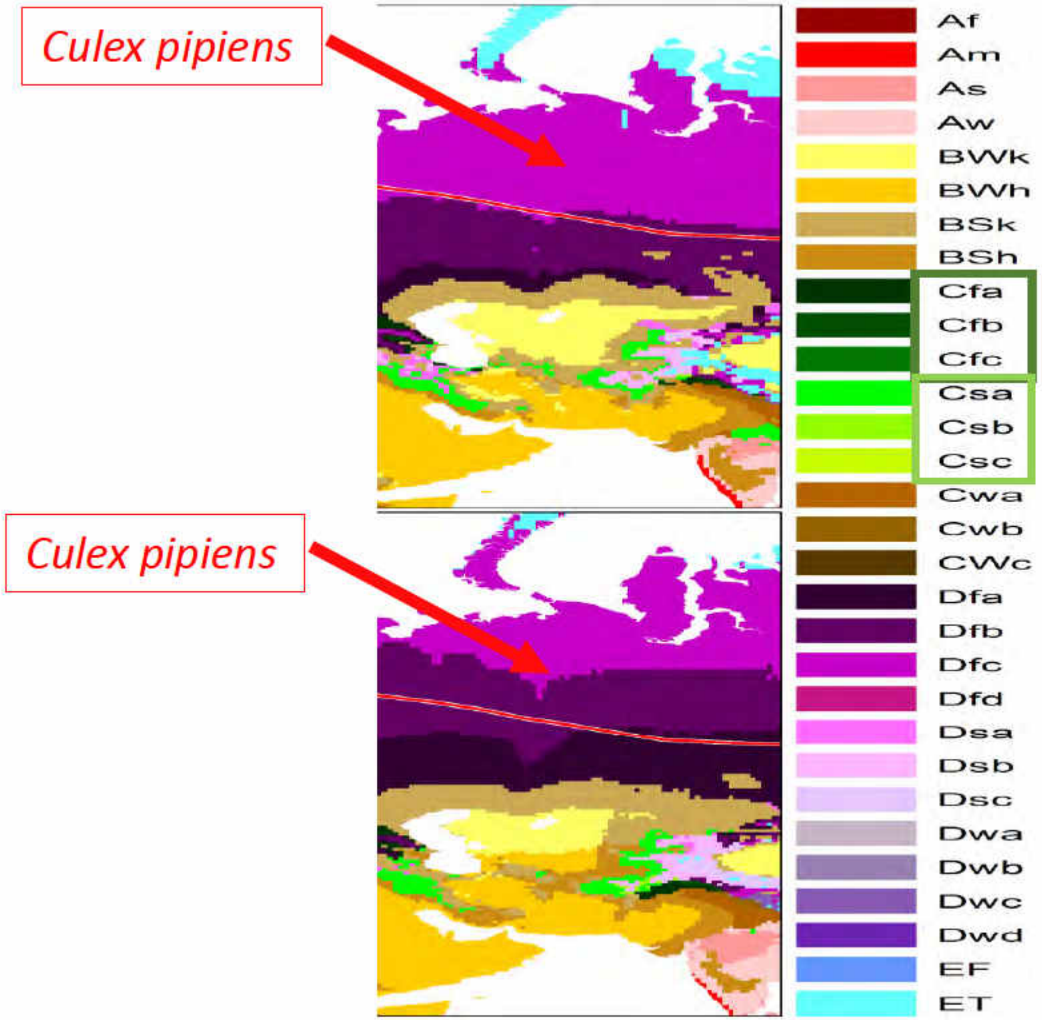
Suitability of July mean temperatures for WNV transmission, Europe 1950–2000

Projected suitability of July mean temperatures for WNV transmission, Europe 2070



Hoover KC and Barker CM. 2016. West Nile virus, climate change, and circumpolar vulnerability. doi:10.1002/wcc.382

Climate Projections



- Vector distribution unchanged but…

- Shift from no significant precipitation difference between seasons.
  - *Cfa* = Humid subtropical climate.
  - *Cfb* = Temperate oceanic climate.
  - *Cfc* = Subpolar oceanic climate.

- To 3x as much precipitation in wettest winter month as in the driest summer month (precip < 30mm).
  - *Csa* = Hot-summer Mediterranean climate
  - *Csb* = Warm-summer Mediterranean climate
  - *Csc* = Cool-summer Mediterranean climate

