The Gestational Age Pattern of Human Mortality

Explaining Ontogenescece

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onto|gen|ecence, noun

"**Ontogenescence** is a population-level phenomenon in which the death rate of each cohort tends to decrease with increasing age between conception and maturity." (Levitis 2011)

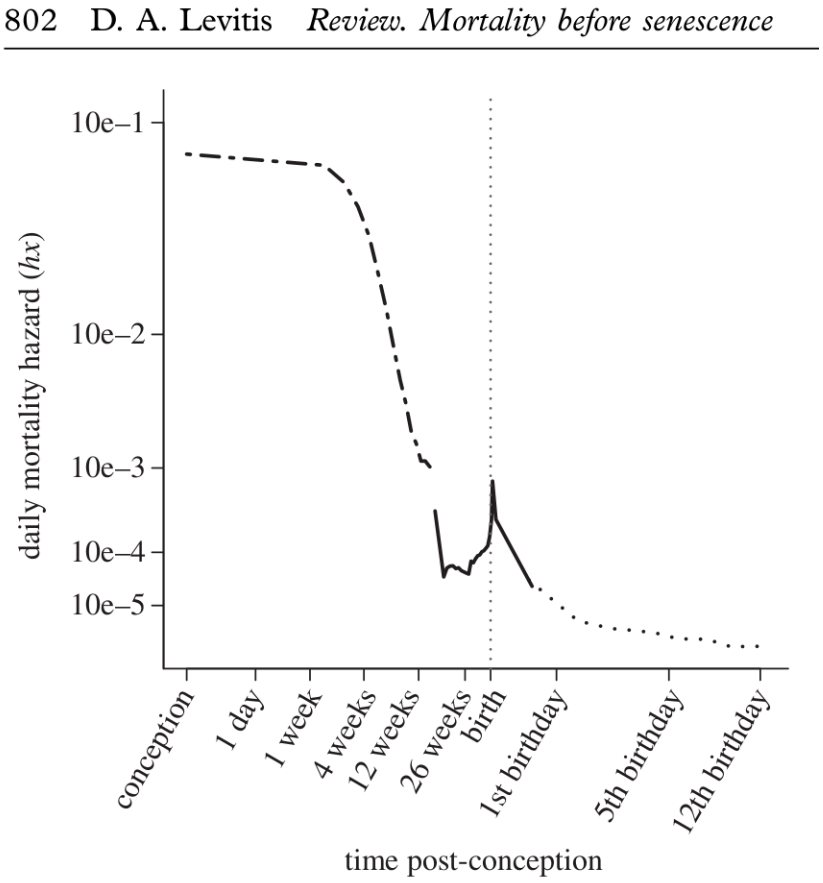


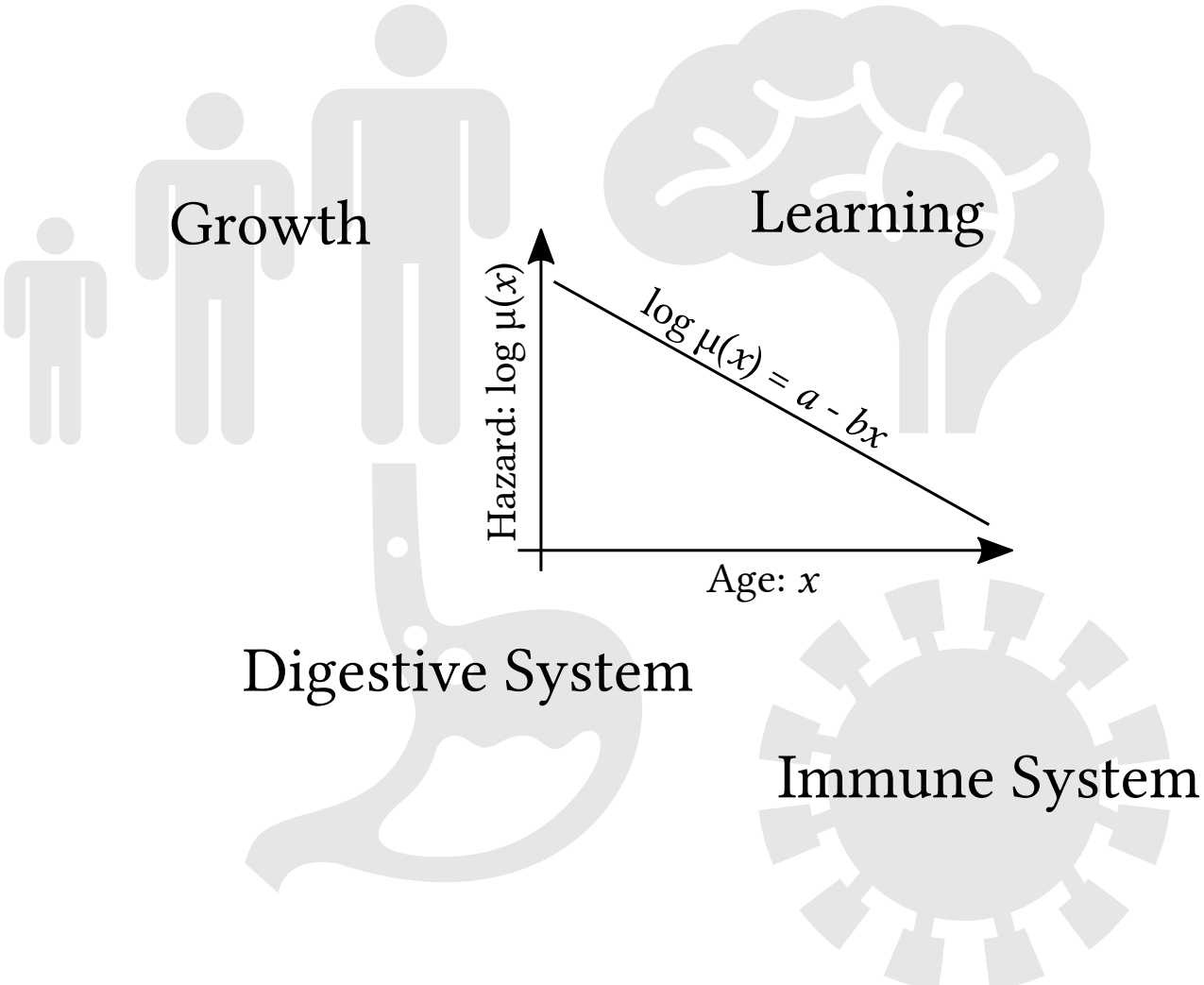
Figure 1. Mortality hazard from conception to 12th birthday.

Ontogenescence in Humans

Fetal- and infant life tables indicate a mortality continuum from conception to maturity disrupted by birth.

Source: Levitis (2011).

