The Gestational Age Pattern of Human Mortality

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Explaining Ontogenescence

2 Levels of Explanation:

- *Individual*: The mortality decline over age represents growth, acquired robustness, adaptation to surroundings, risk mitigation taking place within an organism.
- *Population*: The mortality decline over age represents a selection effect: On average, the frailest individuals die first, the stronger individuals survive. Therefore, on the population level, the mean risk of death decreases over age.

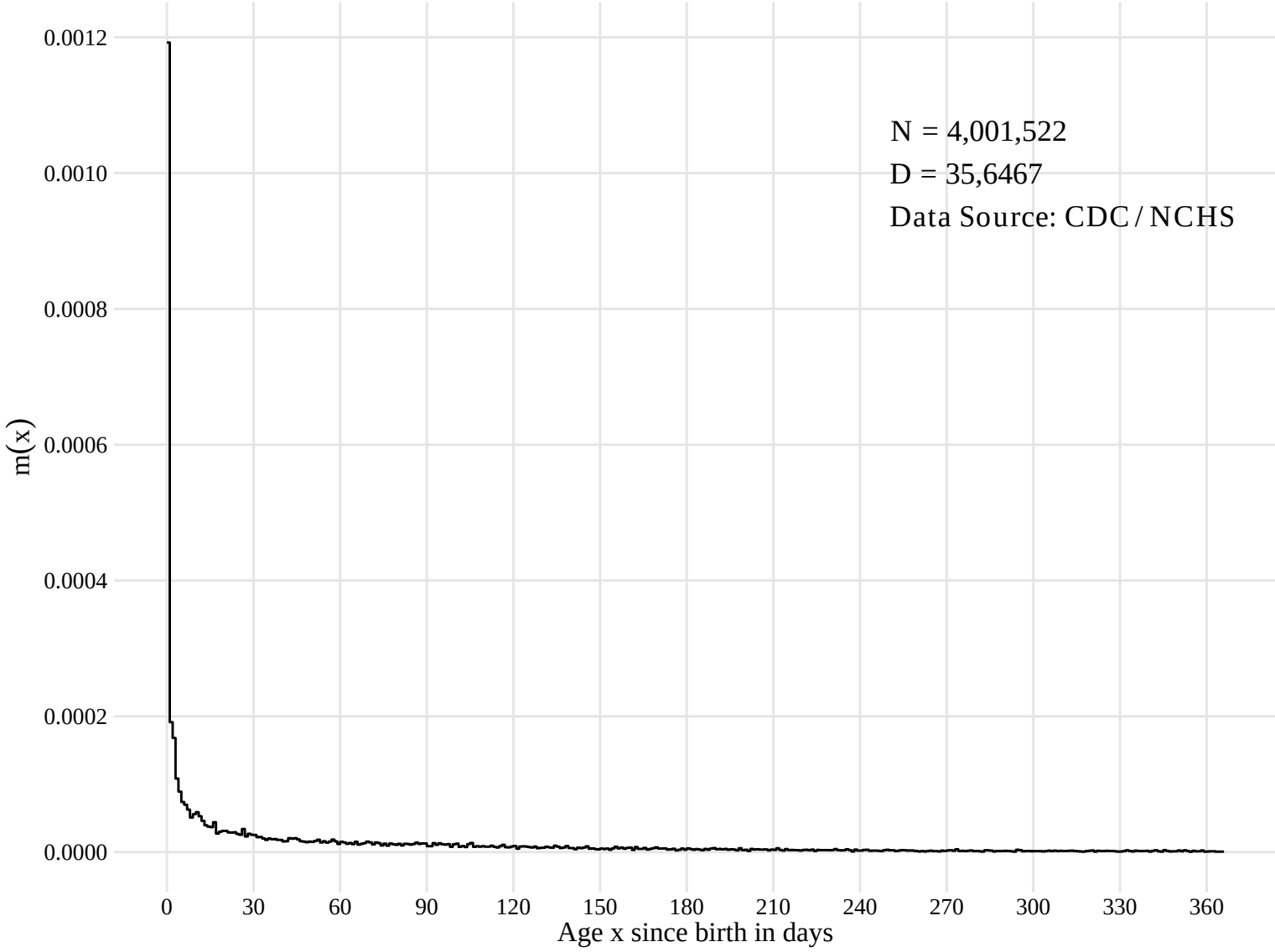
Explaining Ontogenescence

Table 1. Primary hypotheses for the evolutionary basis of ontogenescence.