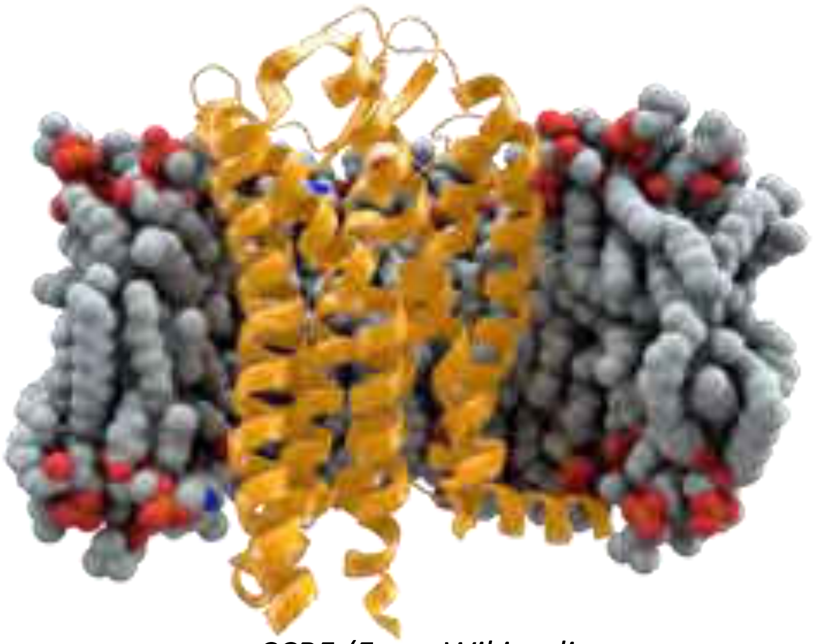
Hoover KC and Barker CM. 2016. West Nile virus, climate change, and circumpolar vulnerability. doi:10.1002/wcc.382

Main points

- *Culex* have strong feeding preferences
  - No dilution effect
  - Significant overwintering more likely in vector, not host
- Temperature significant for
  - *Culex* overwintering
  - Reproductive cycle
  - Transmission season
- Climate significant for
  - *Aedes* overwintering
  - Transmission season
  - Host-vector contact

Genetic Epidemiology

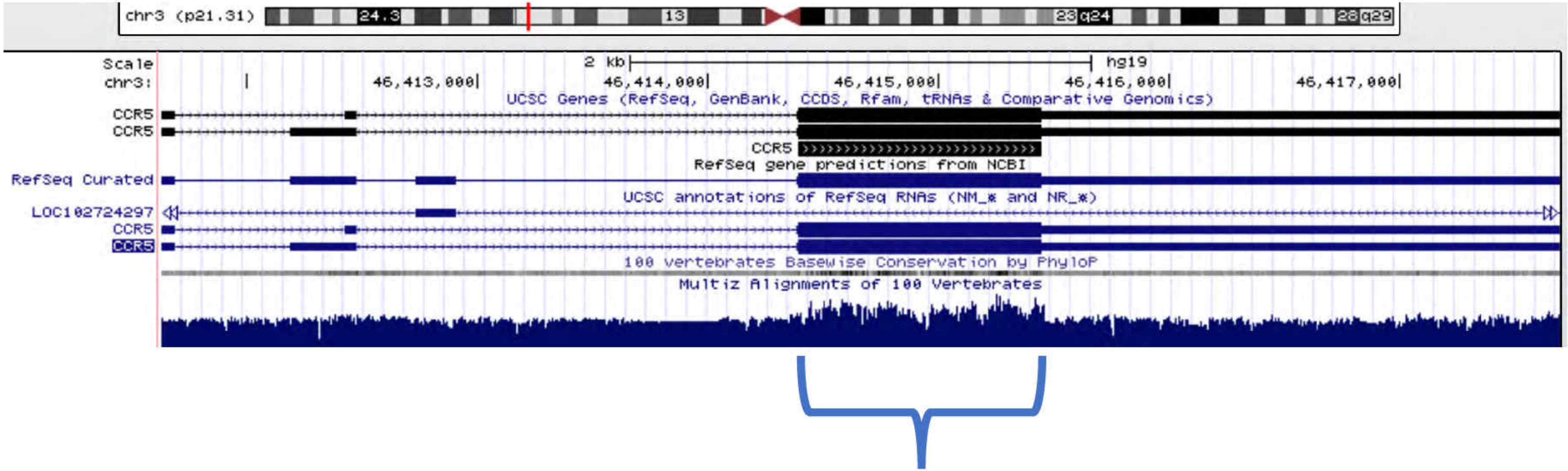
CC Chemokine Receptors and Viruses



CCR5 (From Wikipedia, CC BY-SA 3.0)