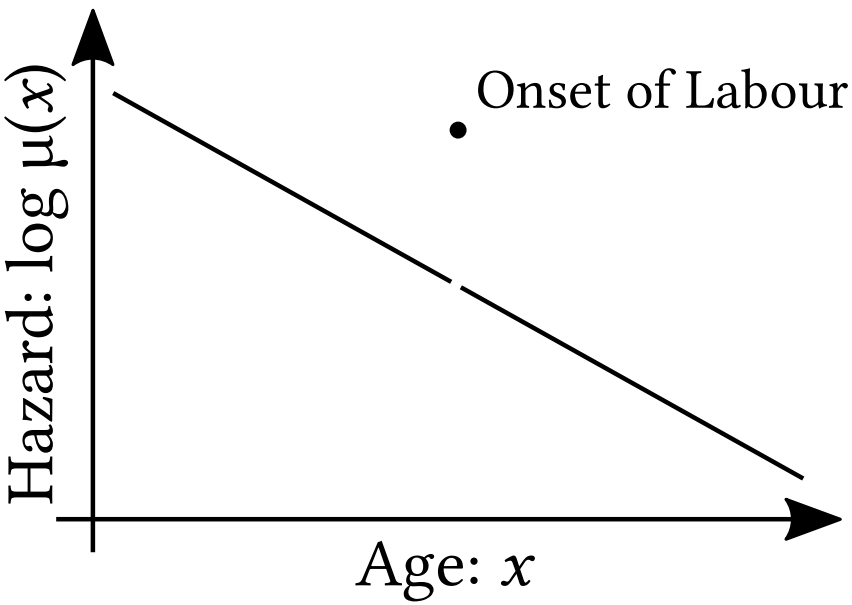
Ontogenescence as Acquired Robustness



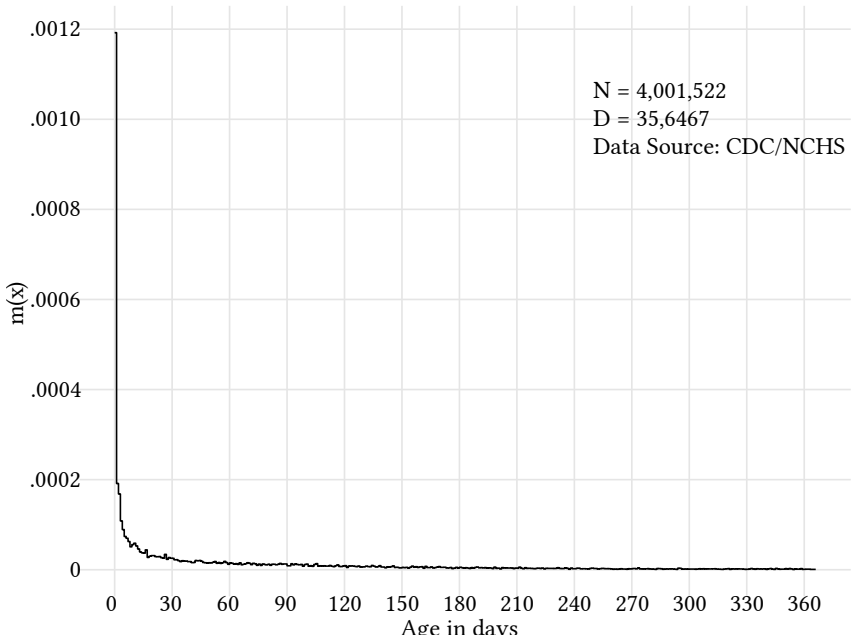
Acquired Robustness
Reduction of an individuals risk of death due to growth and adjustment.
cp. Levitis (2011), Siler (1979)

Ontogenescence as Transitional Timing

Idealized individual hazard
over gestational age.