hypothesis name	hypothesis: death rate decreases with age in developing cohorts because...
quality control hypothesis	... kin terminate potentially inviable individuals early so as to avoid bearing unnecessary costs.
growth trade-off hypothesis	... as individuals grow, they can decrease their relative need for continued growth and therefore accept fewer growth-enabling mortality risks.
robustness hypothesis	... as individuals develop, they acquire characteristics that increase their robustness to insults.
heterogeneous frailty hypothesis	... the frailest individuals die first, causing mean frailty to decline with age.
transitional timing hypothesis	... transcriptional, developmental and environmental transitions are dangerous, and these are concentrated early in life.

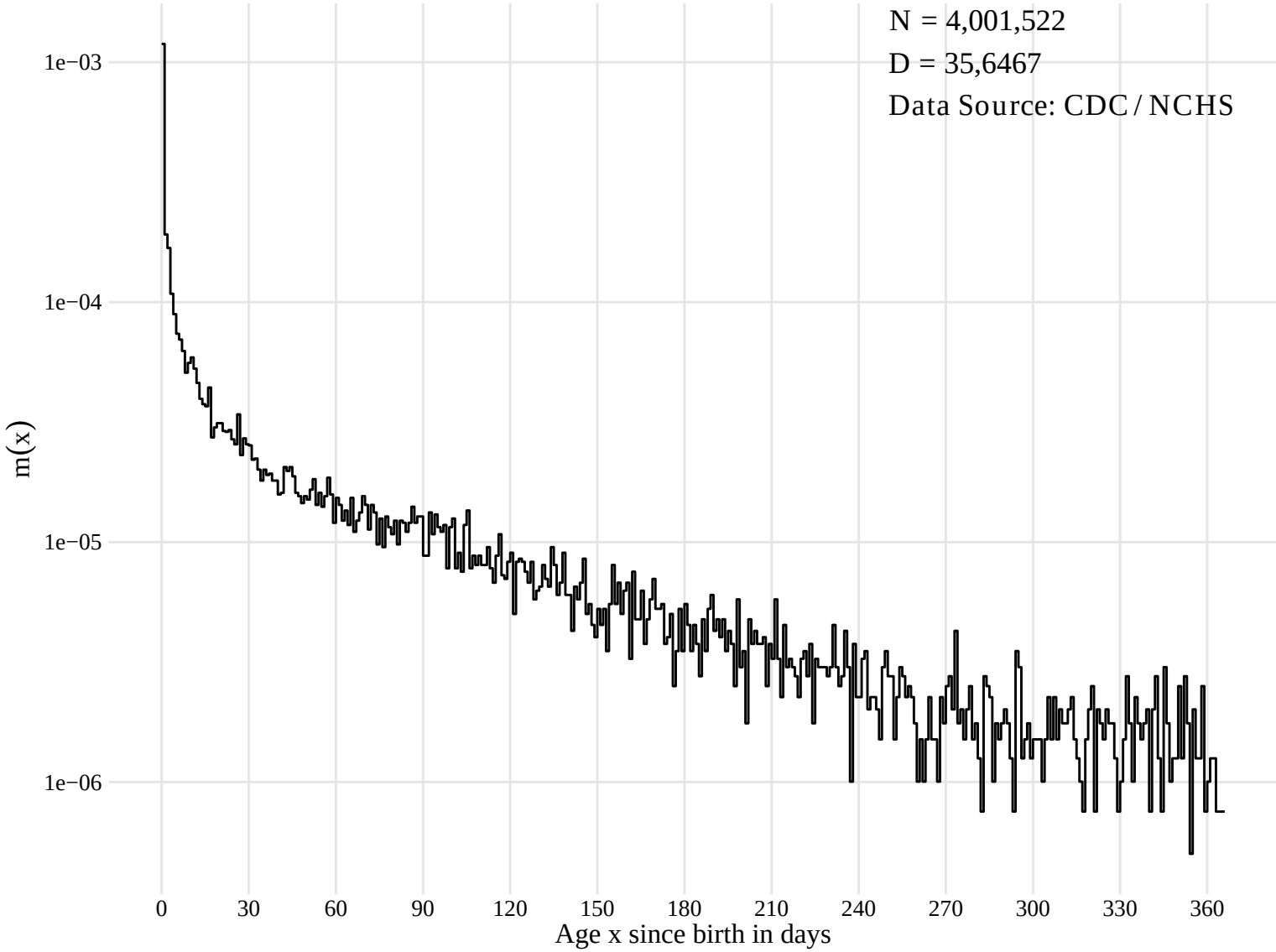
Levitis 2011

The Age Pattern of Infant Mortality



The daily age pattern of infant mortality, US, conception cohort 2009.

