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FÜR DEMOGRAFISCHE
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RESEARCH

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Birth, Death, & Thermodynamics

Tim Riffe

About that title

On the one hand

Birth and death are events experienced by individuals. Both are conditioned by randomness, circumstance, and agency.

On the other hand

Birth and death have very strong and steady age patterns. It's easy to think there might be *laws*.

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Laws? two kinds:

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You can *only* enter a population via birth or in-migration. You can *only* leave a population via death or out-migration. (conservation)

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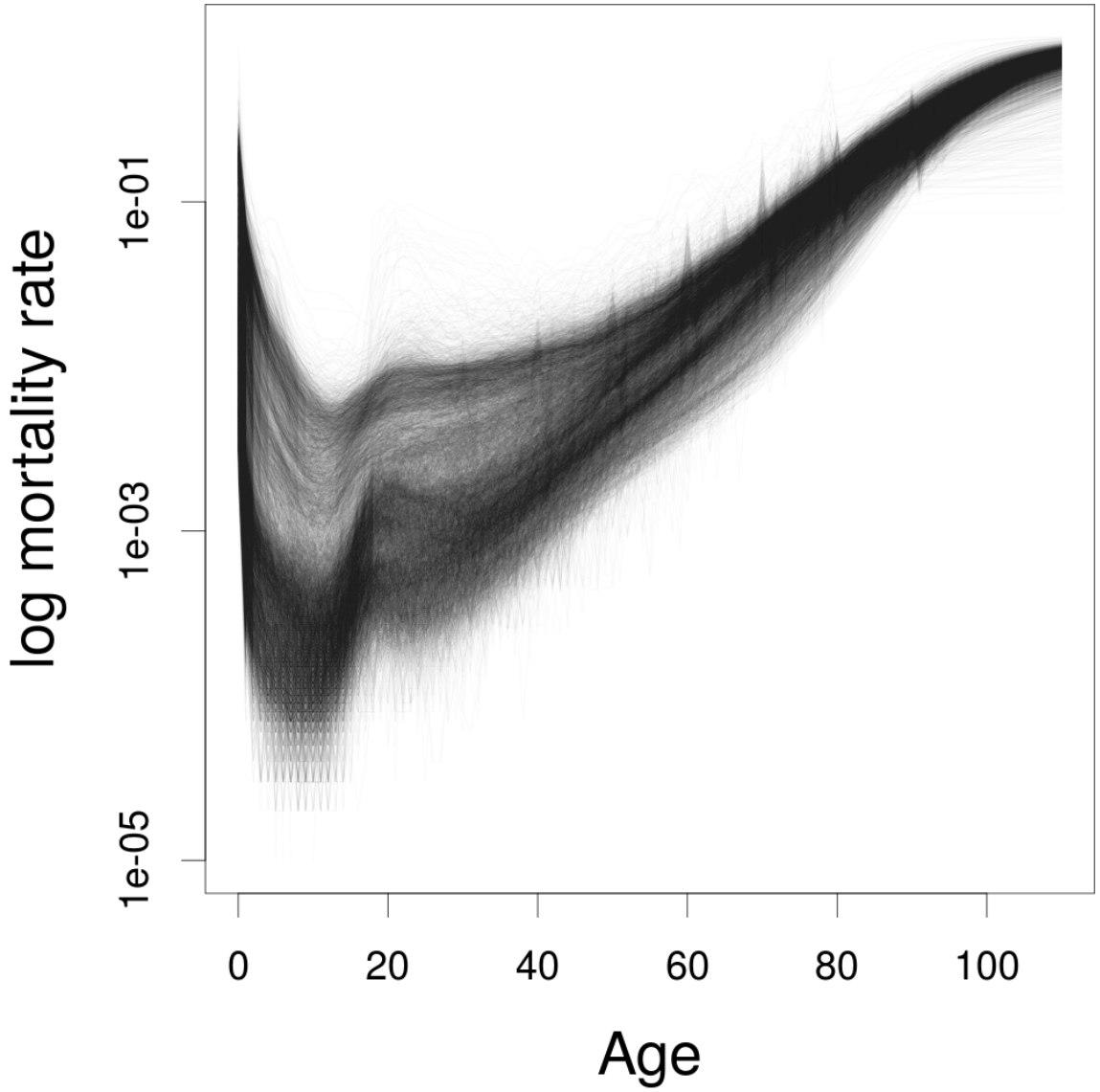
laws for mortality



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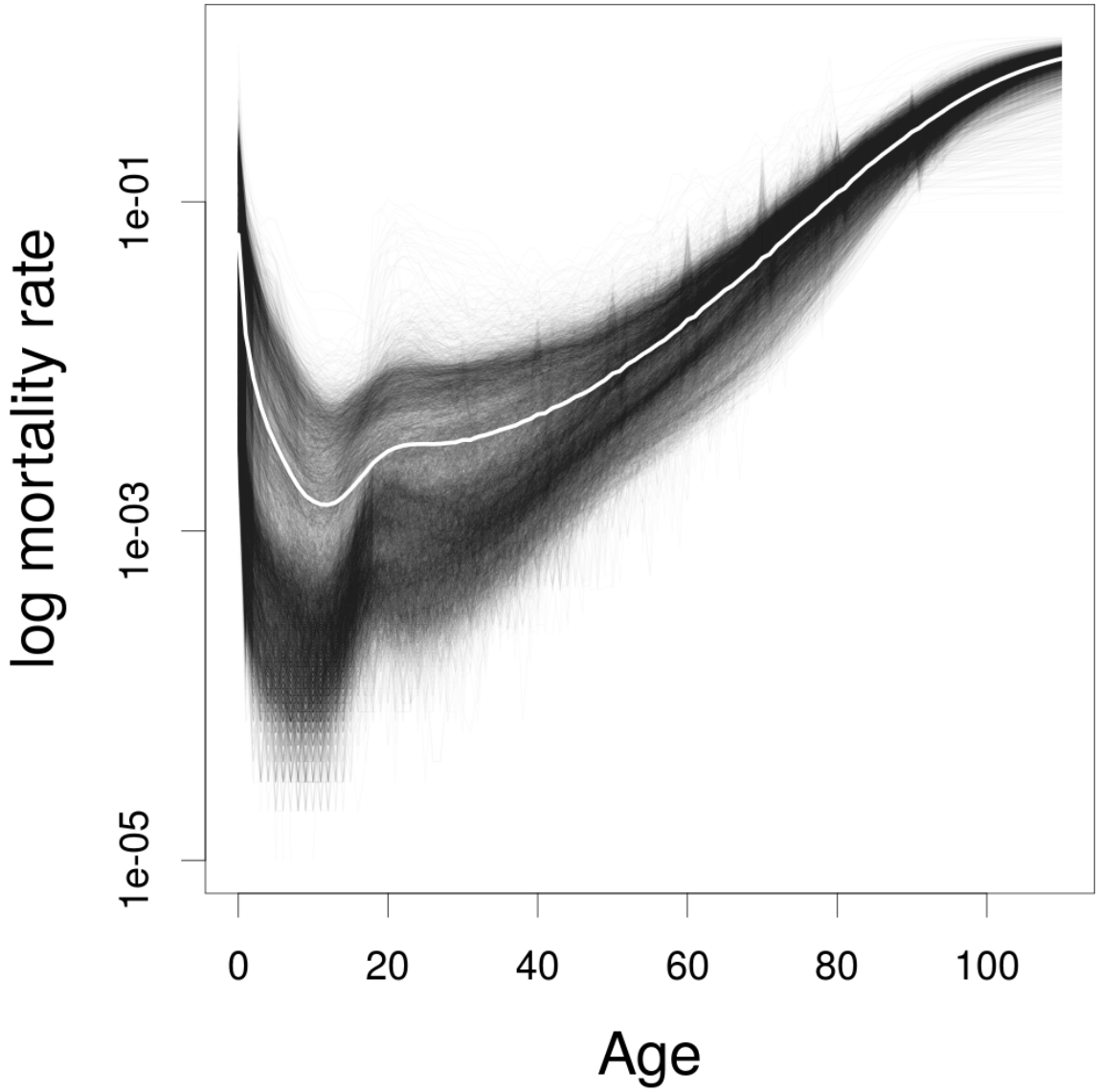