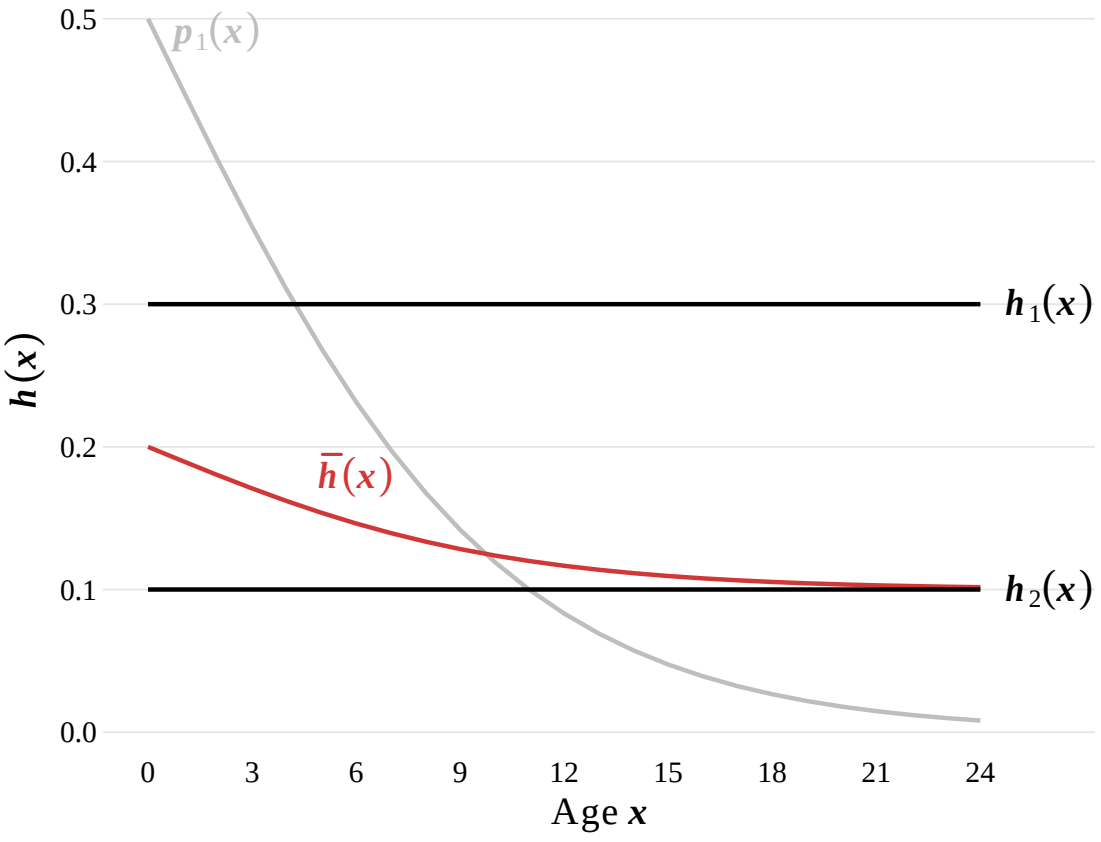


US infant mortality 2014
by day of age.



Transitional Timing Early life is full of risky transitions which increase an individuals mortality risk. The process of birth is a prominent example. *cp. Levitis (2011)*

Ontogenescence as a Selection Process



The selection effect of heterogeneous frailties

