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Food, Population and Health – global Patterns and Challenges Proceedings of an Interdisciplinary Symposium on the Dynamics from Prehistory to Present

Edited by Lars Jørgensen, Niels Lynnerup, Anne Løkke and Henrik Balslev

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Food, Population and Health – global Patterns and Challenges
Proceedings of an Interdisciplinary Symposium on the
Dynamics from Prehistory to Present

Abstract

The present volume is based on presentations at a symposium at the Royal Danish Academy of Sciences and Letters in September 2014 with the title *Food, Population and Health – global Patterns and Challenges*. Food has played a fundamental role in the history of all societies over the World. Availability and abundance of food has been crucial for the health and subsequently for the wealth of societies. In the first section Bothmer points out that agriculture began about 10 000 BP and that the first domesticated crops were grasses that subsequently underwent migration and adaptations and finally were subject to modern plant breeding. Palm demonstrates that the Swedish population in the early modern period was growing rapidly and that the average food consumption of an adult Swede around 1630 was at least equivalent to 2500 calories a day. Because migration and trade are important for developing and providing food products, knowing their provenance is important and the latest technology in that context is the use of strontium isotope tracing as shown by Frei. In a section on mortality and prevalence of diseases from food in historic and prehistoric populations Atkins explains how bovine spongiform encephalopathy and tuberculosis have been passed on from animals to humans through food. Larsson traces the Swedish outbreak of smallpox and dysentery in the 18th century and Revuelta-Eugercios discusses the promises of individual level data analysis on a mass basis as approach to socioeconomic and gender differences in mortality during nineteenth century urbanization. Castenbrandt discusses which sources and methods could make it possible to grasp how morbidity has changed while life expectancy has increased since the mid nineteenth century. In a section on variations in human height Boldsen challenges the common comprehension that more economic wealth automatically results in taller people by analyzing gender differences and different epidemiological regimes. In the same context Öberg points out that the height increase and the longevity increase most likely share some underlying causes but they have also been affected by unique unshared factors. Given that extended breastfeeding has proven to be effective to keep relative low levels of infant mortality in poor economic and hygienic environments, Løkke suggests that infant mortality in prehistorical populations, in some times and places, may have been as low as in nineteenth century Scandinavian low infant mortality regions. Garðarsdóttir demonstrates how increased breastfeeding in Iceland during 1850–1920 reduced infant mortality, but was still viewed with scepticism by many mothers. Based on the Dutch experience of famine 1944–45 Lumey discusses the health effects later in life of under-nutrition in the womb. The dynamics between food, health, population size and economy was the subject of Larsen, who showed how – over prehistoric and historic times – diets have changed, and also that the proportions of energy-rich and more nutritious foods have affected human health. In the same context Harris focuses on 18th and 19th century England with emphasis on the relationship between food availability and height, health and economic development. In a chapter on identification of diet and changes in food culture, Nyvang presents an analysis of 753 cookbooks published in Denmark between 1616 and 1970, and demonstrates how history has involved changes in author groups reflecting large societal transformations. The final chapter by Hastrup wraps up the content of the symposium in the context of Global Food Security, referring to the UN lead concern about food on a Global scale. Two final appendices describe the rich resources available at the Danish National Museum for studying food and its importance in prehistoric and historic contexts.

Food, Population and Health – global Patterns and Challenges

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Preface

Lars Jørgensen, Niels Lynnerup, Anne Løkke and Henrik Balslev

Under the *The Open Academy* initiative the *Royal Danish Academy of Sciences and Letters* opened its doors to an interdisciplinary and international symposium from September 22nd–24th 2014. This event was intended to take a broad look at the role that food has played in the development of societies and in particular in the health of human populations. The emphasis was to be on Denmark and the Nordic countries but the idea was also to trace links to countries outside our region. The purpose was to develop networks and exchange knowledge between different researchers who contribute to this huge subject matter but who have seldom had the chance to meet in a forum including the whole range of disciplines involved in the study. In this case, the disciplines comprised anthropology, archaeology, history, demography, economy, medicine, geography, biology and nutrition, and covered a time span of 10,000 years of human history. Participants were both well-established researchers and young postdocs, engaging in a lively debate across disciplinary borders. The symposium was opened by the Academy's president, Professor Kirsten Hastrup, and the subsequent contributions were organized in eight sessions:

The first session on *Agriculture, Technology, Economy and Demography* had presentations by H. Balslev (Aarhus), L. Palm (Gothenburg), R. von Bothmer (Lund), M. Fischer Mortensen (Copenhagen), and M. Kähler Holst (Aarhus).

A second short session about *Agriculture – the longitudinal development in crops and domestic animals* had a single presentation by K.M. Frei (Copenhagen).

The third session on *Mortality and Prevalence of Diseases from Food in Historic and Prehistoric Populations* offered insights from P. Atkins (Durham), H. Schutkowski (Bournemouth), M. Steyn (Pretoria), D. Larsson (Gothenburg), J. Krause (Tübingen), B. Revuelta-Eugercios (Paris), H. Castenbrandt (Gothenburg), and L. Simonsen (Copenhagen).

The fourth session on *Variations in human height. What does it mean?* was enlightened by talks from J.L. Boldsen (Odense), A.D. Cámara Hueso (Barcelona), and S. Öberg (Gothenburg).

The following session, number five, provided examples of *Infant nutrition, infant mortality and health later in life* by A. Løkke (Copenhagen), Ólöf Gardarsdóttir (Reykjavik), K. Fleischer Michaelsen (Copenhagen) and L. Lumey (New York).

Session six treated the theme *The dynamics between food, health, population size and economy* with lectures by L. Jørgensen (Copenhagen), N. Lynnerup (Copenhagen), C. Spencer Larsen (Ohio), B. Harris (Glasgow) and M. Jakobsson (Uppsala).

The seventh session on *Identification of diet and changes in food culture* offered new insights from M.L. Jørkov (Copenhagen), T. O'Connell (Cambridge), C. Nyvang (Copenhagen), L.O. Dragsted (Copenhagen), T. Kellberg Nielsen (Aarhus), M. Thomas (London) and E. Willerslev (Copenhagen).

Finally session eight treated *Patterns and Future Challenges in Nutrition and Health* in three presentations by A. Astrup (Copenhagen), O. Mouritzen (Odense) and K. Hastrup (Copenhagen).

From this program we selected 16 papers that are presented in these proceedings. They are supplemented by two contributions treating the rich collections of The National Museum of Denmark. The symposium organization was headed by Professor Lars Jørgensen from the National Museum in Copenhagen, Denmark, assisted by a team of colleagues who are co-editors of this volume. We would like to thank the *Royal Danish Academy of Sciences and Letters* for taking the initiative to arrange this symposium and for funding it.