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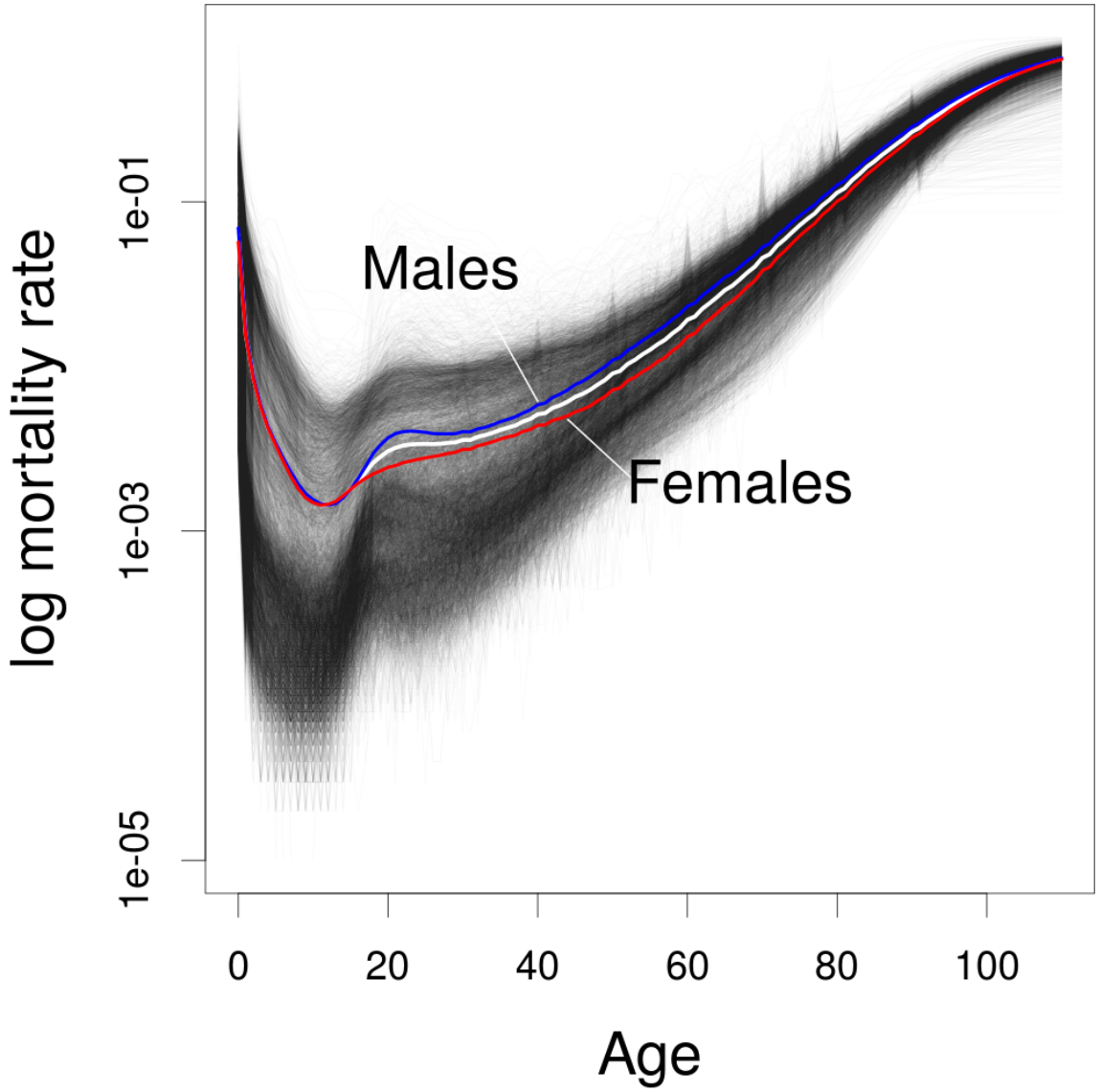

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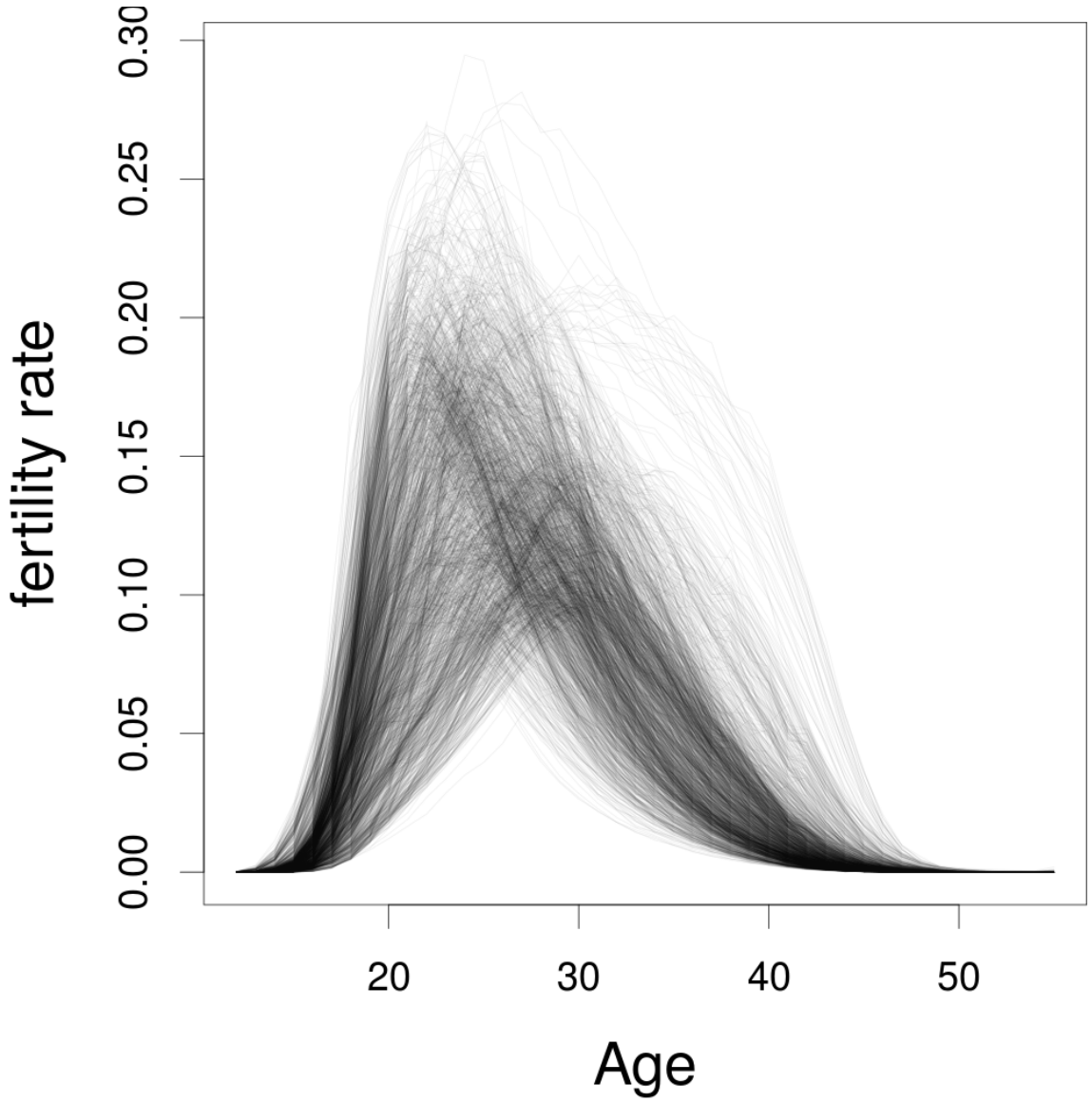