$h_{1,2}(x)$: Baseline hazard for two groups of different frailties

$\bar{h}(x)$: Mean hazard in the population

$p_1(x)$: Share of group 1 on the total population.

See Vaupel and Yashin 1985 for more of "Heterogeneity's Ruses".

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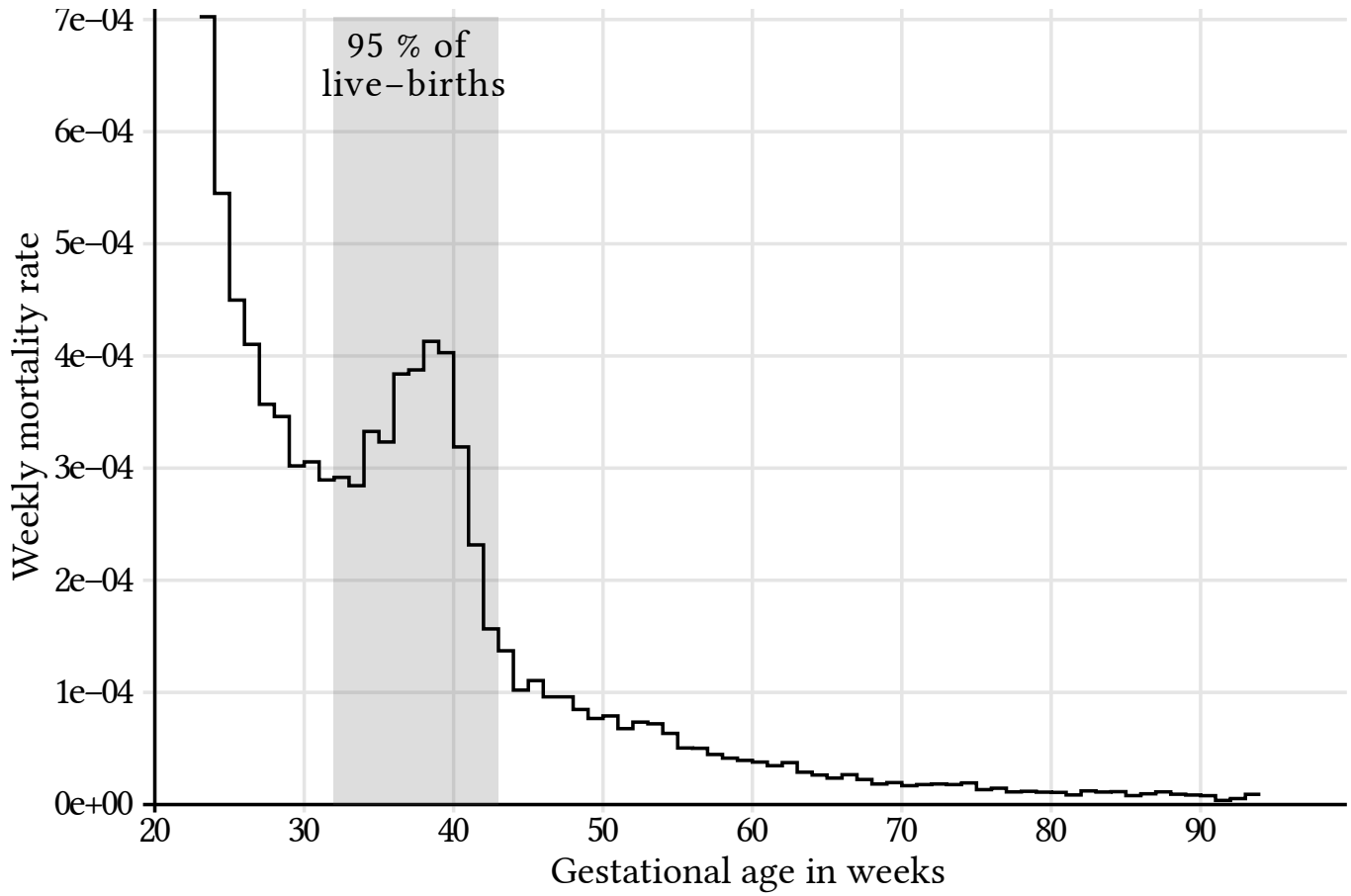