Lars Jørgensen, Niels Lynnerup, Anne Løkke and Henrik Balslev
Copenhagen, 30th November 2015

Agriculture, economy and population size in Sweden in the early modern period

Lennart Andersson Palm

SCI.DAN.H. 4 · 7 · FOOD, POPULATION AND HEALTH – GLOBAL PATTERNS AND CHALLENGES
THE ROYAL DANISH ACADEMY OF SCIENCES AND LETTERS · 2016

Abstract

Using tax lists which enumerate households and average household size, the author previously estimated the population in Sweden in c. 1570 and c. 1630. These estimates have been considered too low by some scholars. Higher estimates have been suggested. To check the probability of the original figures, the author has considered some totally independent, but historically contemporary, sources.

First, vital records, stretching back to the 1630s, have made it possible to compare estimated births and marriages with alternative population assessments. The population for 1630 suggested by the author gives a plausible birth rate of about 34 per thousand, a rate found in most local studies from the period in Sweden and Western Europe. Higher population estimates give unrealistically low rates.

Second, comparisons were made between the estimated possible consumption of cereals (home-grown and imported) and livestock production that would follow from alternative population figures; Sweden has very good source material on agricultural production in the 17th century. Using the author's population estimate, in about 1630, an adult Swede could consume at least 2 500 calories a day. The higher population estimates would have brought famine.

The rapid growth of the Swedish population in the early modern period indicates that it was part of a more general expansion which was found throughout Northwestern Europe at that time.

There has been a long debate among scholars about population sizes in Sweden before the introduction of scientific population statistics in 1749 (tabellverket).

Population estimates from households

In the 1880s Hans Forssell calculated the population within the frontiers of Sweden in 1571 to be between 427,400 and 531,400 people living in 83,900 households.[1] He used as his source material the records from a property tax levied on households, Älvsborgs lösen 1571 – the "First Älvsborg´s ransom", which was introduced following the war with Denmark-Norway from 1563 to 1570 as his source material. Forssell multiplied the households by what he thought was the average household size (AHS) at the time, around 5 people. He also had to make conjectures on tax free households including c. 1,050 rectories, 400 mansions and 70 royal castles and farms.[2]

1. Forssell 1872-1883, p. 348.

2. Sweden proper at the time had c. 1,665 parishes, the Danish provinces later annexed 605, the Norwegian 120, in total c.

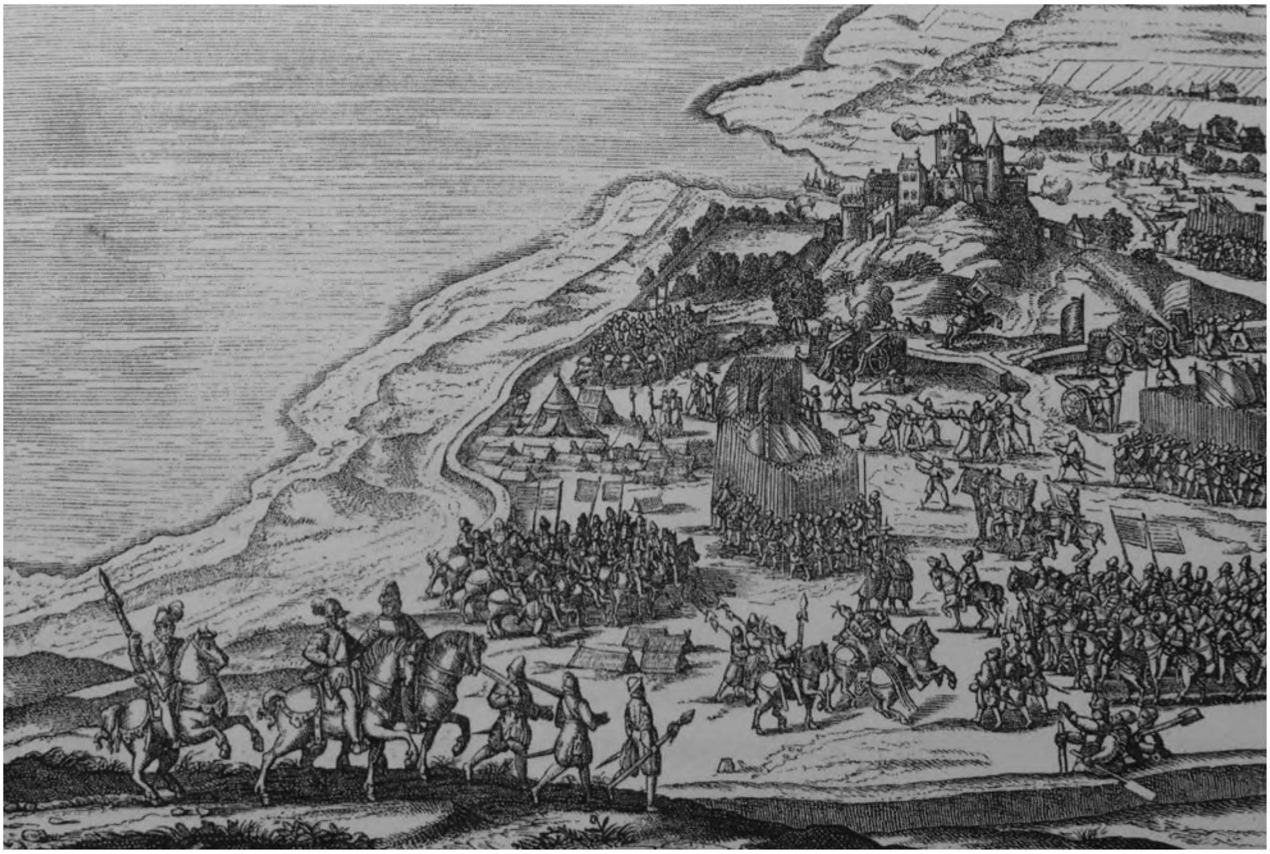


Fig. 1. The Danes taking Älvsborg castle 1563 (after Oskar Alin: Sveriges historia III).

In the 1930s Eli F. Heckscher was critical of Forssell´s figures as he found them to be too low.[3] He based his criticism on an assumption that there was very weak population growth during the period between 1570 and 1749 due to a high mortality rate from wars and plagues. Heckscher's assumption was, as he admitted, pure guesswork however. But he was supported by calculations from Sigurd Sundquist for 1630 on the basis of poll tax lists (mantalslängder, cf. Danish ekstraskattemandtaler).[4] Sundquist assumed in his calculations that there were the same proportions of children, domestics, widows etc. per household in 1630 as there were in the official statistics from the 1760s; the AHS, from the 1760s, was calculated from a number of households that excluded soldier's and poor people's, generally very small, households.