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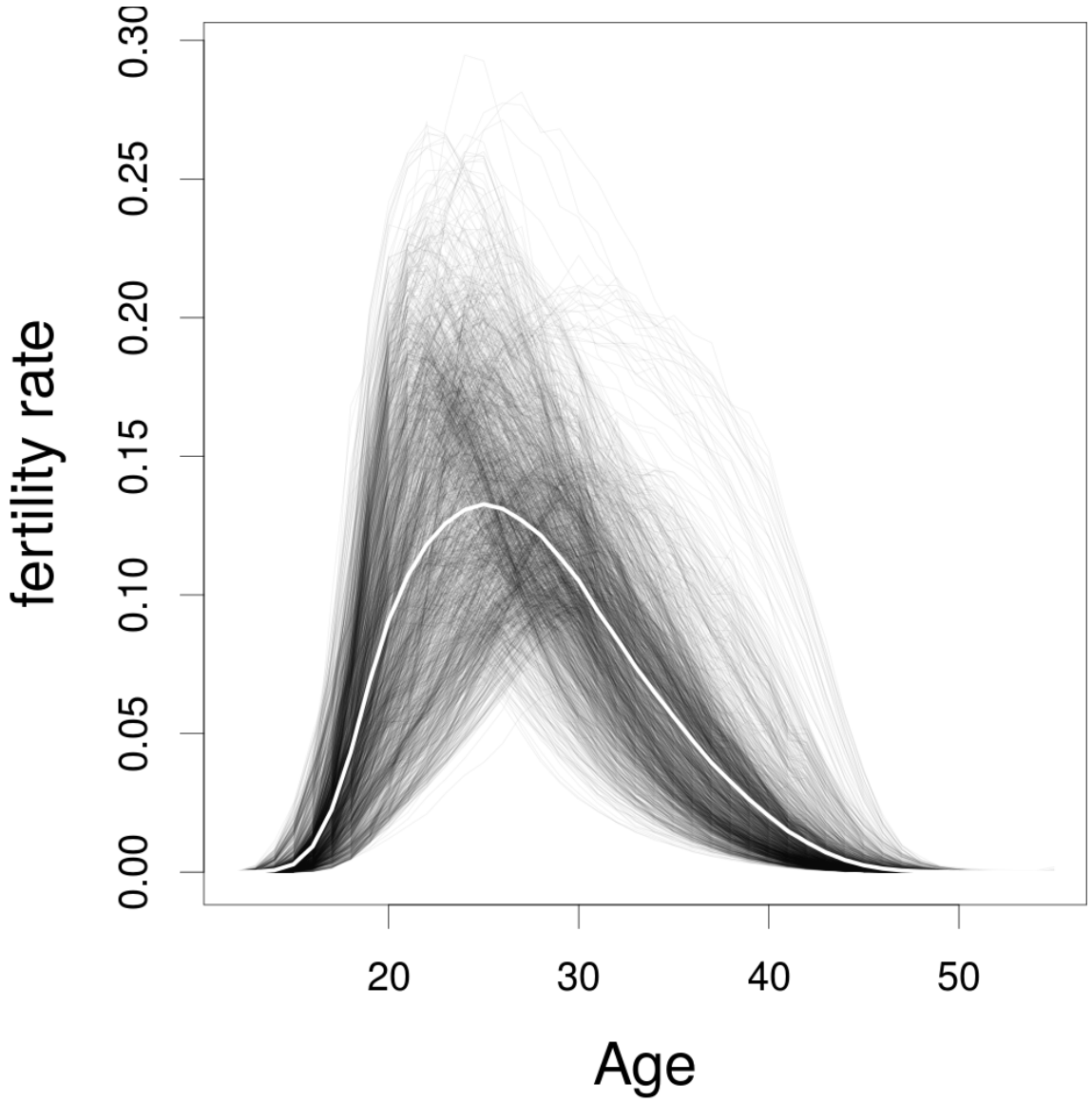

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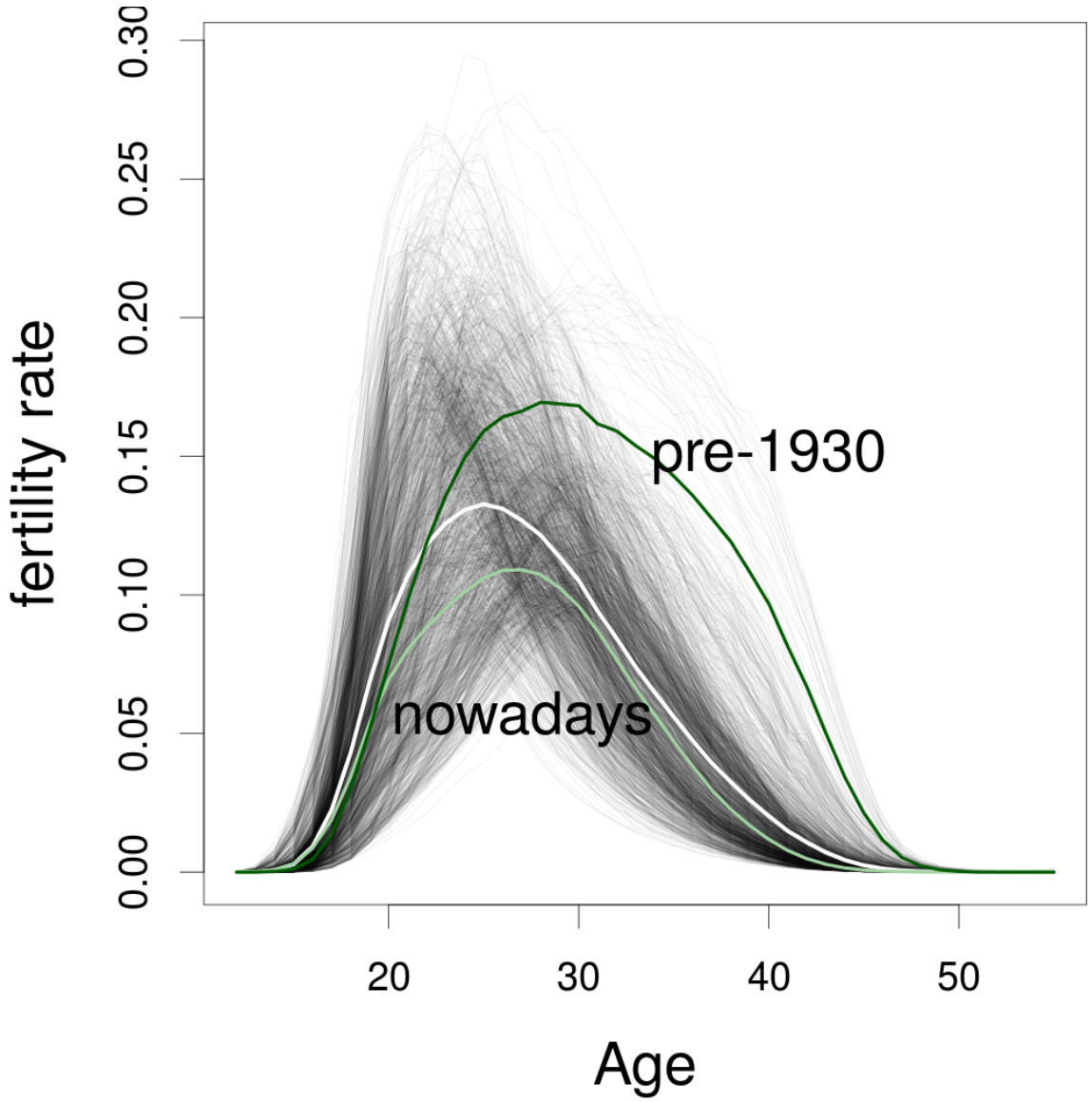
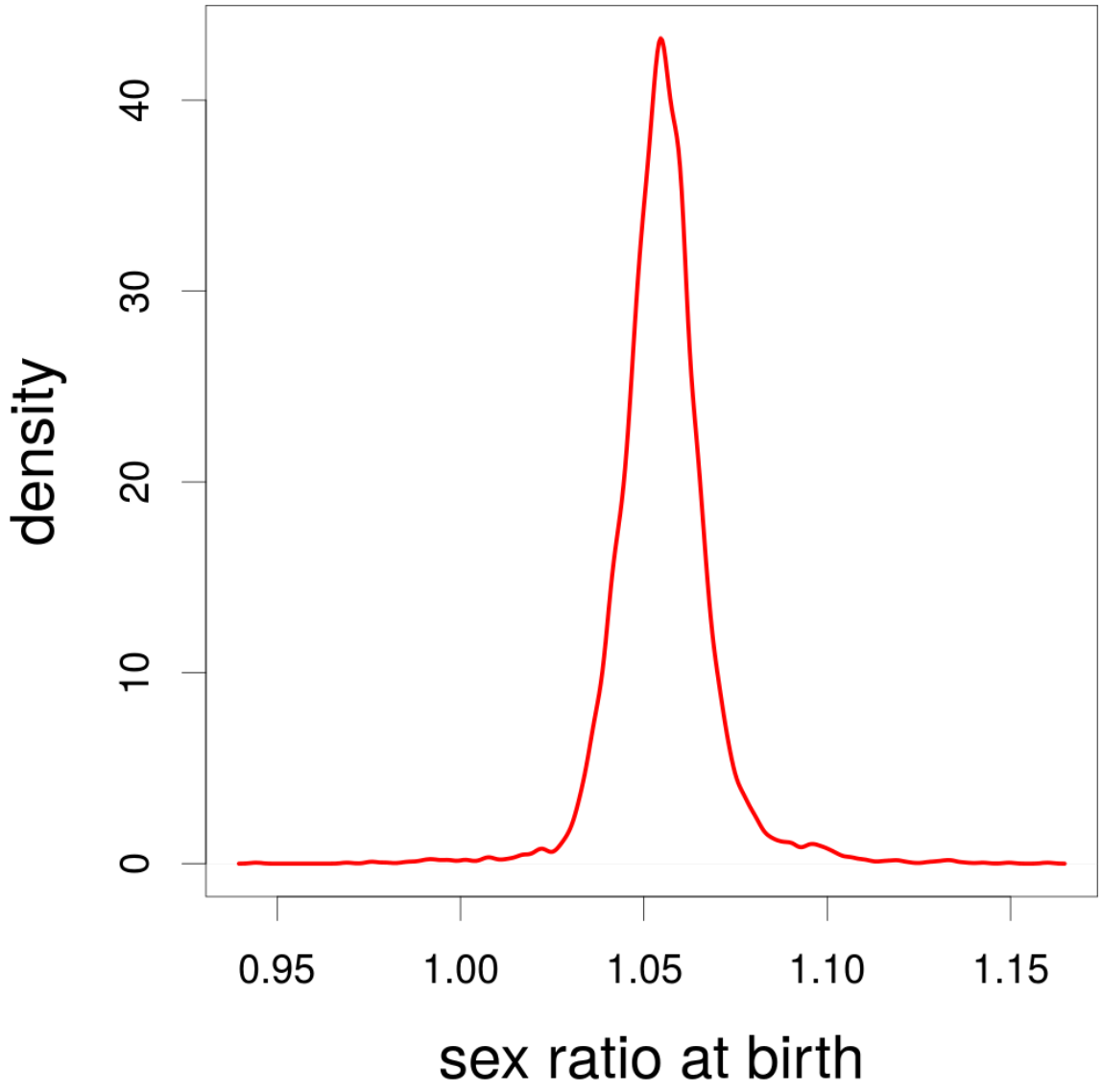