Mortality Rates by Week of Gestation

A joint fetal-infant life table for the US conception cohort of 2009.

Raw Data: Division of Vital Statistics (2015); the mortality rates have been calculated by the author after aggregating individual records of births, fetal- and infant deaths.

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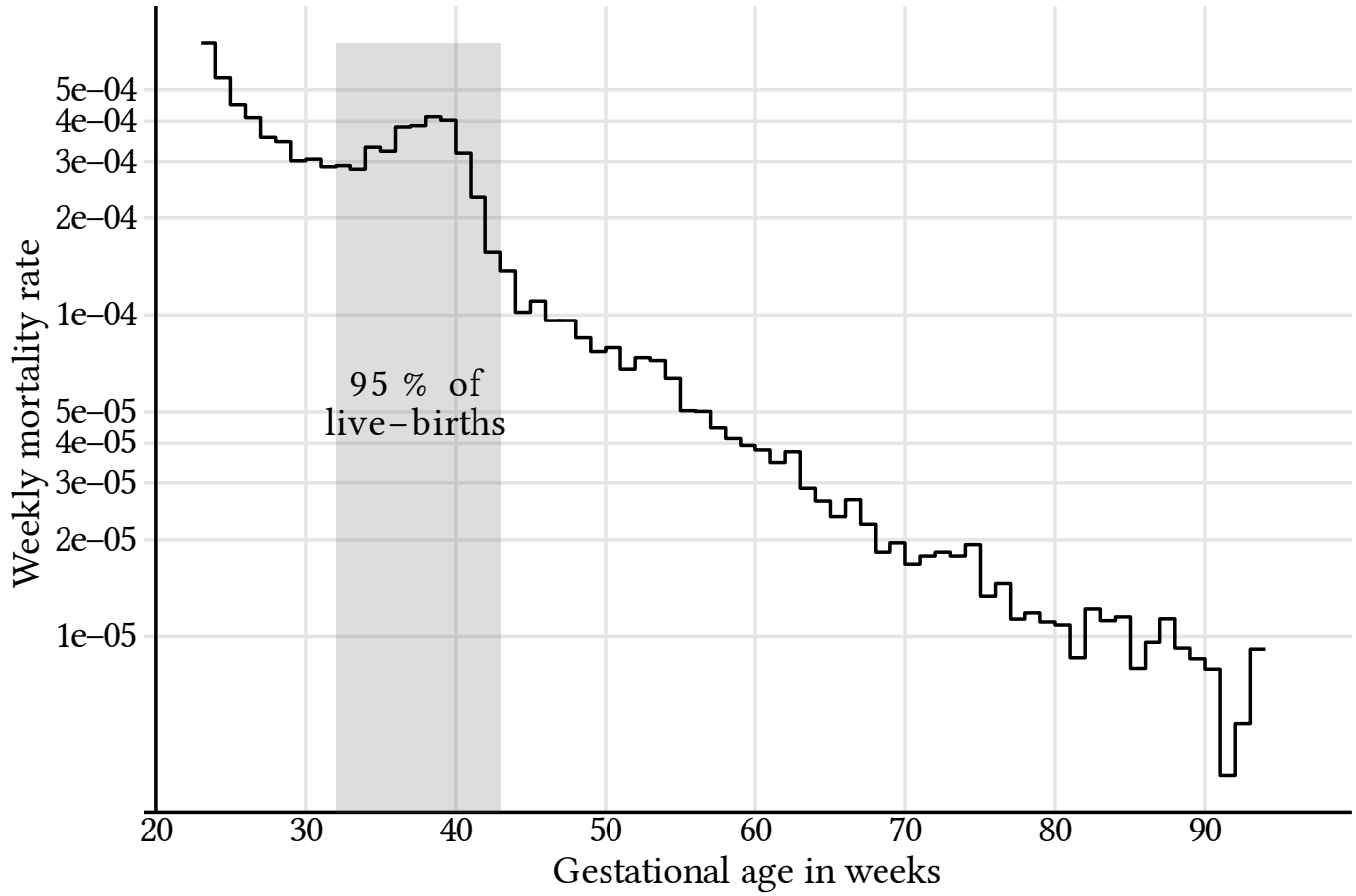