In a project funded by the Swedish Research Council (Vetenskapsrådet), I recounted the population for c. 1620 using poll tax lists. Unsurprisingly I found about the same number of households as Sundquist. Contrary to him, however, I multiplied it by AHSs taken from contemporary sources among which there were lists from the 1620s that included all members of the households, even small children, especially the audit records for the "Second Älvsborg's ransom" (1613-1618). Such lists exist for most of Södermanland province, many *herreds* in Uppland, some in Småland and Västergötland, and throughout the whole province of Dalsland. Together they cover large swaths of Sweden. It became evident that house-

2,390. The rectories include other farms allotted to the priests.
3. Heckscher I.1, 1935, p. 30.
4. Sundquist 1938, p. 274.

Table 1. Population estimates for Sweden c. 1570 – c. 1720

	Sweden within boundaries of 1570		Sweden within borders of today	
Period	My recount	Heckscher et.al.	My recount	Heckscher et.al.
c. 1570	440,000	800,000	640,200	1,022,000
c. 1630	646,000	900,000	905,800	1,150,000
c. 1700			1,300,000	

Note: Figures here somewhat rounded. My figures have been extrapolated somewhat for the time gap 1620-1630.
Sources: Palm 2001, p. 133; Palm 2000, p. 49.

holds in c. 1620 were smaller than those used by Sundquist from the 1760s. The recount accordingly implied a much lower population for 1620 than Sundquist's calculations for 1630 which had determined there to be between 800,000 and 900,000 people; the recount stopped at some 620,500 1620.

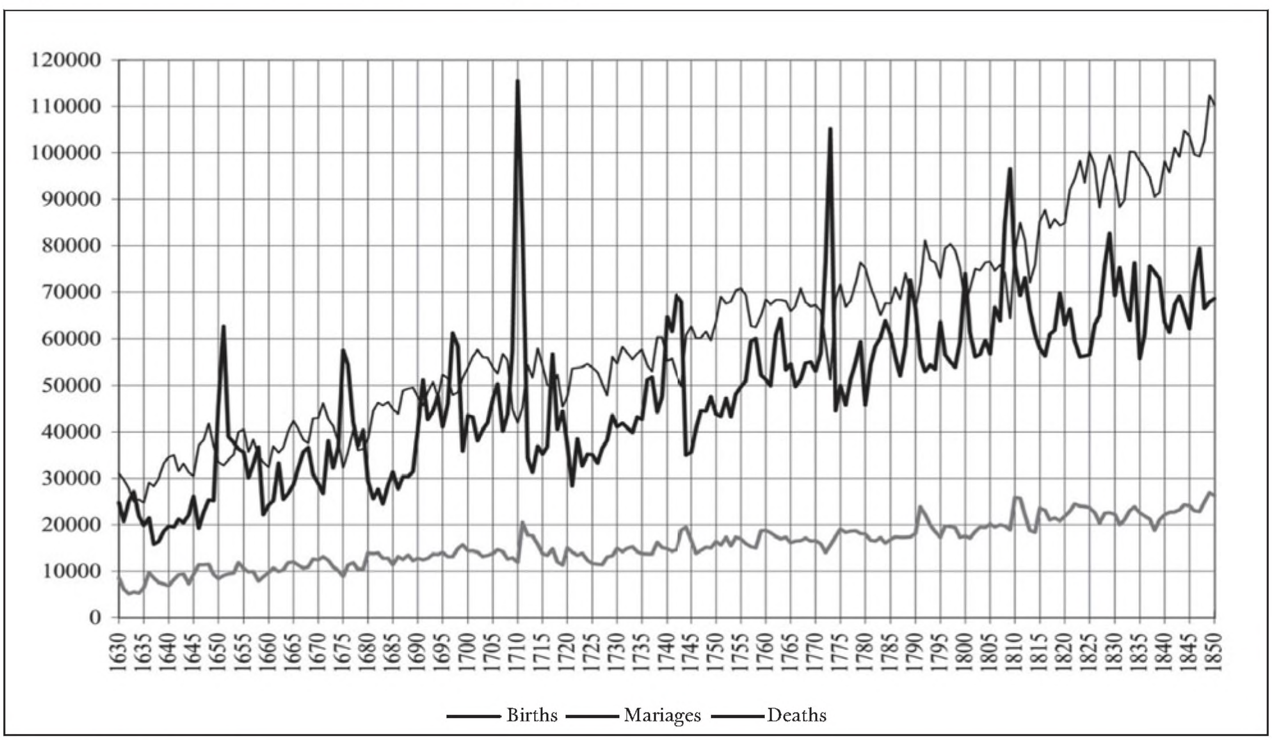
Swedish historians are fairly unanimous about the population c. 1700: c. 1,300,000 (± 100,000) persons lived in Sweden´s frontiers of today. The recounts for 1570, 1620 and the figure for 1700 taken together, point to a relatively fast growth on average during the period 1570-1700.

Can my interpretation be corroborated by other sources?

Population estimates from vital records

To evaluate the realism of one or the other rate of growth, another path was followed which used vital data from church records to aid estimates. Inspiration

Fig. 2. Estimated births, marriages, deaths 1630-1850



Source: Palm 2001, p. 70.

came from Wrigley & Schofield´s well known population history of England from 1541-1871[5]. Such records were compulsory for all parishes in Sweden by 1686 thanks to a new church law, but bishops had introduced church books earlier in parts of the country. From c. 1630 the number of preserved church books grows continuously. Population can then be estimated from a year where population size is known by going backwards successively adding deaths and subtracting births found in the vital records. Factors like migration, under-registration etc. may create important flaws to the calculations however. The number of births can largely be trusted (i.e. stillbirths must be taken into account), recorded deaths, however, tend to be too low (soldiers who died abroad were excluded, crisis mortality insufficiently recorded etc.). When inflated for the probably lacking dead (i.a. adjustments for dead soldiers according to elaborate calculations by professor Jan Lindegren), the diagram above for Sweden within today's borders could be constructed. I expand the studied period here to 1850.

The trends clearly suggest that in the early modern period population growth in Sweden was much faster than Heckscher and others thought.

A comparison between births and deaths and my recounted population estimates above gave the following vital rates:

Table 2. Estimated vital rates for Sweden within today´s borders 1630-1850 (per 1,000 inhabitants)

Period	Births	Marriages	Deaths
1630-1720	34.4	9.4	29.2
1721-1750	32.9	8.6	25.8
1751-1800	33.6	8.5	27.4
1801-1850	33.2	7.3	23.9

Sources: Palm 2001, p. 73; Hofsten & Lundström 1976, p. 16.

The rates for births and marriages are the most reliable. If we concentrate on the birth rate it seems to be fairly stable over time. For the early modern period it is slightly higher than for the following periods, but still very much compatible with calculations for many other European localities or countries for the same period. This suggests the recount from households is realistic.