laws for fertility: Sex ratio at birth



continuous and discrete time

On the one hand

Populations are composed of a finite number of individuals. Events (birth, death) are usually observed in discrete intervals. Problem for differentiable equations for things?

On the other hand

We can think of underlying risk as a continuous and smooth function. And we can think of population processes in the limit as continuous functions. Plus continuous math is easier on the eyes.

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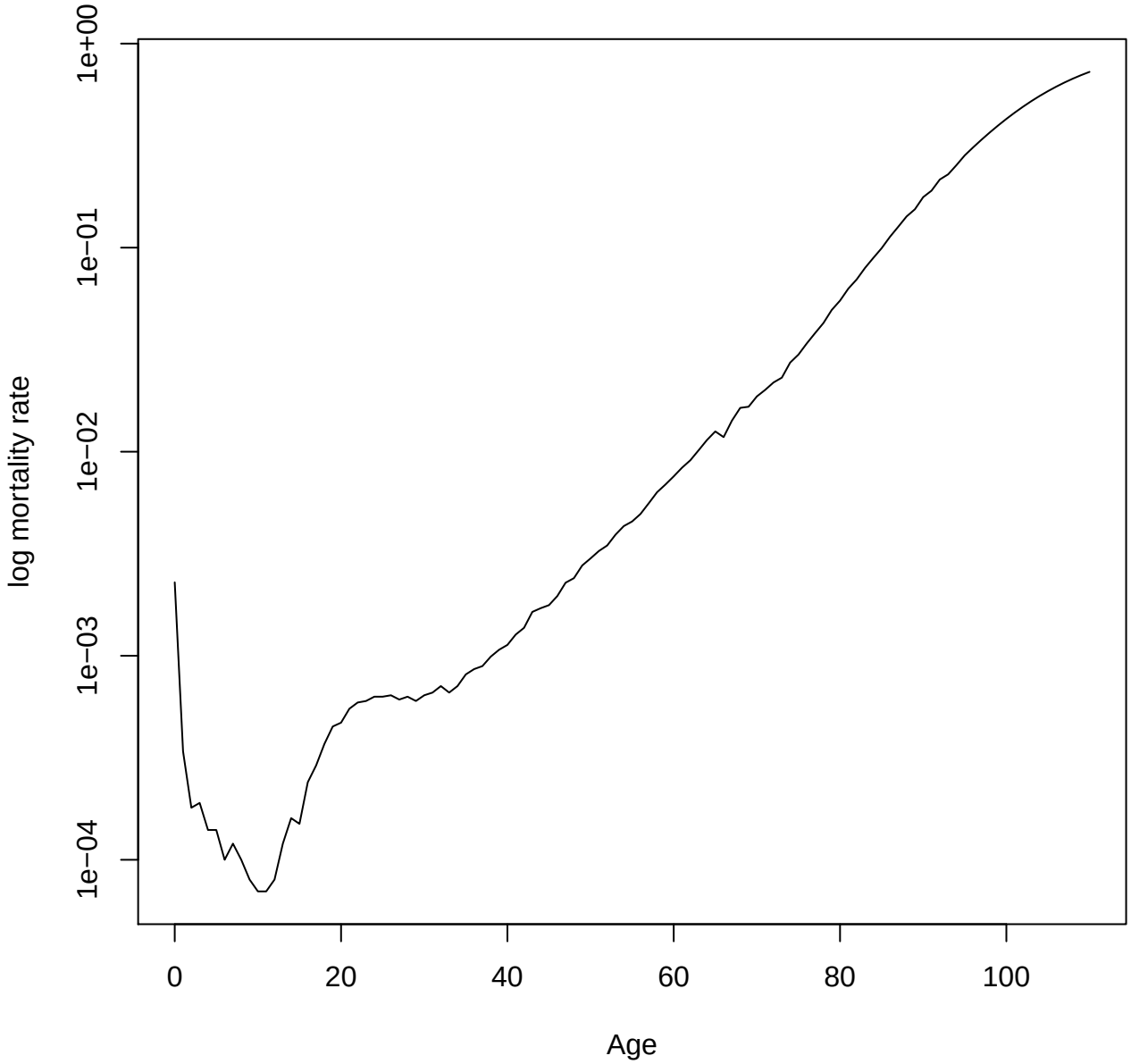
Models of understanding