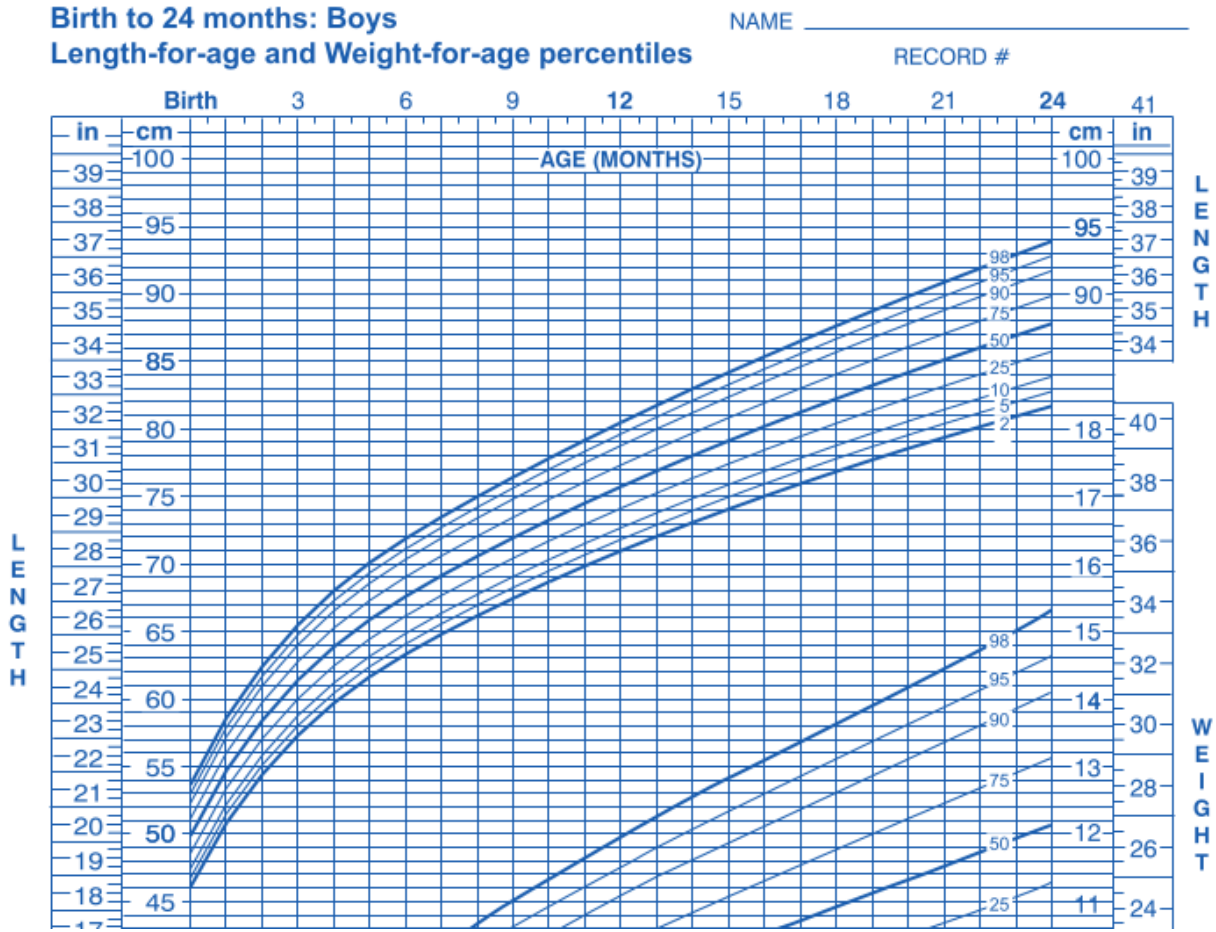
The Age Pattern of Infant Mortality



The daily age pattern of infant mortality, log-mortality scale, US, conception cohort 2009.

The Shape of Adaptation

Assumption: The age pattern of adaptation is inverse to the age pattern of growth level (and should therefore be negative exponential).

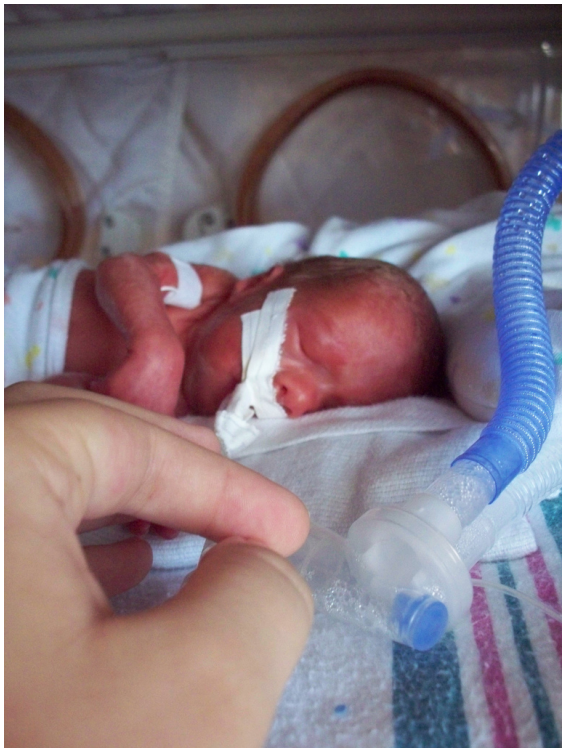


Average growth levels of infants over weeks after birth.
World Health Organisation 2009.

The Three Components of Infant Mortality

1. Mortality outlier at day of birth explained by *transitional timing*
2. Exponential decrease of mortality after 50 days of age explained by *adaptation*
3. Super exponential decrease of mortality right after birth explained by *selection* of the least frail

The Gestational Age Transformation ...