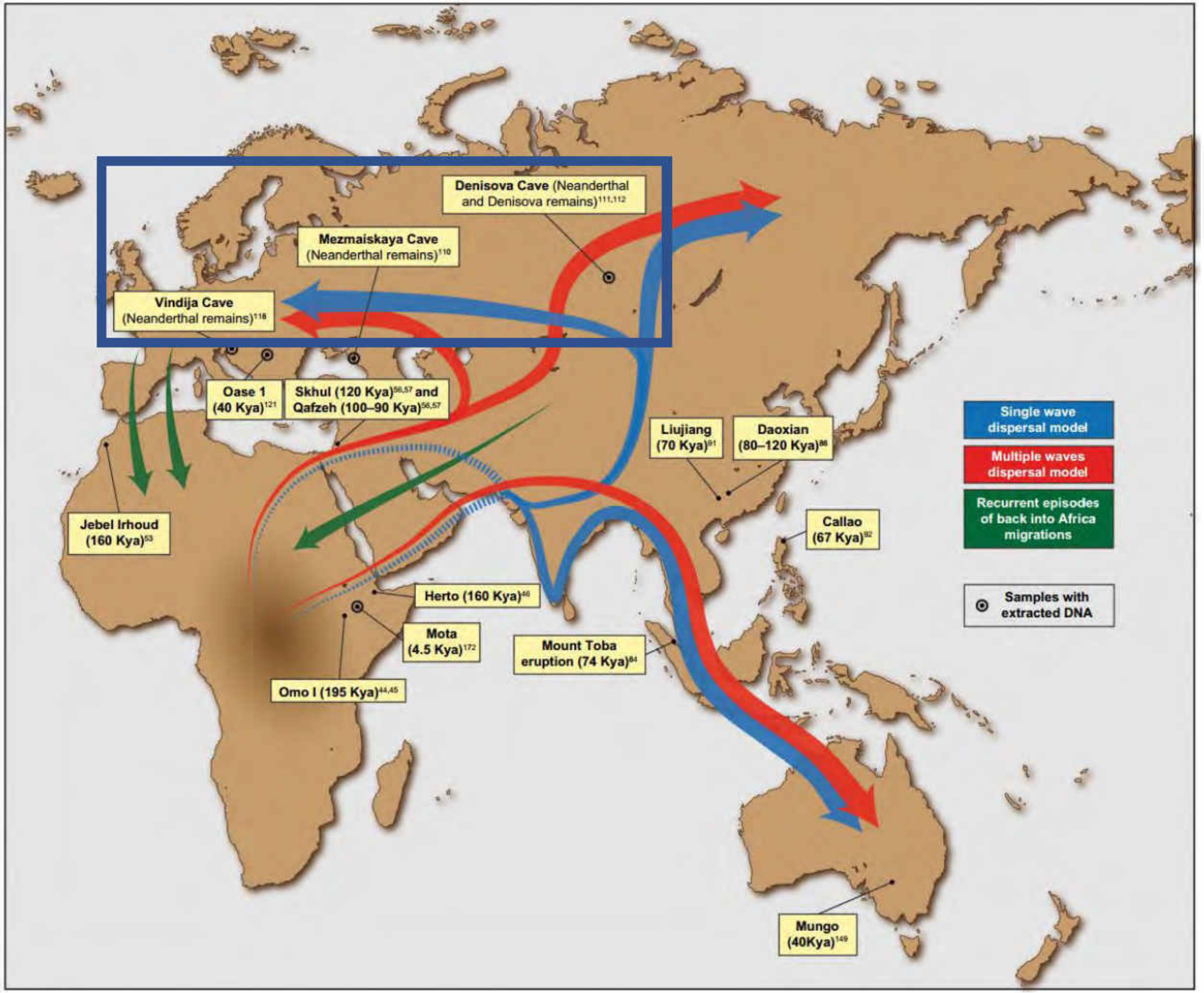
- Virus
  - Innate immune system
  - No memory
- Chemokine
  - Cell-environment communication
  - Direct chemokine activity
  - Recruit immune cells to infection sites

Evolutionary Conservation of CCR5



Coding exon for protein
Data from UCSC Genome Browser (GRCh37/HG19)