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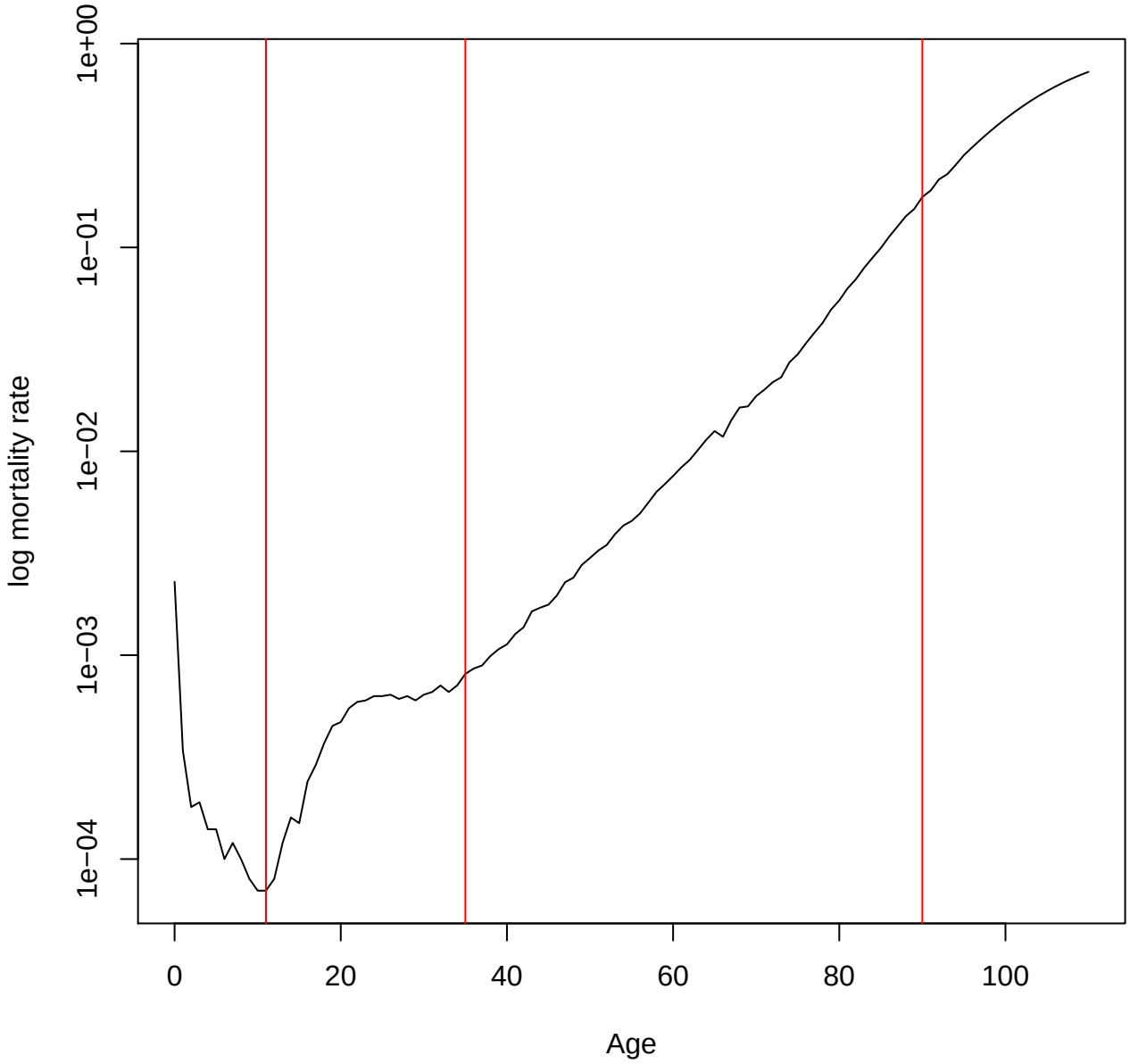
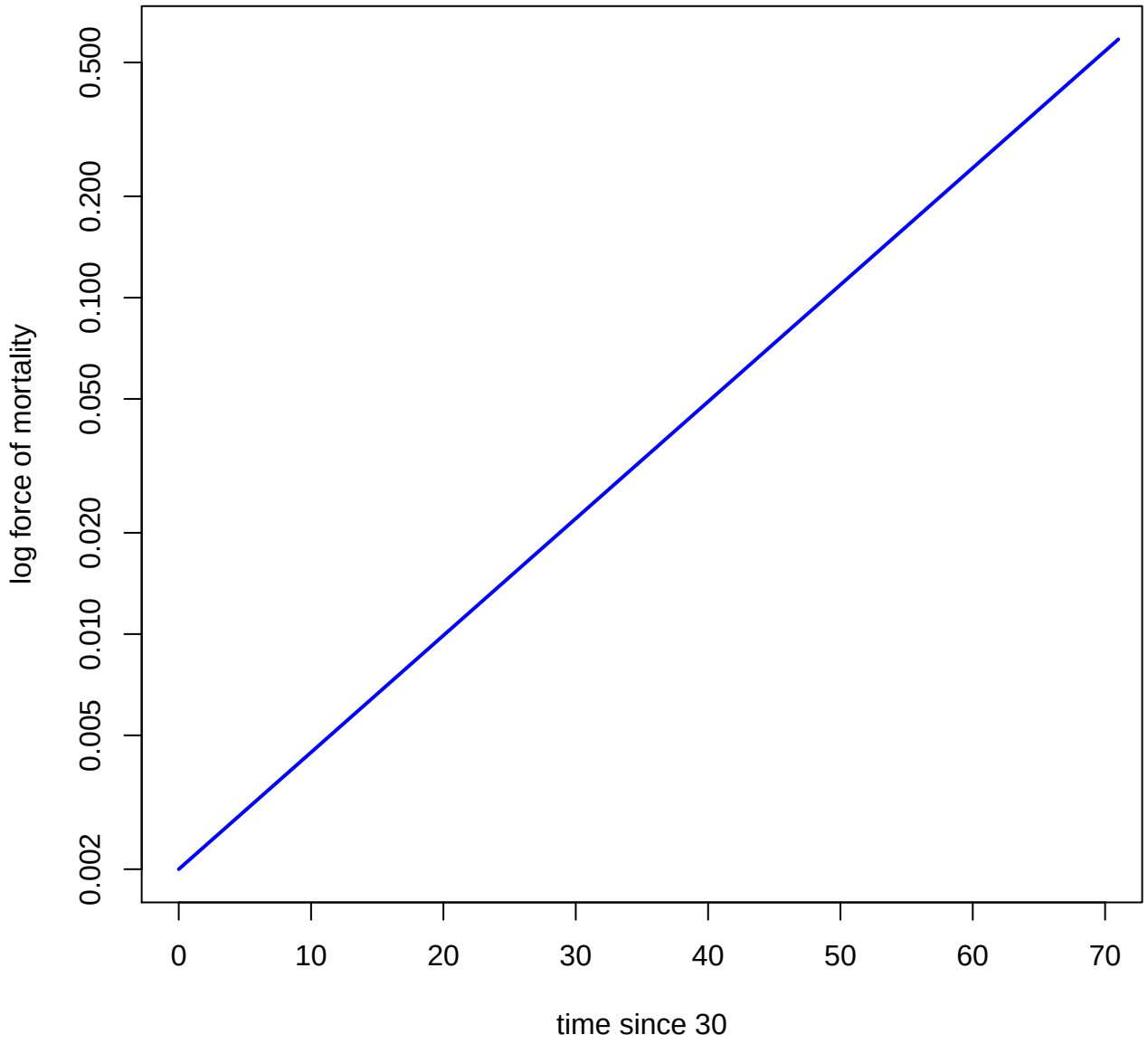


Models of understanding: frailty



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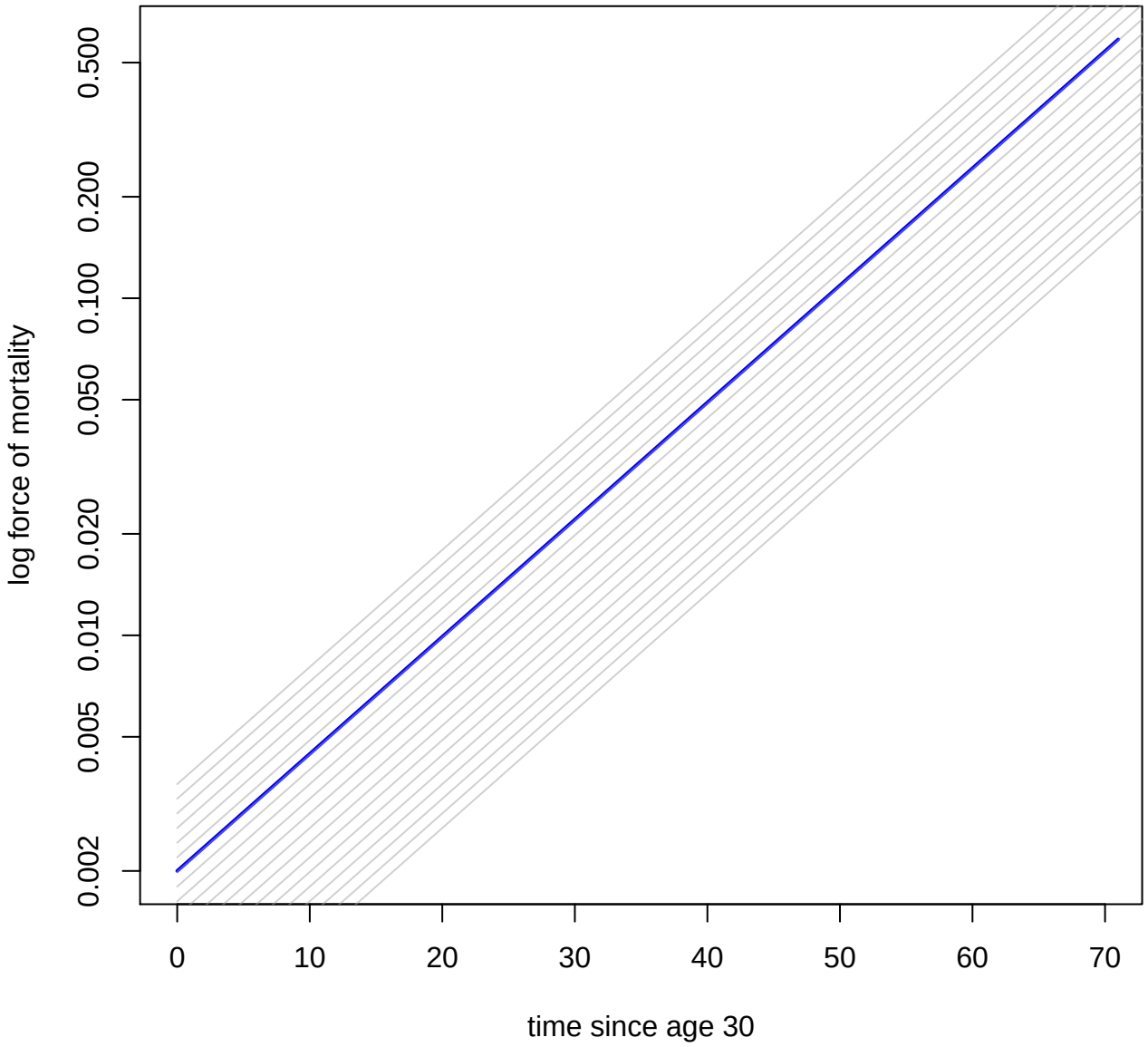