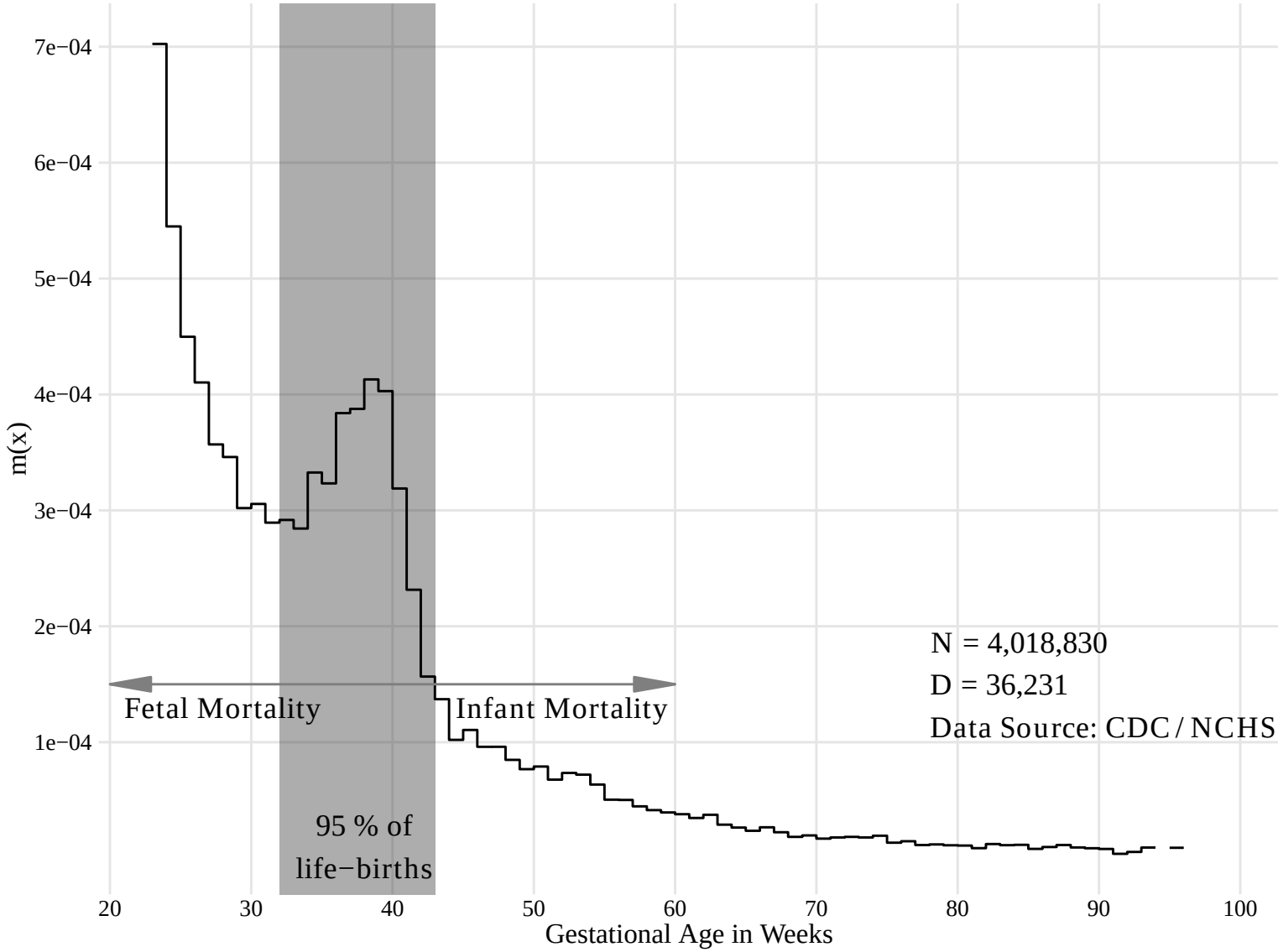
Newborn, gestational age 26 weeks.

Newborn, gestational age about 40 weeks.