If we consider net migration other than military negligible, the rates of growth can be estimated from the births and deaths in the previous table as follows:[6]

Table 3. Estimated growth rates in Sweden within today´s borders for periods 1630-1850

Period	Growth ‰
1630-1720	5.2
1721-1750	6.2
1751-1800	6.6
1801-1850	9.3

How do they stand in comparison with estimates of growth for other countries? Here we can only compare the average for a longer period, 1500-1820.

Table 4. Growth rates in some Western European countries 1500-1820

Country	Growth ‰
United Kingdom	5.3
Sweden	4.8
Finland	4.3
Norway	3.7
Portugal	3.7
Switzerland	3.2
Belgium	2.8
The Netherlands	2.8
France	2.3
Germany	2.3
Denmark	2.0
Italy	2.0
Spain	1.8
Austria	1.6
Average for Western Europe	3.1

Source: Maddison 2007, p. 242. Johansen 2002, *passim*.

5. Wrigley & Schofield 1989

6. Palm 2000 p. 105 gives c. 6 ‰ 1571-1699.

Judging from the table the suggested fast growth in Sweden seems to have parallels. With the exception of Portugal it is not farfetched to suggest differences in economic settings between the dynamic and stagnant countries, where Sweden seems to be part of a vigorous north-western Europe. Most important however, the figures do not make fast growth in Sweden during the early period implausible.

Too many people, too little food?

Alleged low agrarian production levels have been used as an argument against relatively fast population growth in 17th century Sweden. Rodney Edvinsson studied grain prices, subjective harvest assessments and tithes in order to reconstruct an annual volume series of GDP and GDP per capita for Sweden within its present borders from 1620 to 1800.[7] As it was mainly based on tithe trends he found that, at least per capita, cereal production displayed a stagnating tendency.

Swedish statistics for agrarian production started to be reliable from as late as the beginning of the 20th century, despite agrarian statistics having been introduced in 1802. There are plenty of other earlier sources that could be used for statistics however. The number of cattle can be estimated from cattle tax registers 1571, c. 1630, from the thousands of land surveyor protocols c. 1570 and c. 1690, and peasant inventories from 1735 onwards. Tithe records, preserved in the Swedish archives in an immense series from the 1540s onwards, picture a certain share of the harvest volumes.

For a long time many scholars have been critical of much of the evidence from fiscal records. Such records are known for under-registration due to tax evasion etc. However due to some aspects of the tax system as a whole – especially the cadastral system – much of the under-registration can generally be adjusted for. From the 1540s onwards, Sweden developed a cadastral system that included nearly all types of settlements (cadastral units, cadastral farms, "byar", "jordeboksgårdar" etc.) except rectories and a few very old mansions. As tithes and other taxes were successively registered according to the cadaster units, "virtual" tithe totals, and hence harvests, can be estimated by inflating tithes in proportion to the total number of units in the cadasters and the number of decimants ("tiondegivare"). For example: A parish consisted of 50 cadastral units and registered 40 decimants giving 20 barrels of tithe. An adjustment can be made as 50/40*20, which gives 25 barrels. The calculated resources of the unregistered rectory and mansions must be added to this if there are any. The resources for these can be estimated from, inter alia, their equivalents in cadastral units as they were finally registered in the cadasters during the 17th or early 18th century. There are many small details which are not in the scope of this paper. When the harvest dependant tithe system was finally abandoned, peasant inventories starting from c. 1736 including seed corn and yields per seed corn, indicated in a variety of sources from all over the country, can be used instead. A similar reasoning can, *mutatis mutandis*, be applied for estimates of animal production.[8]

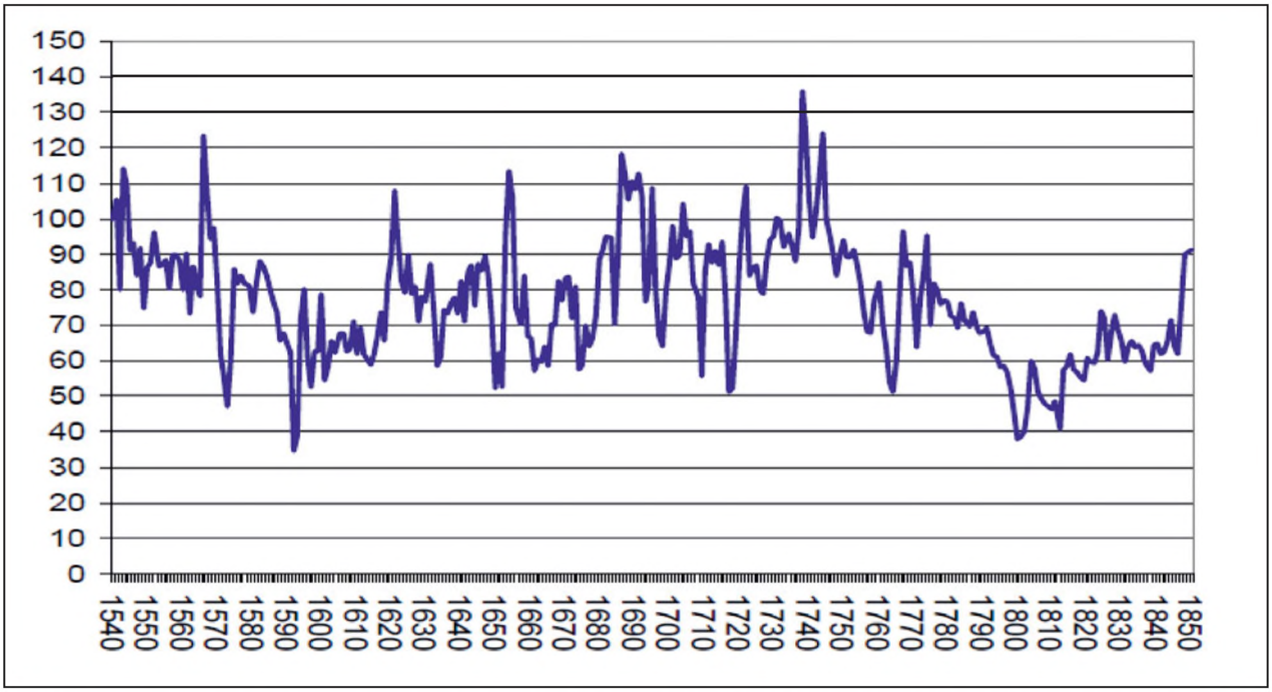
The Swedish Research Council finances research infrastructure projects, especially the production of databases. Martin Linde and I were given the opportunity to build such a database covering agricultural and population development from 1570 to 1810. Our idea was to make calculations for every sixtieth year. In our reports we also made calculations of the levels of nutrition in the five periods. It´s not possible here to go into detail about how the calculations were made. The interested reader can find elaborated discussions on method etc. in our reports published on the Internet.[9]

7. Edvinsson 2008.

8. In the northern parts of Sweden – with relatively low cereal production – tithes could be registered per peasant household. Adjustments can also be made for rectories etc.