Migration of *Homo*



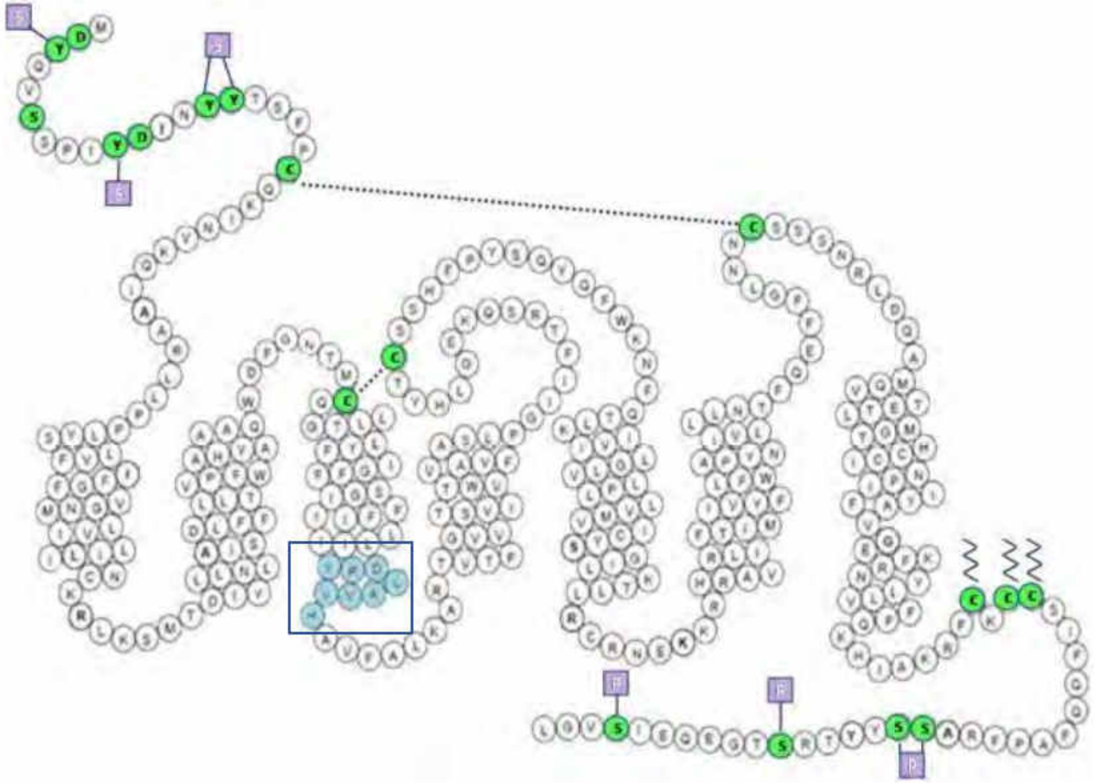
Lopez S. et al. 2016. Human Dispersal Out of Africa: A Lasting Debate. doi:10.4137/EBO.S33489. ISSN 1176-9343

Variation in *CCR5* in *Homo*

	Expected Variation	Actual Variation						
		Human		Neandertal			Denisova	
	Human Reference Genome, European	1000 Genomes	Ust'-Ishim	Altai	Mezmaiskaya	Vindija	3	2
Gene	17%	22%	0%	0%	11%	0%	0%	32%
Gene regulation	34%	33%	36%	75%	55%	60%	100%	29%

Hoover KC. 2018. Intragenus (*Homo*) variation in a chemokine receptor gene (*CCR5*).
doi:10.1371/journal.pone.0204989