The Gestational Age Transformation …

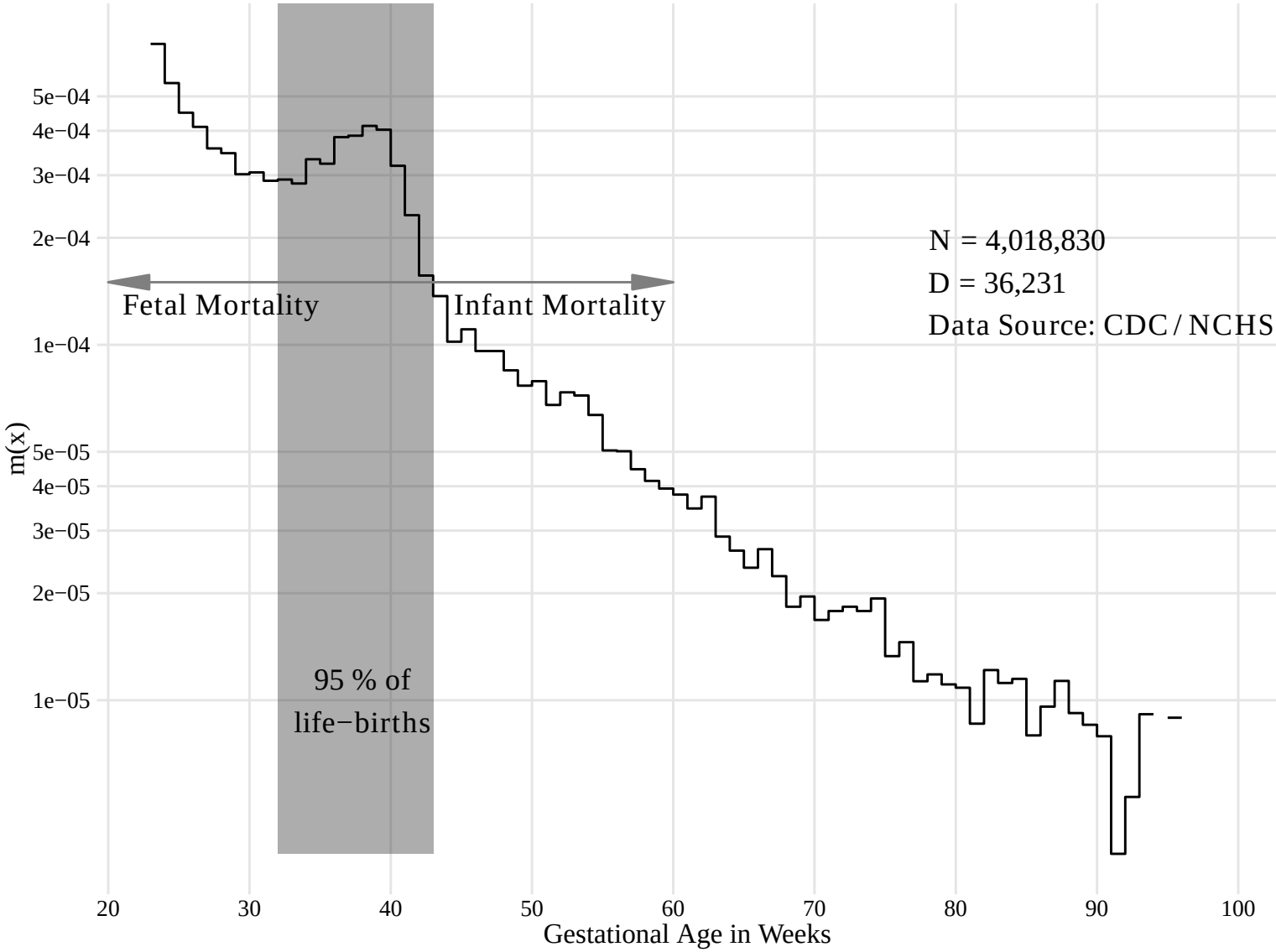
- …de-clusters the event of birth
- …eliminates *all* unobserved heterogeneity resulting from different gestational ages at birth

The Gestational Age Transformation …



The gestational age pattern of human mortality, US, conception cohort 2009.

The Gestational Age Transformation …



The gestational age pattern of human mortality, US, conception cohort 2009.