9. The sources and methods used for our calculations are found on the Internet in the following publications (in Swedish): Linde 2012; Linde & Palm 2014; Palm 2012a, 2012b, 2013. For the areas taken from Denmark and Norway, mostly after the Roskilde peace treaty of 1658, the sources for the period before c. 1690 are scarcer. Tithe records have survived from e.g. Scania

Fig. 3. Real wage index for daily labour in Stockholm 1540-1850. 1540 = 100.



Source: The Riksbank project *Historical monetary statistics for Sweden 1668-2008*. Wage is presented by Johan Söderberg, and the CPI by Johan Söderberg and Rodney Edvinsson.

In the following table (page 15) the possible consumption from cereals and cattle is shown based on my population recounts and estimates by earlier scholars. The estimated dietary requirements for an adult manual labourer in the 18th century has been calculated to be around 3,000 Kcal:

It should be noted that, contrary to studies based only on tithe records, the possible cereal consumption levels in the table below include net cereal imports. Net imports, which were commenced around 1650, soon reached very high levels, especially during late 17th century – For some years import figures have been preserved in the archives: 1686 – 206,000, 1695 – 11,000 (!), 1696 – 800,000, 1697 – 600,000 barrels.[10]

The population estimates of Heckscher & Co. give, especially that for 1630, per capita consumption levels clearly below subsistence needs.

The calculations can be compared to the real wage index above for manual workers in Stockholm:

Trends in the wage diagram correspond fairly well with the calculated consumption levels for Sweden in the table on page 15. The dip in the curve around 1810, however, shows that the absolute levels in the diagram cannot be directly translated into nutritional levels for all of Sweden over time.

(Skåne) c. 1570 ("Lunds stifts landebok") however, and cattle units can be estimated from revenue sums paid to the central Danish tax authority from several cattle taxes around 1570. Sources from c. 1630 still remain weak for Scania. After the 1680s the source material for these areas has the same quality as for the rest of Sweden. The Swedish surveys from c. 1690 are similar to the Danish "Matrikel" of 1688.

10. Net exports of cereals started in the 1830s.

Table 5. Calories for "normal consumer" (=0.8*pop) 1560-1810.

	My pop. estimate	Kcal	Alternative pop. estimate	Kcal
1560	703,100	3,240		
1570	640,200	3,562	1,000,000	2,278
1630	905,745	2,500	1,150,000	1,957
1690	1,362,000	2,515		
1700	1,300,000	2,634	1,300,000	2,634
1750	1,780,700	3,219	1,780,700	3,219
1810	2,396,400	3,500	2,396,400	3,500

Note: Figures somewhat rounded. The 1690 Kcal figure includes an estimated average yearly net import of 500,000 barrels. The 1560 figure is an estimate for the pre-wartime 1563-1570, 10 % higher than 1570.

Conclusion

I suggest that the discussion above creates a strong argument for a rapidly growing population in Sweden during the 16th and 17th centuries, although a more precise margin of error of course is hard to set. Three independent studies however – of households, church records and consumption levels – all point in the same direction.

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2

The evolution of northern European crops

Roland von Bothmer

SCI.DAN.H. 4 · 7 · FOOD, POPULATION AND HEALTH – GLOBAL PATTERNS AND CHALLENGES
THE ROYAL DANISH ACADEMY OF SCIENCES AND LETTERS · 2016

Abstract

Agriculture was first initiated in SW Asia ca 10 000 BP. The first species to be domesticated were grasses in four major areas of the world. Evolution in crops can be divided into three distinct phases: 1. Domestication; 2. Migration and adaptation; and 3. Modern plant breeding. The presently cultivated crops in N Europe have a diverse evolutionary history and age and some examples are described in the paper. Northern Europe has had a restricted contribution to crop domestication but the area is rich in genetic resources of some groups, in particular forage grasses and legumes. For future food security a careful conservation and utilization strategy must be implemented.

The dawn of agriculture and the first crops

The first deliberate cultivation of plants and thus the dawn of agriculture took place in the region of SW Asia called "The Fertile Crescent" (Zohary *et al.* 2012). That is the mountainous area in the Levant that comprises parts of present-day northern Israel, Syria, SE Turkey, northern Iraq and the Zagros mountains in W Iran. Some of the world's most important temperate crops entered the scene here, in particular wheat, barley, broad bean, flax and lentil. The archaeological remains are numerous and the evidences are strong that this took place around 10 000 BP when the crops where not only cultivated but also *domesticated*, which is when the plants were genetically changed from being well adapted to wild, natural habitats to being selected for the specialized biotopes of farm land (see below). The domestication process might have been a comparatively rapid event, perhaps only a couple of hundred years (Fuller *et al.* 2012). There was, however, a long "pre-domestication" period of several thousand years, since large amounts of older remains of wild species (particularly barley) have been found at human dwellings which do not show the characteristic traits of domestication. Humans had used many plant species for food and other purposes as hunters and gatherers and were certainly familiar with collecting, storage, and preparation for food, in particular of nuts and grass seeds before agriculture was implemented. The seeds of wild *Hordeum* (barley) and *Triticum* (wheat) were in some cases picked in great quantity for consumption (Harlan 1992, Savard *et al.* 2006).

During the early periods of domestication a large number of wild species were domesticated and many of our present crops dates back to this early period (10 – 4 000 years ago). Great civilizations such as the Sumerians and Egyptians in the west and The Chinese societies in the east based their progress on many of the main crops we know today, such as rice, wheat, flax, lentils, rice and several millets. Only a few agricultural crops have been domesticated during the last 500 – 1 000 years but more so among horticultural crops and ornamentals. Our forefathers prepared well for the further societal growth and migrations of people.

Grasses became cereals

Among the first crops to be domesticated were grasses and still after 10 000 years they are staple food for the majority of people in the world. In four major areas in the world and probably completely independent of each other and rather close in time, several species of the grass family (Poaceae) many not related were domesticated and became cereals. These four major areas of cereal domestications are:

- The Fertile Crescent has obviously been the oldest region for domestication and then for the cereals wheat and barley at ca 10 500 - 10 000 BP.
- About the same time or some centuries later, in an area at the mouth of the Yellow River in China rice and some species of millets became crops. Rice was domesticated in the lowlands and humid areas suited for cultivation of paddy rice. Two species of millets were domesticated namely *Panicum miliaceum* (common millet) and *Setaria viridis* (foxtail millet) in drier, more mountainous areas.
- From the wild relative teosinte (*Zea mays* subsp. *parviglumis*) maize (subsp. *mays*) developed in parts of C America ca 6-8 000 years ago. The first corns to be cultivated were small seeded and with small inflorescences, not the large, swollen, many seeded cobs we know today.
- In Africa sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*) became crops. The problem here is the dating of the domestication process since there are only restricted numbers of archaeological remains for analysis. The domestication dates probably back to 5-6 000 BP.