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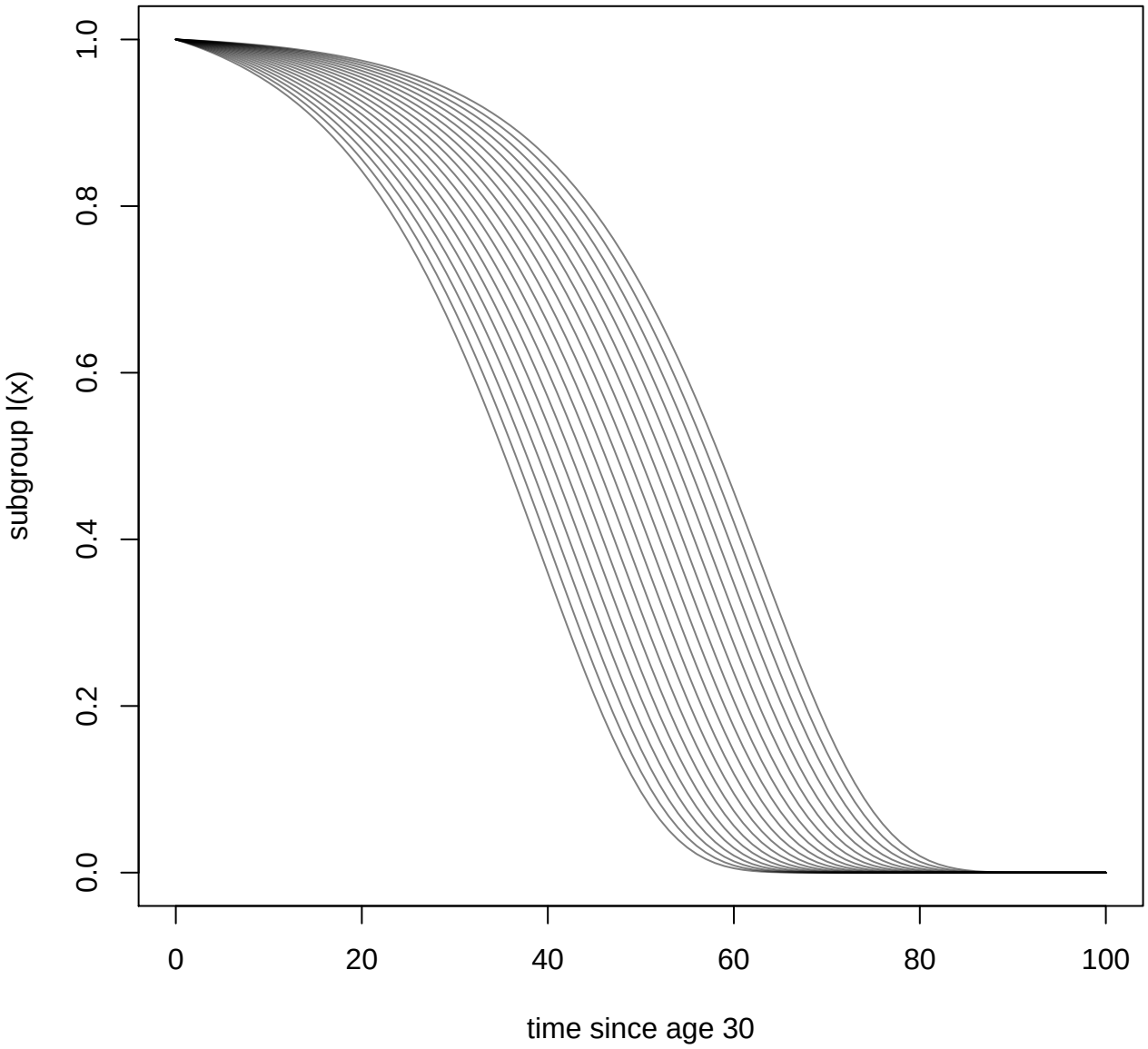

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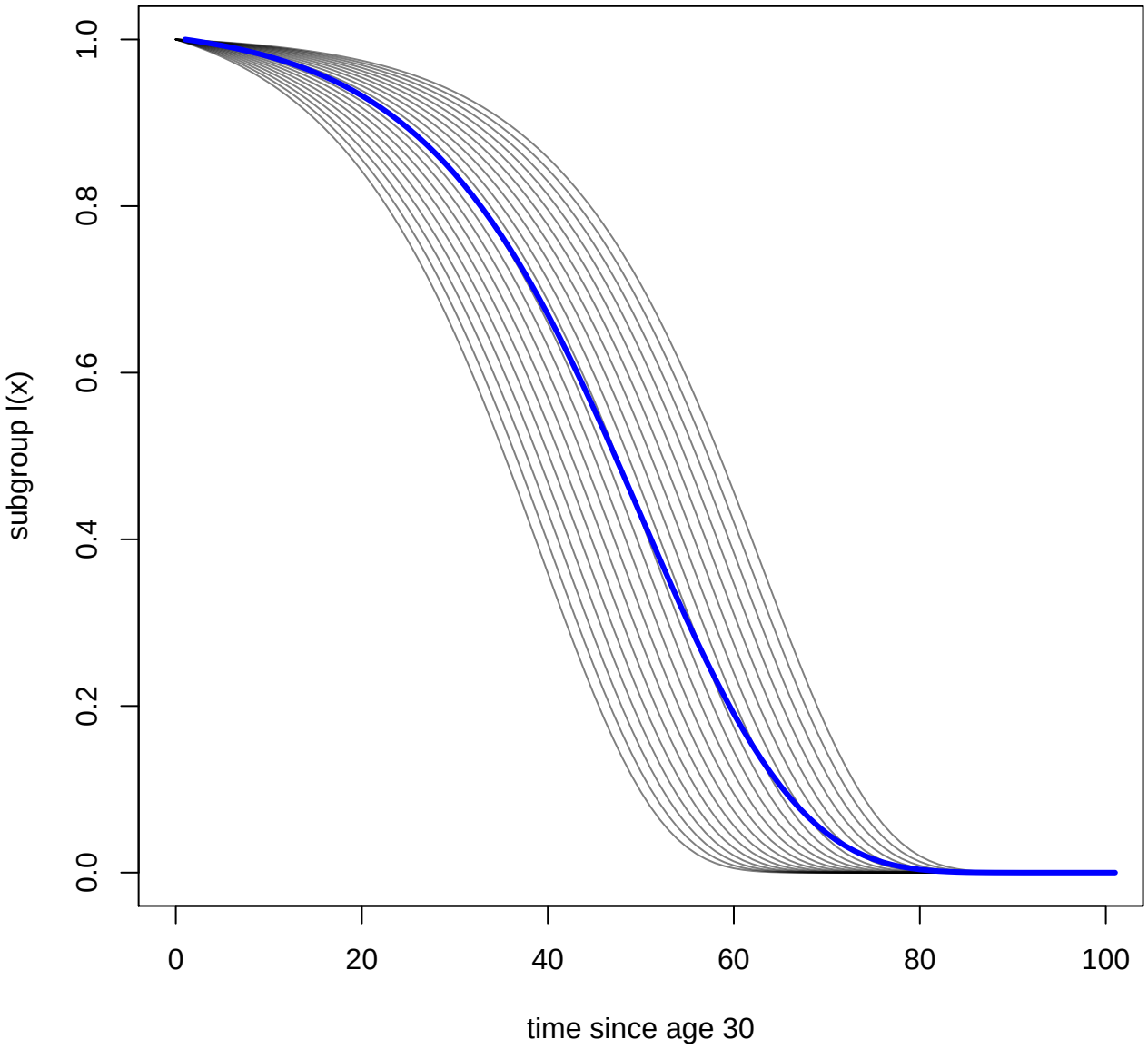