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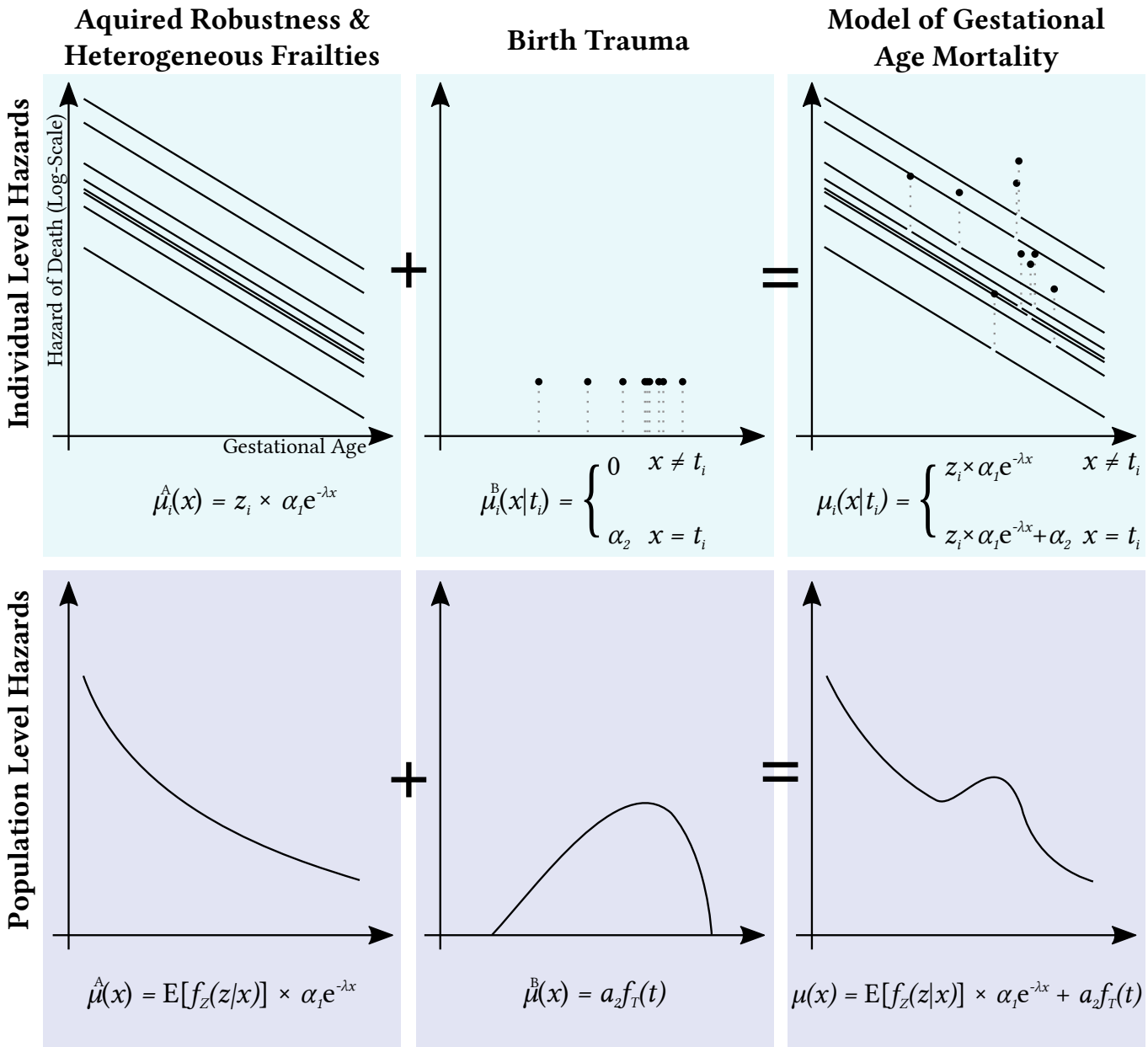
Modelling the Pattern