There are several reasons why the small grass seeds were the targets for collecting in a large scale before the farming era started. The grass seed is a remarkable and complex organ with many advantages. It can be dried to low water content and in this stage the viability can be preserved and the seed can be stored for a long time. The seed is light and can easily be transported into other areas and thus promote the spreading of agriculture and the migration of people. The grass seed is comparatively nutritious containing a number of proteins and starches and for humans many essential minerals and vitamins even if it is by no mean a complete food supply.

The evolutionary process in cultivated species

In nature evolutionary mechanisms including selection and subsequent adaptation to new environments or new conditions result in new life forms and new taxa in a never-ending process. It is based on genetic recombination and occasional mutations of genes, which creates new favourable types. Evolution in nature is usually a slow process in stable environments but is speeded up in periods of drastic and more sudden environmental changes. The evolutionary process in nature is also complemented by the action of random factors, such as random survival of new forms accumulating as neutral genotypes in a stable environment, which may be of an advantage when conditions are changed.

The same evolutionary factors operating in a wild organism are active also in an agricultural context. However, humans have partly replaced nature for creating new types of crops and domesticated animals not adapted to the wild stage but only for life in a manmade habitat - the agricultural ecosystem. During the domestication process and later (see below) the action of evolutionary forces are significantly increased (100-1 000 times) in comparison to what happens in nature. Man has selected which types are suitable for his purpose and are allowed to survive - and the strong selection for a special type leads to a simultaneous change. The lethality of unwanted types is no longer gradual as in nature but has gone up to 100 % in one generation.

The evolution of crop plants can be divided into three major phases in the ongoing story of alterations: 1. Domestication; 2. Migration, selection and adaptation; 3. Modern plant breeding.

Domestication

This phase is the transfer from the wild state to an agricultural ecosystem. During a comparatively short period (some centuries) the plants went through drastic genetic alterations with major phenotypic changes in rather few genes, a process called macroevolution. The changes for adaptation to the cultivation system affected biological system such as:

- *Loss of seed dispersal mechanism*. A wild plant must have an efficient dispersal mechanism of its seeds either by wind, water or by animals in order to survive. In cultivation all seeds can be harvested without loss and the plants have lost their shattering capacity and any special arrangements for dispersal (hairs, thorns, long awns etc, see Figure 3).
- *Even maturation and germination*. In cultivation all seeds can be harvested at the same time and all seed should germinate more or less simultaneously leading to an even development of the crop. This has lead to loss of successive maturation and seed dormancy, which predominates in nature.
- *From cross- to self-fertilization*. Many wild species have a higher degree of out-crossing, which promotes the development of genetic variation of importance for survival in a changing environment. For example, the wild progenitor of barley has up to at least 10 % of outcrossing whereas modern barley cultivars have less than 1 % out-crossing (Bothmer *et al.* 2003). However, a higher outcrossing rate often leads to a lower degree of fertilization and thus a lower seed set. In cultivation homogeneity in the offspring combined with high seed set is the preferred character.
- *Changes in life form*. In an agricultural context it is vital to get yield annually for food supply. Many domesticated crops emanate from biannual or even perennial ancestors and a shortened life cycle has been selected during domestication.

Migration, selection and adaptation

The second phase in the evolution of crops contains the further development and spreading of agriculture. It is a much more prolonged and slower process than the domestication. Cultivation together with the newly domesticated crops spread to new areas where the plants faced new climatic and edaphic conditions. New combinations of adapted traits were needed for the new environments, which include tolerance to other abiotic stresses such as frost and drought and changed day length. The crops faced the infection of new pests and diseases, which required particular resistance. The new habitats had also other edaphic conditions. New gene combinations and new mutations resulted in adaptation to the new surroundings. At the same time the new human category – the farmers – made their own selections for particular, preferred traits such as better taste, efficient growth and a higher yield or for other useful characteristics. In this way adaptation to very extreme conditions were possible (Figure 1).

The migration phase became a much more gradual process – influenced by several genes and alleles each one having a minor influence on the phenotype, called microevoltion. The major crops, such as the cereals were very successful and were eventually dispersed to suitable areas all over the world. The temperate cereals wheat and barley reached Scandinavia as early as 6 000 BP. Simultaneously they also spread eastwards and reached China ca 5 000 BP. In this gradual manner, new types, *landraces*, developed, which were well adapted to new conditions. The landraces were locally adapted often to very restricted areas. In this way a rich genetic variation, so called domesticated biodiversity, was created over time. The landraces were quite successful and when modern plant breeding started the initial material was the landraces.

Modern Plant Breeding

During the 19th century large, revolutionary changes of agriculture took place with, for example, land reforms, increased mechanisation, development of new

Figure 1. A genetically variable landrace of wheat in Tibet, at an altitude of 4 000 m.

farming technology and increased use of fertilizers. In this period there was also an increasing demand for better seed material for increased yield and yield stability, better quality properties and better disease resistance. Modern plant breeding was born and the first plant breeders were small, very local seed companies often with governmental support in many countries. The initial material was the older, well adapted but heterogeneous and genetically variable landraces often with uncertain yields. The methods practiced by the first breeders were simple selections. From genetically variable landraces plants with the best sets of characters were chosen and after some generations of continued selection a new cultivar was released. When Mendel's genetic inheritance laws were rediscovered in the year 1900 it became evident that further selections in already homogeneous and homozygous lines were not possible. The variability had been exhausted and new variation must be created. The next step was based on the ability to combine favourable traits from different parents by sexual crosses and the creation of new, genetically variable populations from which new circles of selections for producing the new cultivars could be performed.