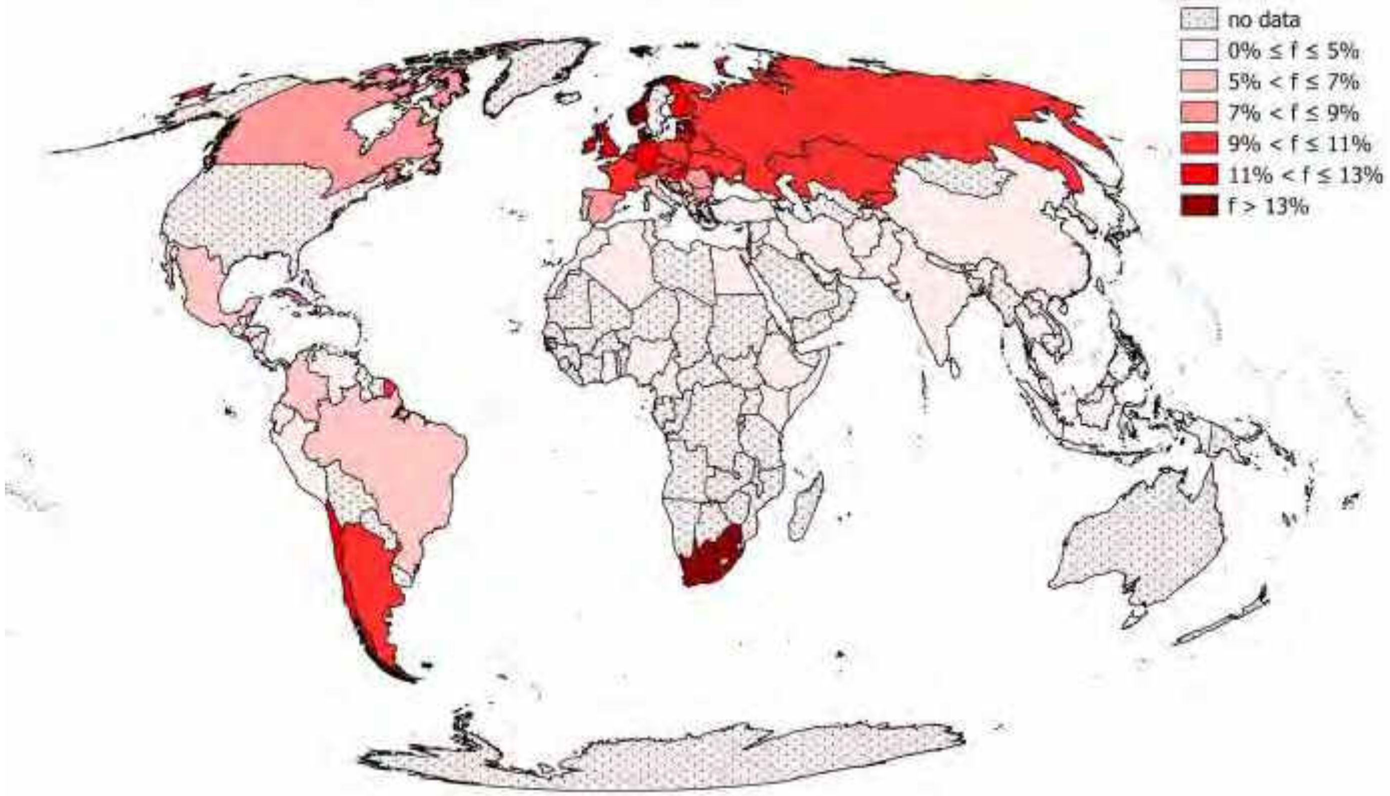
CCR5 and CCR5Δ32



Barmania, F, Pepper, MS. 2013. C-C chemokine receptor type five (CCR5): An emerging target for the control of HIV infection. doi:10.1016/j.atg.2013.05.004. CC BY-NC-ND 3.0

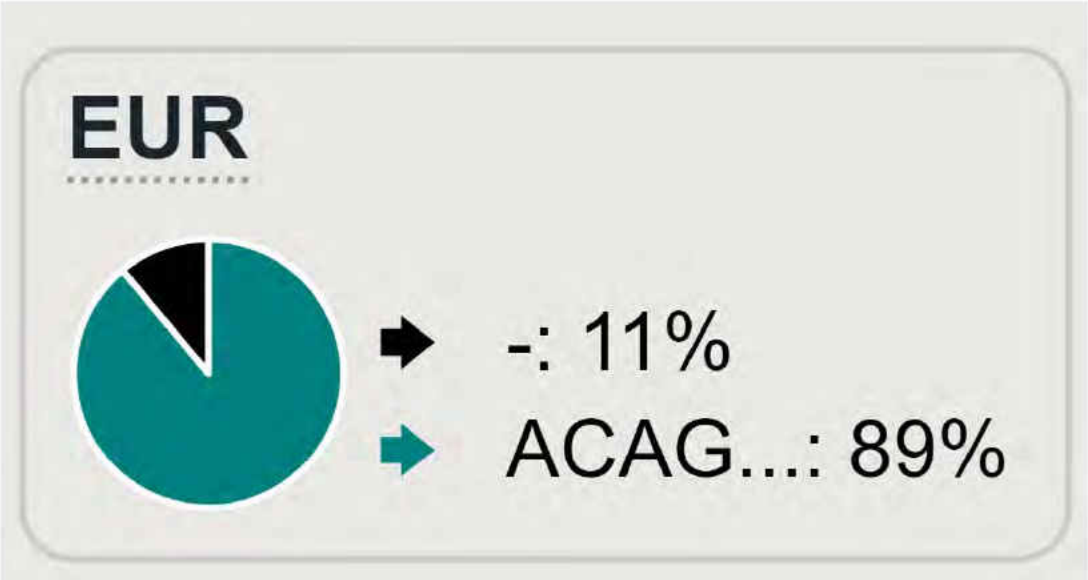
CCR5-WNV resistance	CCR5-HIV susceptibility
CCR5Δ32-WNV susceptibility	CCR5Δ32-HIV resistance

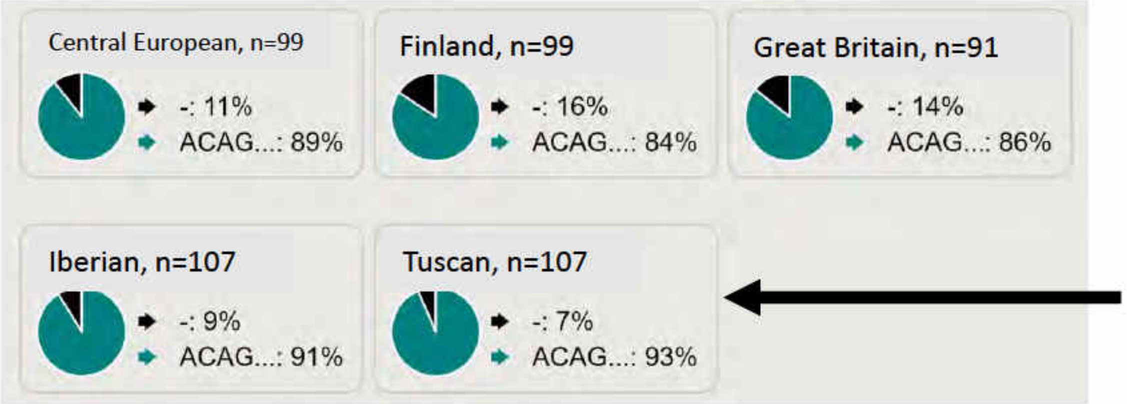
Distribution of CCR5Δ32



Sulloch et al. 2017. Frequencies of gene variant CCR5-Δ32 in 87 countries based on next-generation sequencing of 1.3 million individuals sampled from 3 national DKMS donor center. Doi: 10.1016/j.humimm.2017.10.001