The Model

1. Mortality outlier at day of birth explained by *transitional timing*
2. Exponential decrease of mortality after 50 days of age explained by *adaptation*
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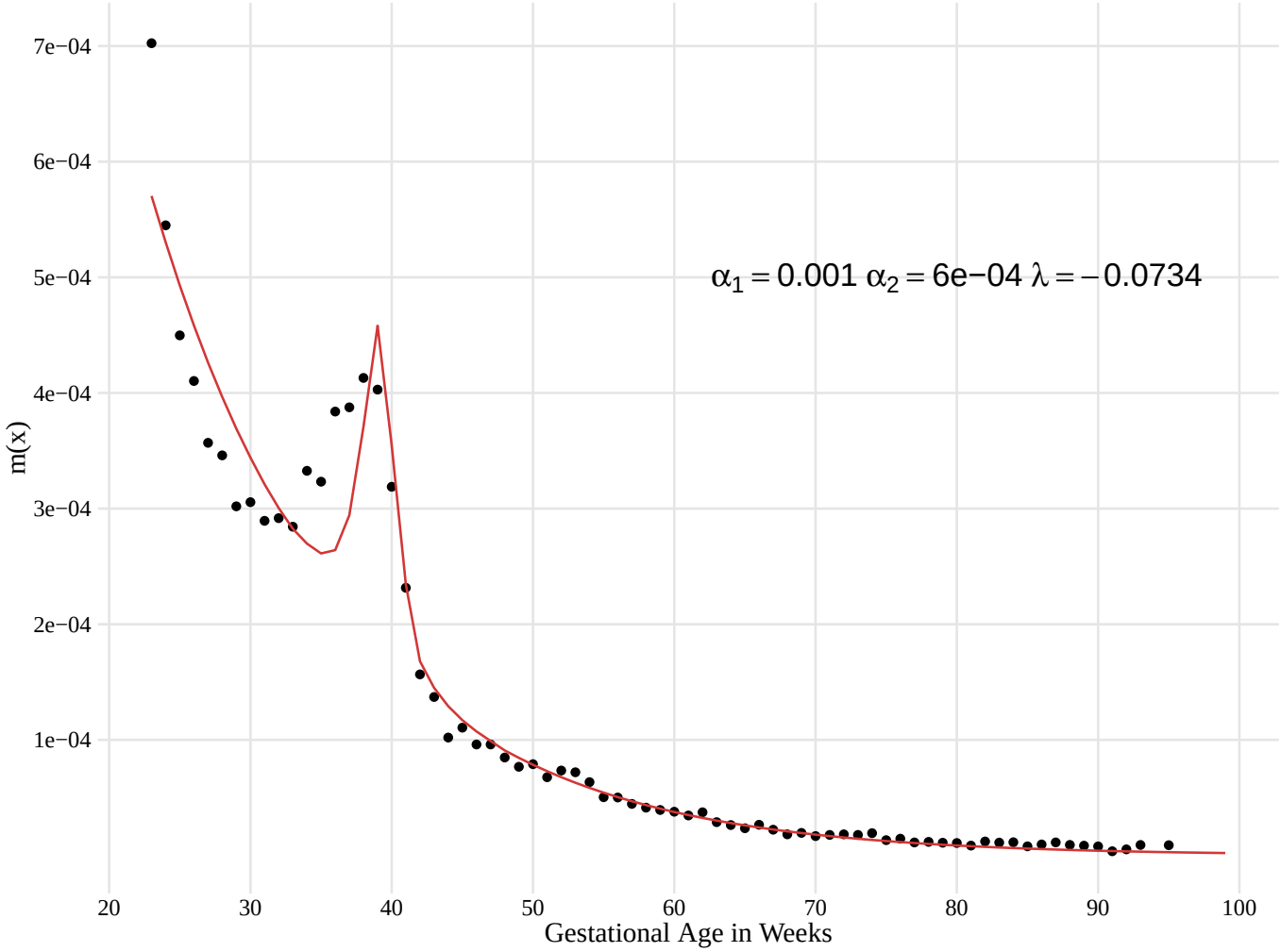
The Model

1. $\alpha_1 F(b)$: A factor representing the increased mortality risk in the perinatal period, weighted by the distribution of gestational ages at onset of labour
2. $\alpha_2 e^{\lambda x}$: A negative exponential function representing individual level adaptation and acquired robustness with age
3. $Z(x)$: A distribution of frailties at age x