Combination breeding and selection are more than 100 years old but they are still important in modern plant breeding. However, over the century these older technologies have been complemented with a number of other more sophisticated methods in the tool-box of the plant breeder (Kingsbury 2009). In each decade new and more efficient methods have been developed. Artificially induced mutations, chromosomal rearrangements and alterations in chromosome numbers (polyploidy), cell- and tissue-culture with fusion of protoplasts, which are single cells of different species for getting new hybrid combinations

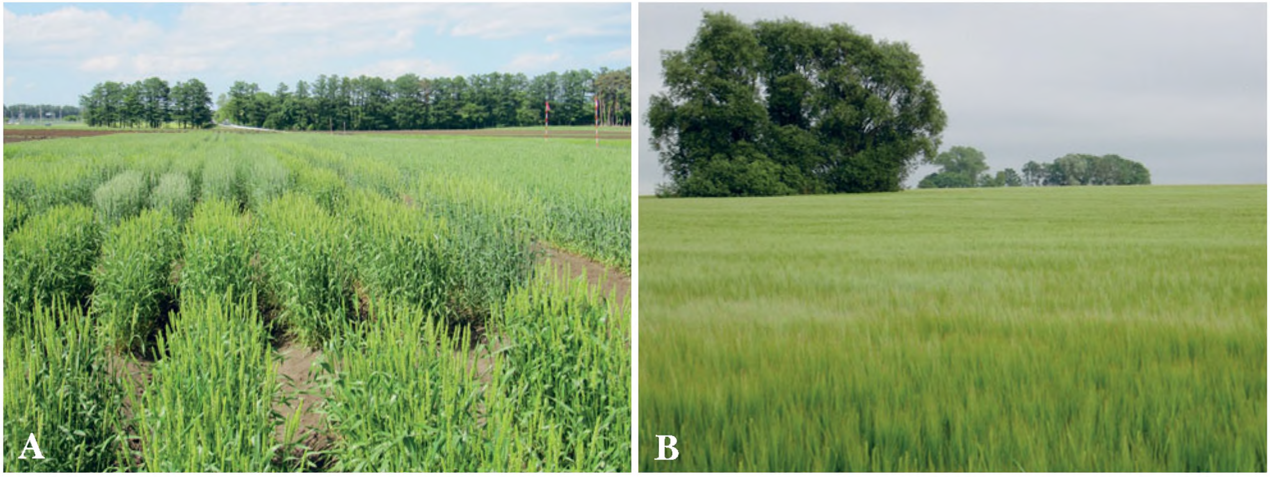

Figure. 2. Modern plant breeding. The genetic variation is present in the experimental fields of the breeder (A). A modern cultivar of barley is completely homogeneous and homozygous (B).

lead to the molecular era. Nowadays characterization of the whole genomes or mapping of genes has lead to effective marker-assisted breeding. In the mid of the 1980s the transformation technique was developed (Genetically Modified Organisms, GMO) for transfer of individual genes within and between species. The newest methods now in progress include how the function of single genes can be regulated. The evolutionary process has thus been speeded up considerably and man now controls in what direction the development goes.

The development of new methods in plant breeding is continuous and it is closely connected to the scientific development in genetics and related disciplines. In the old landraces the genetic diversity and heterogeneity were present in the farmer's field. The most obvious change from the times of the local landraces is that genetic variability is no longer present in the same way farmer's fields as was the case when landraces were grown. A modern cultivar of an inbreeding species is completely homogeneous and homozygous. The genetic diversity has been moved to the field trials of the plant breeders or in their stock of seed material (Figure 2). The major genetic variation in the crop species is now stored in the world's gene banks (see below).

Origin and developmental history of some northern European crops

The wealth of cultivated plants we presently grow have a very diverse background. They emanate from different times and different areas of the world and they represent different plant groups and different biological systems. Here a few examples of crops presently cultivated in northern Europe will be presented showing quite different developmental histories. The nomenclature here follows Aldén & Ryman (2009) and where references are not given specifically, these case studies draw on Harlan (1992) and Smartt & Simmonds (1995).

Barley

Barley *(Hordeum vulgare* subsp. *vulgare)* is one of the original, ancient crops emanating from the Fertile Crescent and it has a very simple developmental history (Bothmer & Komatsuda 2011). The ancestor (subsp. *spontaneum*) is still abundant and grows in suitable habitats in SW Asia. Domestication took place at the diploid level ($2n=14$) and the wild and cultivated forms are fully compatible with each other (Bothmer *et al.* 1991). Spontaneous hybridization may occasionally take place where they meet and the wild form is

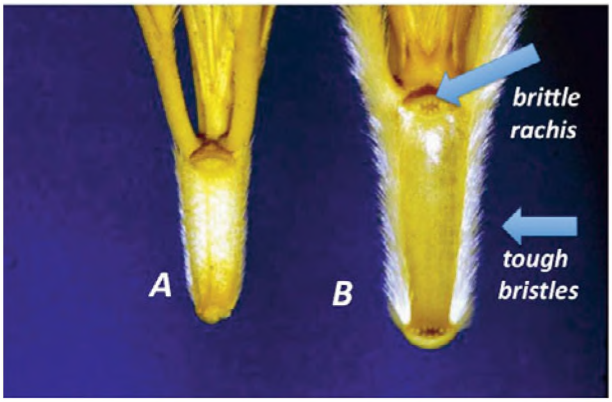

Figure 3. Dispersal units of two wild species of barley. A. *Hordeum murinum*; B. *Hordeum vulgare* subsp. *spontaneum*, the progenitor of cultivated barley. Both wild species have brittle spikes, which easily shatter at maturity and large bristles, which effectively adheres to the furs of animals for seed dispersal.

an important gene source for breeding with many interesting characteristics. The main traits differing the cultivated and the wild form involve the biological systems of reproduction and dispersal. Cultivated barley is mainly inbreeding, has a non-brittle rachis and has lost the seed dispersal mechanism whereas the wild form has a rather high rate of out-breeding. It is shattering with a very brittle rachis and very efficient structures for seed dispersal by animals (Figure 3).

Wheat

The history of wheat is much more complex than that of barley. Both cereals were domesticated at the same time (10 000 BP) but whereas in *Hordeum* a single crop developed several different species of wheat were domesticated including einkorn (*Triticum monococcum*), emmer and spelt wheat (*T. dicoccum*), and bread wheat (*T. aestivum*). The domestication has been gradual including many evolutionary steps such as polyploidization and interspecific hybridization. Einkorn and emmer were the oldest whereas bread wheat is much younger. Einkorn is diploid (2n=14) and emmer is tetraploid (2n=28) both occurring in a wild and in a domesticated form. Emmer probably developed through a hybrid between einkorn and a wild goat grass (*Aegilops* sp.) before it was domesticated. The last major step in wheat evolution took place around 4-5 000 years BP probably somewhere in present day Iran when emmer or durum wheat hybridized with another goat grass (*Aegilops squarrosa*) giving rise to the hexaploid bread wheat (2n=42). Still the details of this complex evolutionary history of the wheat are not completely understood.

Rye

In contrast to the primary cereal crops wheat and barley, rye is a secondary crop, which means that it became established as a weed in the fields of the other to cereals. When agriculture spread the weed migrated together with the crops. It was noted that the weed had large seeds, which often were contaminated with the seeds of the crops and the weed seeds could also be used as food. Gradually, selection for the best types took place. Dating for the domestication of rye is rather uncertain, but obviously it was a gradual process dating back at least to 4 000 BP. It is neither quite clarified where the original area for domestication is. According to different theories it happened either south or north of the Caspian and Black Seas on the migration route to Europe.