Δ32 mutation rate, 1000 Genomes



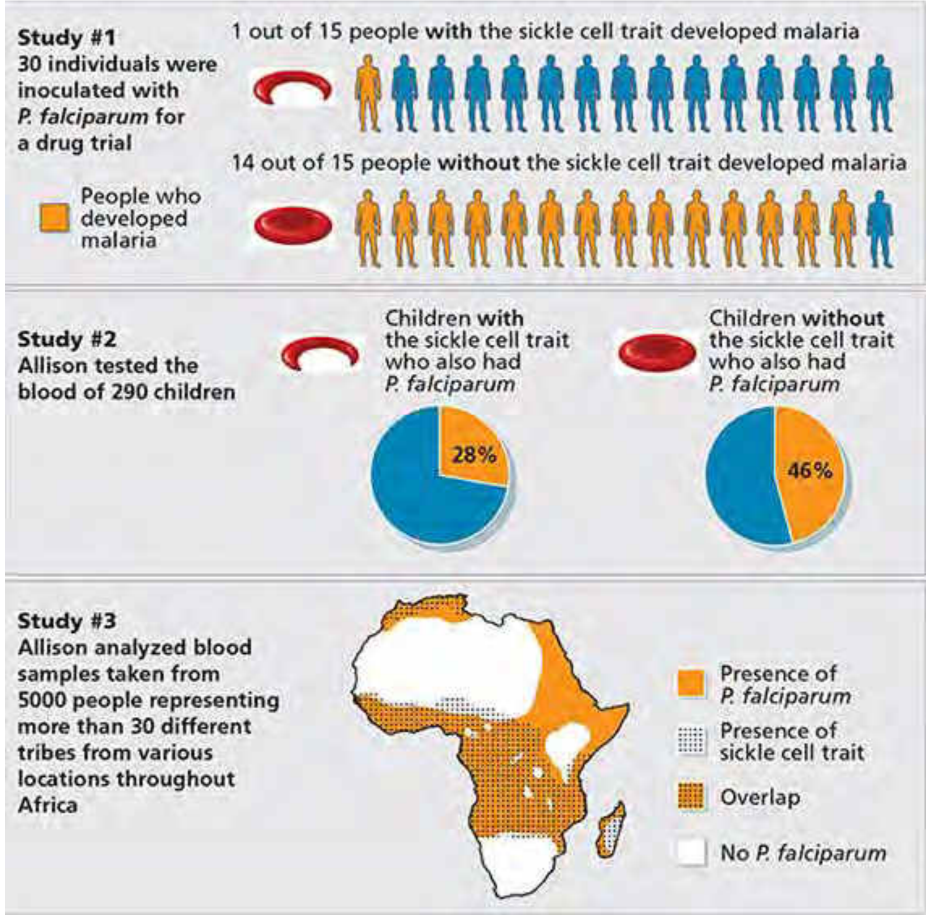


Main points

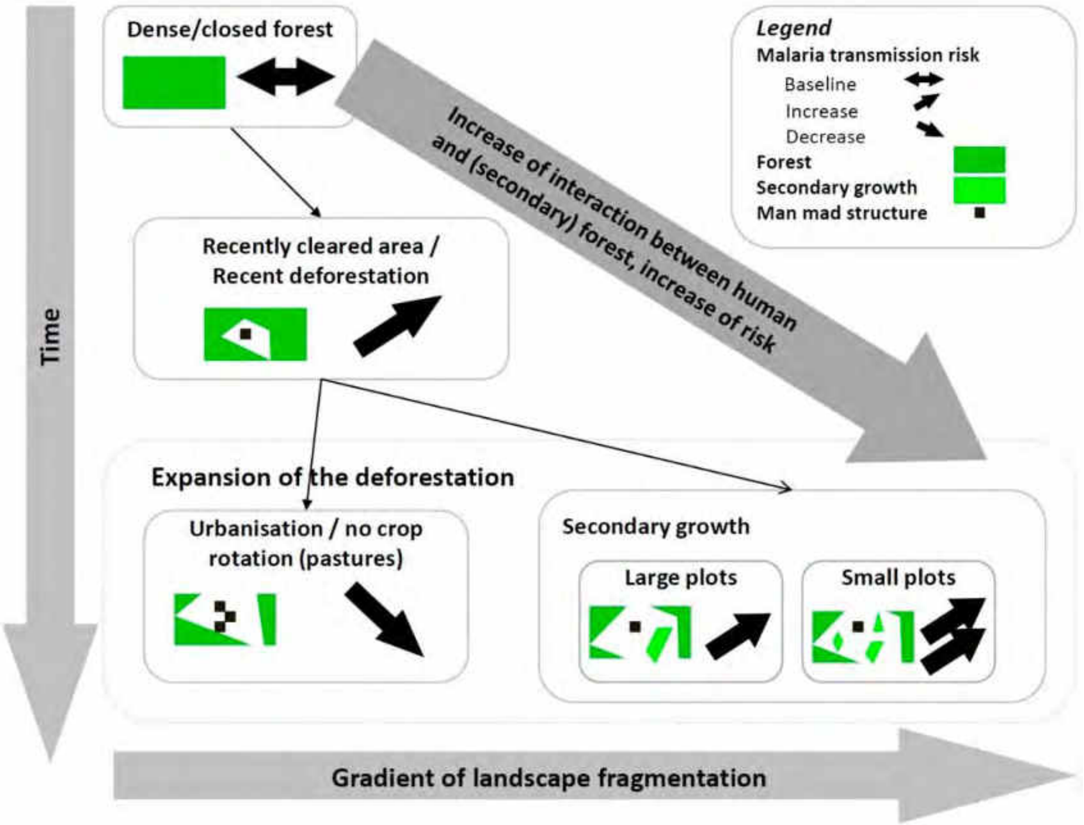
- Our genus, *Homo*, has evolved a flexible response to viral load
- Humans have genetic variant increasing susceptibility to WNV
- Susceptibility variant is common in Europe
- Important part of understanding infection risk and severity of disease progression