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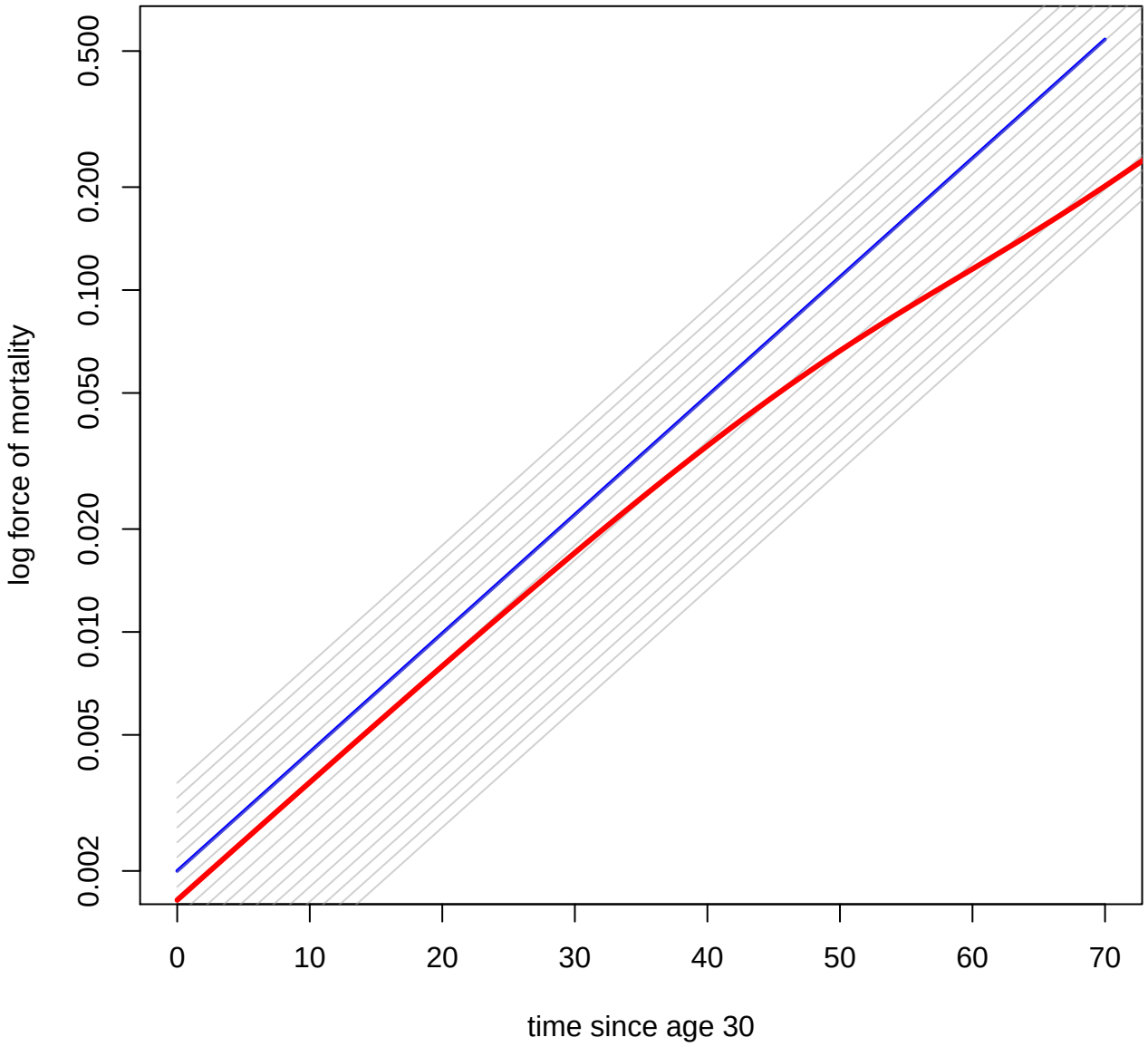


Models of understanding: and yes, there's math

$$P_B(y,t) = \frac{1}{1 + h\ exp(-k(t)(1-\lambda_B)\phi_s(y))} \tag{8.16}$$

$$\frac{\partial P_B(y,t)}{\partial t} = -\frac{\partial \ln(k(t))}{\partial t}\left[h\ k(t)\phi_s(y)(\lambda_B - 1)P_B(y,t)(1-P_B(y,t))\right] \tag{8.17}$$

$$\frac{\partial \ln(P_B(y,t))}{\partial t} = \frac{\partial \ln(k(t))}{\partial t}\left[k(t)\phi_s(y)(1-\lambda_B)(1-P_B(y,t))\right]$$

where $\phi_s(y) = \int_{Y_1}^{y} \mu_s(x)dx$ and $h = (1-g)/g$.

The mean value of frailty at age y and time t is:

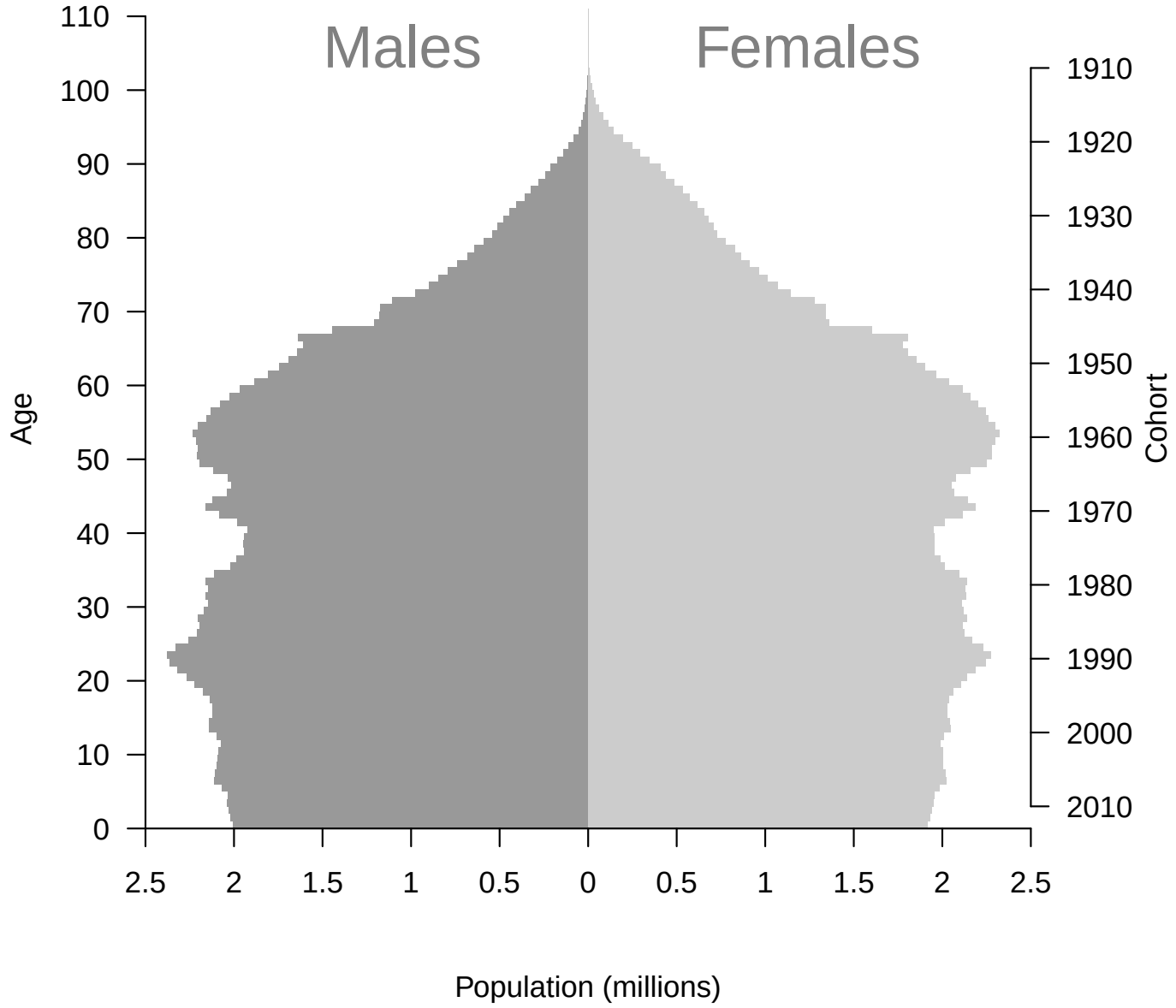
$$E_{yt}(\lambda_B) = P_B(y,t)(\lambda_B - 1).$$