Modelling the Pattern

Modelling human ontogenescence across gestational age taking into account *acquired robustness*, *birth trauma* and *selection*.

$$\underbrace{\overline{\mu}(x)}_{\substack{\text{Population hazard} \\ \text{at gestational age } x}} = \underbrace{E[f_Z(z|x)]}_{\substack{\text{Average frailty} \\ \text{in population} \\ \text{at gestational age } x}} \times \underbrace{\alpha_1 e^{-\lambda x}}_{\substack{\text{Acquired robustness} \\ \text{component of hazard} \\ \text{at gestational age } x}} + \underbrace{\alpha_2 f_T(t).}_{\substack{\text{Birth trauma component} \\ \text{of hazard} \\ \text{at gestational age } x.}}$$

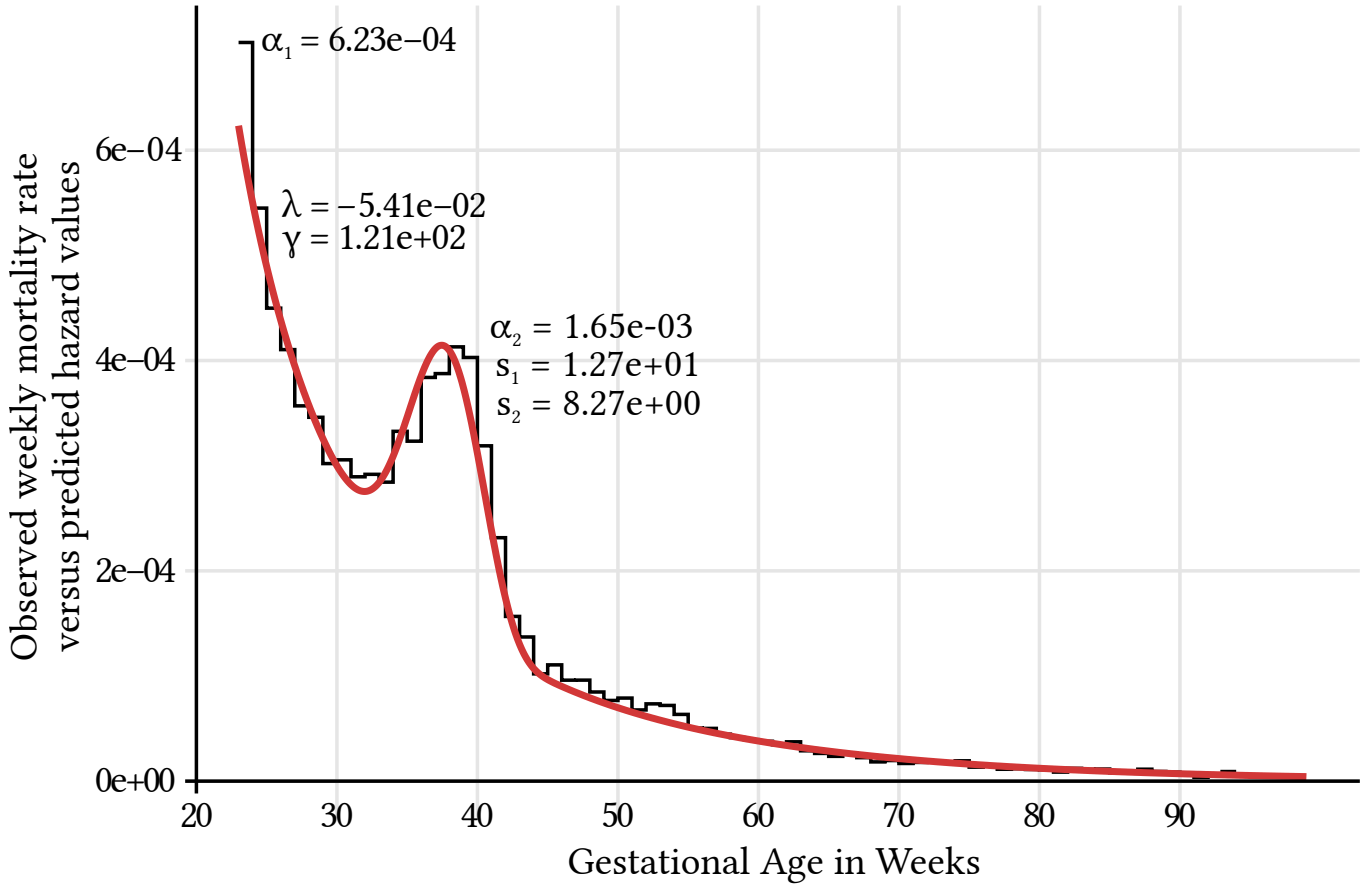
Modelling the Pattern

Frailty is assumed to be *Gamma* Distributed, the gestational age at onset of labour *Beta* distributed.

$$\underbrace{\bar{\mu}(x)}_{\substack{\text{Population hazard} \\ \text{at gestational age } x}} = \underbrace{\frac{\alpha_1 e^{-\lambda x}}{\frac{\gamma\alpha_1}{-\lambda}(e^{-\lambda x}-1)+1}}_{\substack{\text{Gamma-Gompertz} \\ \text{Frailty Model}}} + \underbrace{\frac{\alpha_2 x^{s_1-1}(24-x)^{s_2-1}}{B(s_1,s_2)\cdot 24^{s_1+s_2-1}}}_{\substack{\text{Birth trauma component} \\ \text{of hazard} \\ \text{at gestational age } x.}}$$

α_1	The initial mortality level (at week 23 and process time 0).
λ	The relative rate of mortality decline over age.
γ	The initial variance of frailties in the population (at week 23 and process time 0).
α_2	The added mortality risk due to the stress of birth.
s_1	The modal gestational age at onset of labour (in weeks after week 23).
s_2	The shape of the age distribution at onset of labour.

Modelling the Pattern



Mortality Rates by Week of Gestation,
Observed versus Predicted

A joint fetal-infant life table for the US conception cohort of 2009.

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References

Division of Vital Statistics (2015). *Vital Statistics Data. Period Linked Birth-Infant Death Data Files and Fetal Death Data Files.* Online 2015-12-14. National Center for Health Statistics. URL: http://www.cdc.gov/nchs/data_access/Vitalstatsonline.htm.

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Vaupel, James W. and Anatoli I. Yashin (1985). "Heterogeneity's Ruses: Some Surprising Effects of Selection on Population Dynamics". In: *The American Statistician* 39.3, pp. 176–185.