$$m(x) = \alpha_1 F(b) + Z(x) \cdot \alpha_2 e^{\lambda x}$$

The Model

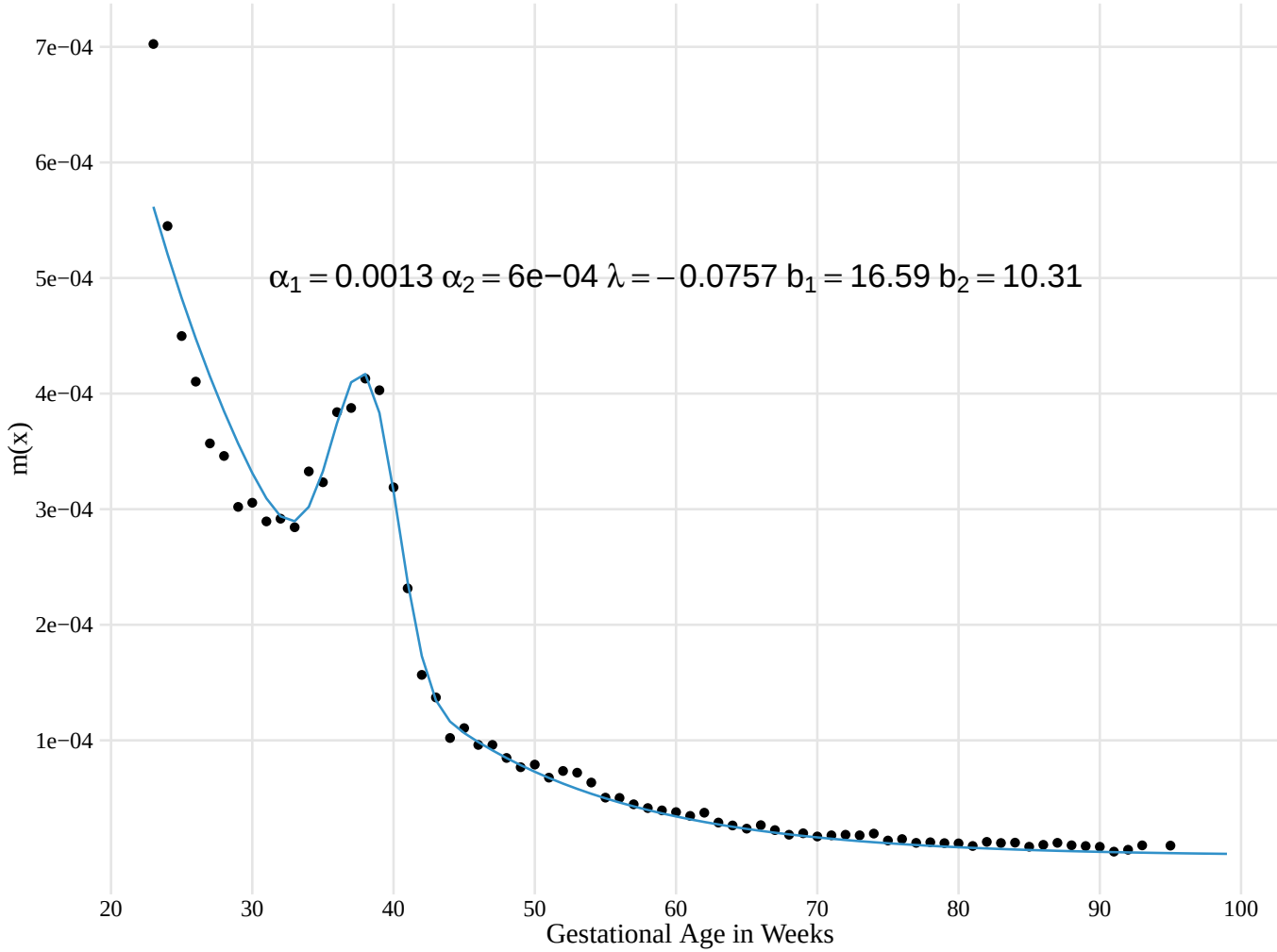
f(b) empirical, e.g. taken from data.



Modelling the gestational age pattern of human mortality, US, conception cohort 2009.

The Model

f(b) assumed to follow a Beta distribution bound to weeks 23 to 47.



Modelling the gestational age pattern of human mortality, US, conception cohort 2009.

References

Levitis, Daniel A. (2011). "Before senescence: the evolutionary demography of ontogenesis". In: *Proceedings of the Royal Society B* 278, pp. 801–809.

World Health Organisation (2009). *Birth to 24 months: Boys Head circumference-for-age and Weight-for-length-percentiles.* Online 2015-11-08. CDC. URL: http://www.cdc.gov/growthcharts/data/who/grchrt_boys_24hdcirc-l4w_rev90910.pdf.