Human Disease Ecology

Human-Environment Interaction: Sickle Trait

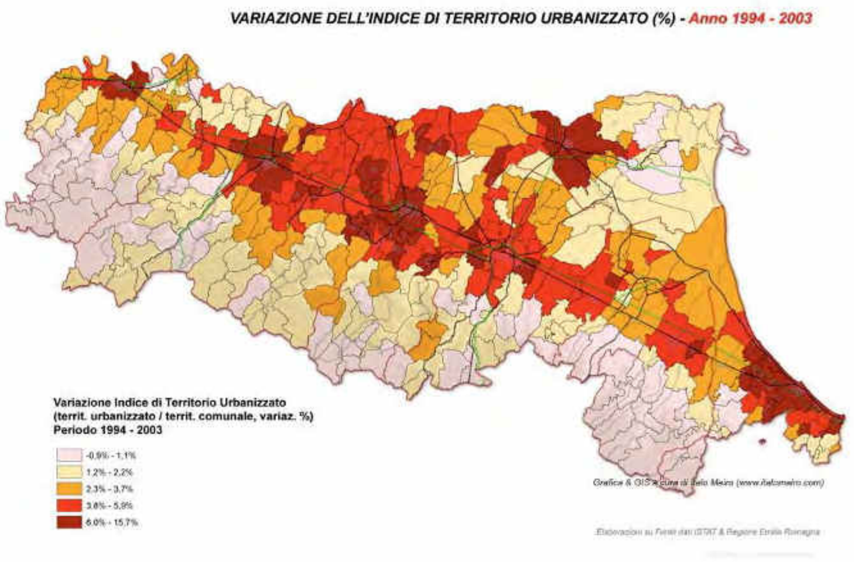


From: Bozzone DM. 2013. Sickle cell disease, malaria and human evolution. In, Biology for the Informed Citizen with Physiology. ISBN:9780195381993



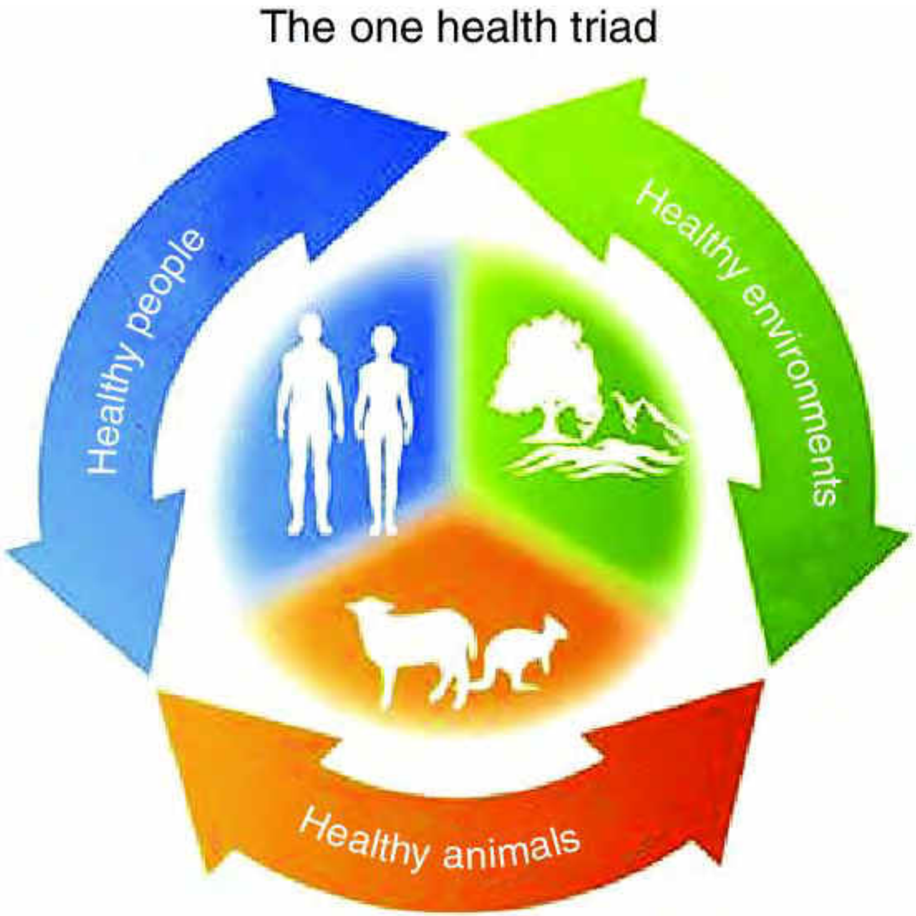
Stefani A. et al. 2013. Land cover, land use and malaria in the Amazon: a systematic literature review of studies using remotely sensed data. doi:10.1186/1475-2875-12-192. CC-BY-2.0