Taking logs in (8.15) and then derivatives with respect to time we get

$$\frac{\partial \ln(\bar{\mu}(y,t))}{\partial t} = \frac{\partial \ln(k(t))}{\partial t} - \left\{\frac{(\lambda_B - 1)(\partial P_B(y,t)/\partial t)}{P_B(\lambda_B - 1) + 1}\right\}. \tag{8.18}$$

screenshot from Palloni & Beltran-Sanchez (2016)

Population renewal



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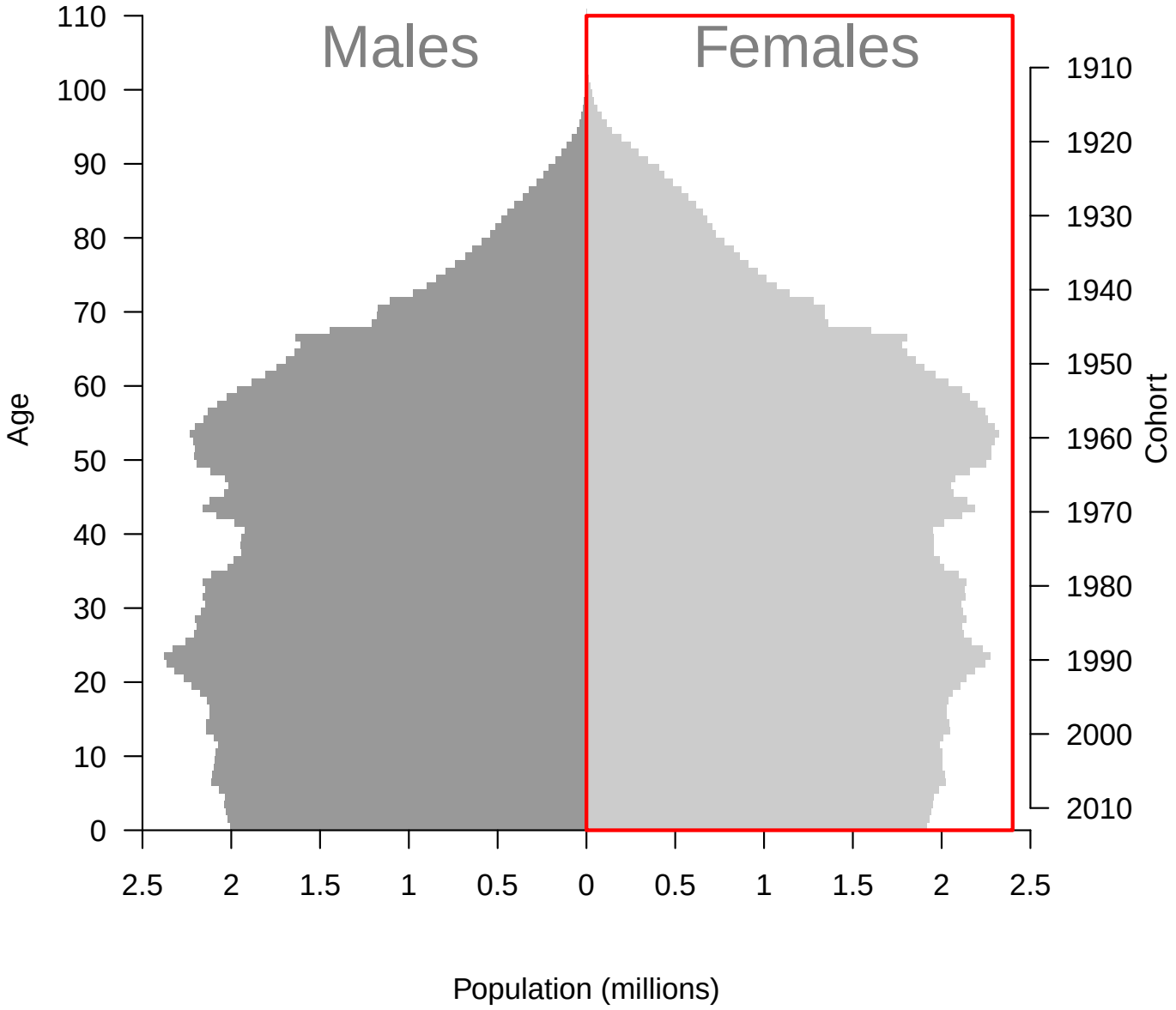

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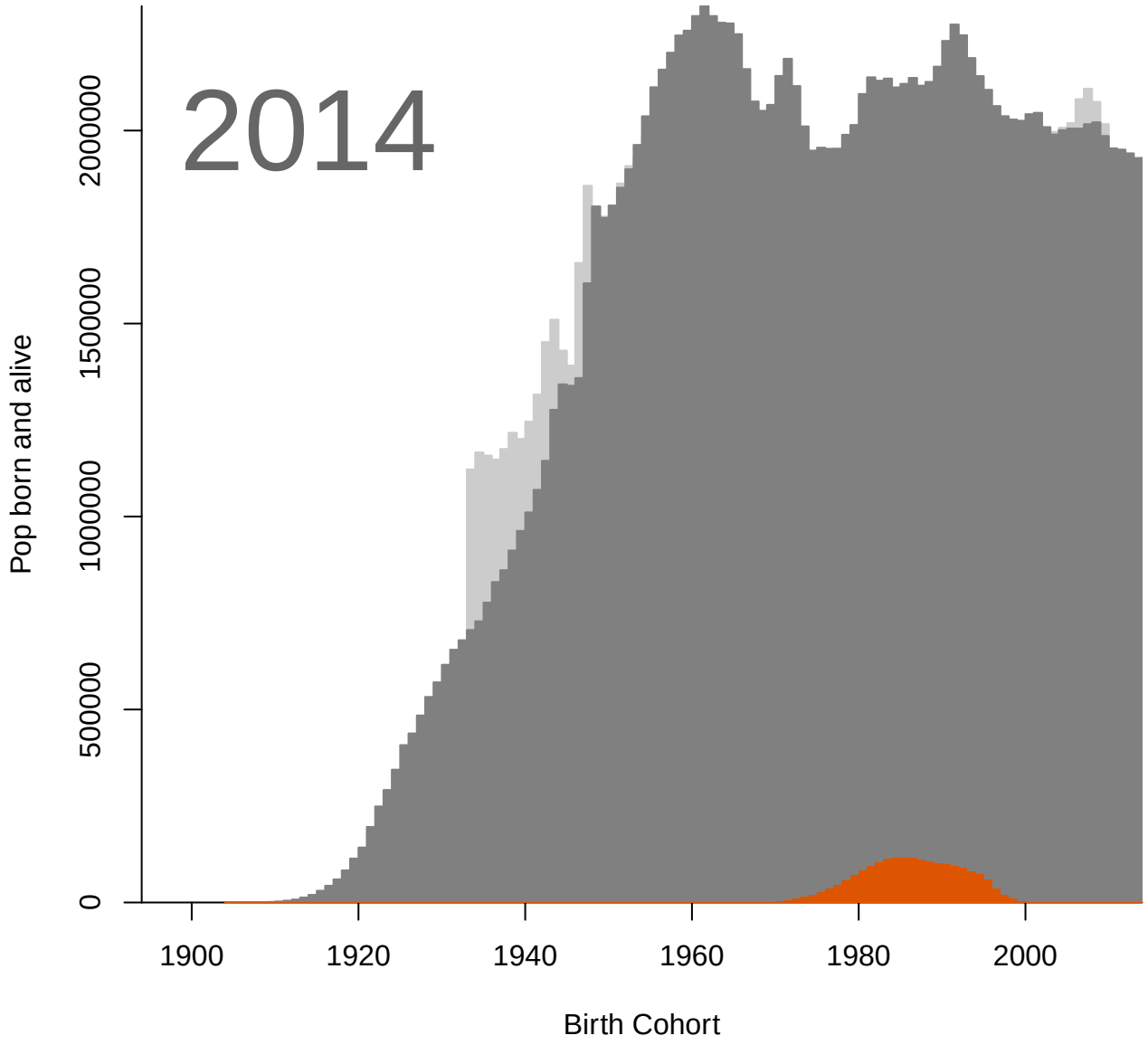

more math in demography

- indirect methods of estimation: requires models
- data quality control: requires models
- models of interactions, contagion, mixing: populations are heterogeneous
- models of health and disease transitions
- parametric models of mortality and fertility
- Math is at the core of demography

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where can you get paid to do this stuff?

- the Census Bureau, CDC, NIH, State govs
- academia: Berkeley, Princeton, Penn, IHME
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