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Deciphering infant mortality

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HIGHLIGHTS

- Infant mortality is considered in a systems science perspective.
- The "Transient Shock" conjecture predicts death rate spikes.
- The predictions are confirmed by a whole range of observations.

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ABSTRACT

This paper is about infant mortality. In line with reliability theory, "infant" refers to the time interval following birth during which the mortality (or failure) rate decreases. This definition provides a systems science perspective in which birth constitutes a sudden transition falling within the field of application of the *Transient Shock* (TS) conjecture put forward in Richmond and Roehner (2016c). This conjecture provides predictions about the timing and shape of the death rate peak. It says that there will be a death rate spike whenever external conditions change abruptly and drastically and also predicts that after a steep rise there will be a much longer hyperbolic relaxation process.

These predictions can be tested by considering living organisms for which the transient shock occurs several days after birth. Thus, for fish there are three stages: egg, yolk-sac and young adult phases. The TS conjecture predicts a mortality spike at the end of the yolk-sac phase and this timing is indeed confirmed by observation.

Secondly, the hyperbolic nature of the relaxation process can be tested using very accurate Swiss statistics for postnatal death rates spanning the period from one hour immediately after birth through to age 10 years. It turns out that since the 19th century despite a significant and large reduction in infant mortality, the shape of the age-specific death rate has remained basically unchanged. Moreover the hyperbolic pattern observed for humans is also found for small primates as recorded in the archives of zoological gardens.

Our overall objective is to identify a series of cases which start from simple systems and move step by step to more complex organisms. The cases discussed here we believe represent initial landmarks in this quest.

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1. Introduction

Whereas the process of aging has been and still is much studied, the rapid fall of the infant death rate in the hours, days, weeks and months after birth has received relatively little attention.

1.1. Origin of the questioning

The present study originated from the conjunction of two separate (and, at first sight, fairly disconnected) observations.

- The first observation is the rapid (hyperbolic shaped as will be seen later) fall of the postnatal death rate. It is usual in medicine to consider infant mortality up to 12 months or one year after birth. However, we shall see that for humans, the hyperbolic decrease of the death rate extends over a period 10 times longer. Then, after the age of 10, the decrease stops and is replaced by a phase that increases through to end of life (see Fig. 1b). This naturally leads to the idea that there are two different regimes: the postnatal regime and the senescence regime. Whereas the senescence regime is fairly well understood, the postnatal regime appears much more mysterious. Why is the fall of the death rate hyperbolic? Why is the duration for humans approximately equal to 10 years?
- From plants to fish, to birds, to mammals there is a bewildering diversity of living organisms. Yet, if one leaves aside the arthropods,[1] there is a deep similarity in the mechanism through which a new organism starts its life. It begins as a tiny one-cell embryo which divides and grows. In the case of a plant the energy required for the growth process is generated from the food reserve contained in the grain (or in the egg in the case of fish and birds) and the oxygen which diffuses through the grain's (or egg's) envelope. For a mammal the nourishment and the oxygen come through the umbilical cord. After germination, hatching or birth the new organism must become autonomous in the sense of relying only on the resources (oxygen, carbon dioxide, light, food) available in its environment.

  The similarity of these mechanisms naturally leads to the question of whether or not postnatal death rates follow a general pattern.

There is a common saying according to which "science starts with the discovery of a pattern". In the present paper, we identify two patterns of infant mortality, namely the yolk-sac death spike pattern and the hyperbolic decay pattern. The first pattern is fairly well understood, however the second raises questions for which we have no complete answer so far. We believe that, taken together, these patterns give us a new insight into the mechanisms of infant mortality.

1.2. Previous studies

There are fewer studies about infant mortality than aging and senescence.[2]

But we note a connection with a series of papers by Canadian researchers [1–4]. These develop the notion of *frailty* of individuals and its relationship with the likelihood of death. After defining a frailty index made up of several dozen "deficit" indicators ranging from fairly light deficits such as hearing problems to more severe deficits such as cancer or heart disease, they demonstrate that it has a strong correlation (over 0.98) with the death rate.

Two phenomena are analyzed in the present paper: (a) the yolk sac effect for fish and (b) the preterm effect in humans for which the notion of frailty provides a clue. Termination of the yolk sac phase requires fish to switch from one form of feeding to another. This elevates their frailty level with the result that changes in the environment which otherwise would have gone unnoticed bring about a death spike. Similarly, preterm babies have an excess degree of frailty which, as we will see, results in a huge amplification of the postnatal death spike.

In their studies the Canadian researchers restrict their attention to the frailty which comes with aging. The two previous cases illustrate situations of *temporary* frailty, a useful extension of the concept. Incidentally, the notion of frailty can also be extended to the social sciences as was masterfully illustrated by another Canadian researcher, Naomi Klein [5], in a book entitled "The shock doctrine". This is a generalization in the sense that drastic socio-political changes which would not be accepted by a nation in normal times may be imposed and tolerated in times of a natural disaster or social crisis.

1.3. Previous studies in a "physics perspective"

We know of no study of infant mortality that relies on a *physics perspective*. By this we mean simply a comparative cross-species approach in which one investigates a specific phenomenon across a number of different species and where the

[1] Because they have a rigid exoskeleton their development involves widely different instar stages. This mechanism leads to a different postnatal death rate pattern. An example will be shown later. Note that the arthropods are a very large group which includes all insects and crustaceans. Altogether it includes about 80% of all described living animal species.

[2] This situation was confirmed in a message received from an eminent bio-demographer. In an email to one of us (BR) dated 31 January 2016 Prof. Tom Kirkwood wrote:

> "There has been relatively little attention given to the patterns of early mortality. I am not aware of experiments that were done especially for exploring early mortality".