Human-environment interaction & Risk



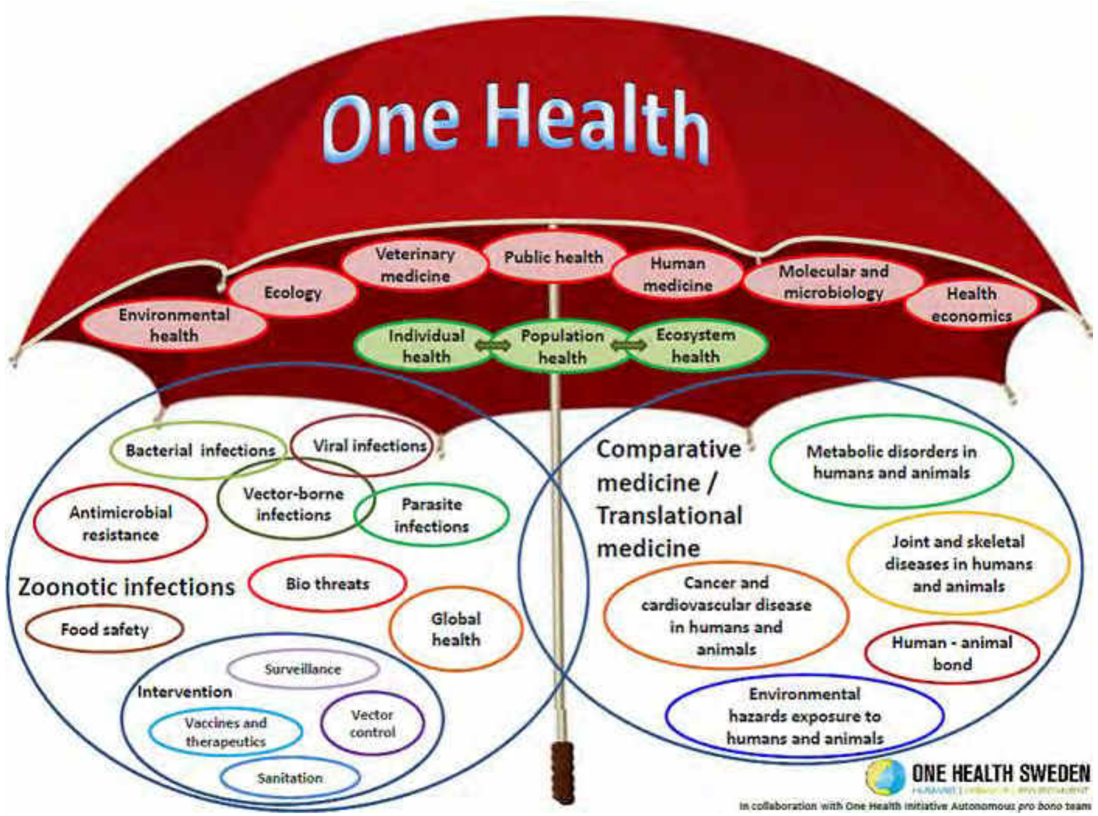
Prospects

Olaf Hajek: *Ecology of Disease*



One Health

- Vector-Host Factors
  - Amplify viral load
  - Accelerate transmission
- Ecology Factors
  - Feeding preference
  - Temperature
  - Climate
- Genetic Epidemiology
  - Plasticity
  - Susceptibility
- Human Factors
  - Environment interaction



Acknowledgements

- Dr. Michele Dottori, Istituto Zooprofilattico Sperimentale, Lombardia ed Emilia Romagna, Area territoriale di Reggio Emilia
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