The evolution of rye took place at the diploid level (2n=14) and with various chromosomal rearrangements (mainly translocations) as the driving forces. It was a complicated process with several taxa involved. The cultivated crop (*Secale cereale*) is part of a species complex with weedy and wild forms. It comprises both in- and out-breeding forms originating from *S. montanum* with an eastern Mediterranean distribution. The original species is a perennial from which annual forms of the weedy type of *S. cereale* as well as the cereal crop were developed.

In a Nordic context rye together with turnip (*Brassica rapa*, see below) has been an important element. These two species were the main crops in the slash-and-burn farming system in remote, meagre areas mainly in C and N Scandinavia with poor farming under several hundred years, until the end the 19th century (Emanuelsson 2009).

Figure 4. Wild and cultivated Brassicas in southern Italy. A. *Brassica rupestris*; B. An old landrace of leafy kale (*Brassica oleracea*).

Brassica crops

The genus *Brassica* comprises a number of cultivated species and types all interrelated and showing much genetic diversity. Most wild *Brassicas* are perennial or biannual and with a European, W Asiatic and N African distribution whereas the cultivated ones are annual. The genus, and particularly the domesticated species, shows a reticulate evolutionary pattern including several examples of interspecific hybridization followed by chromosome doubling. Most species are thus interrelated. One example of this pattern is rapeseed (*Brassica napus*), which is a natural hybrid, probably recent, between wild kale (*B. oleracea*) with 2n=18 and wild turnip (*B. rapa*) with 2n=20. The hybridization was followed by spontaneous chromosome doubling giving rise to rapeseed (2n=38). Other cultivated crops in *Brassica* are for example Black mustard (*B. nigra*), Ethiopian mustard (*B. carinata*) and Indian mustard (*B. juncea*).

B. oleracea was domesticated in historic times in the Greek-Roman area around 3 000 BP. In Greece and southern Italy a number of closely related wild species occur. During domestication in S Greece and in Calabria and Sicily in southern Italy diversification to different forms such as leafy kales, cabbages, broccoli and cauliflower can be followed in ancient literature in the period (Maggioni *et al.* 2010). All these cultivated forms are fully interfertile (Bothmer *et al.* 1995). The original, wild type was probably a leafy kale similar to the wild types growing in the area today, which are woody, perennial shrubs (Figure 4). Plants of *B. oleracea* occur in wild habitats at the Atlantic coast (France, N Spain and Britain) leading to a theory that kales and coles were domesticated here in Celtic times. However, newer research shows that it is more likely to assume that the central Mediterranean Greek-Roman area was the locus for domestication (Maggioni *et al.* 2014). The different coles became important foodstuff for the Romans and when the empire extended westwards the legionaries brought the coles with them for cultivation in the newly conquered areas. The *Brassicas* have a very efficient reproduction and are effective to compete with other species in certain habitats, particularly in and around cliffs. The so called wild *Brassica oleracea* still growing in or around cliffs in the Atlantic region thus represents older escapes from cultivation which have naturalized in these maritime cliffs.

Sugar beet

Whereas the domestication history of the new industrial crop, sugar beet (*Beta vulgaris* var. *altissima*) is of recent origin, the domestication of its relatives in the same species has a much longer history. The ancestor of all forms of the cultivated beets (*Beta vulgaris s. lat.*) is the low grown, prostrate somewhat fleshy sea beet, *B. maritima* native to stony beaches at the Atlantic and N Mediterranean coasts. The first domestication was for consumption of the leaves and took place in pre-Roman time (ca 4 000 BP) in the Mediterranean. It developed to leaf beets, chard or Swiss chard (mangold) (var. *cicla*), of which the leaf petioles are enlarged and swollen and nowadays eaten as a delicacy (formerly it was poor man's food!). The next step in its evolution was the development of forms with swollen upper parts of the roots with fodder beet (var. *crassa*), which was important for animal feed up to the 1950s and red and other edible beet roots (var. *esculenta*). This happened probably in historic times but the dating is rather uncertain.

Sugar beet has an increased sugar content in comparison to the beet roots from which it was selected. This took place in France around 1780. The first beets from which sugar was extracted had a sugar content of 5-6 %. A century later breeding had resulted in a sugar content of ca 18 %. During the last century, up to present, no increase in sugar content has occurred – it is still 18-20%. Obviously one has reached a biological limit for the sugar content. However, breeding for other traits such as beet size and shape, seed structure, growing efficiency and disease resistance has much increased the sugar yield per hectare.

Garlic

Already in Egyptian time fully domesticated garlic (*Allium sativum*) was present and remains of bulbs and stalks have been found in Pharaonic tombs and are well preserved by the very dry conditions. The morphology and structure of the ancient plants are remarkably similar to the garlic cultivated today. The domestication history of garlic is incompletely known but it seems that it was domesticated already ca 7 000 BP. One particularly interesting condition is that garlic is sterile. It sets no seeds and is multiplied vegetatively by the bulbs, which was the case already in ancient times. No wild forms of the species *A. sativum* are known. The closest wild relative might be the central Asiatic species *A. longicuspis*. It is a tetraploid species (2n=32) with a restricted distribution in Central Asia whereas garlic is diploid (2n=16). The evolutionary history is thus obscure since there is a considerable distance from C Asia to Egypt in the Mediterranean from where the ancient garlic is known and there are no other intermediate forms.

Strawberry

Fragaria is a widespread genus with around 20 species distributed in Eurasia and America. The more or less tasty fruits of most species have certainly been picked and eaten everywhere the different species grow. The European representative of wild strawberry, *F. vesca* (2n=16) was highly praised by Linnaeus not only for its taste but also for its medicinal use. However, this species was not involved in the development of the cultivated strawberry, *F. ananassa*, as often believed. Instead two American species are the ancestors and the hybridisation took place recently. *F. chiloensis* (2n=56) was introduced to The Netherlands in the early 1700s and half a century later the N American *F. virginiana* (2n=56) came to Europe. Around 1750 the hybrid between the two species was made, also in The Netherlands, and in the offspring a favourable combination was selected resulting in the cultivated strawberry. In later years also other species, including *F. vesca*, have been used in breeding particularly for introducing the delicate taste of the other wild taxa.

North European contribution to evolution and crop diversity

Northern Europe has had a restricted contribution to crop domestication in general. For some plant groups, however, the area has been and still is important. It is a centre of diversity for crop wild relatives and for old landraces of many crops with origins elsewhere the area is important as a genetic resource.

Even if seeds of many forage species mainly of legumes, domesticated in C or S Europe were imported to the Scandinavian countries already at the time of Linnaeus (early 1700s) the area has in later years contributed much to the breeding of new cultivars. This is the case particularly for many forage grasses such as *Dactylis glomerata* (cock's foot), *Phleum pratense* (timothy), *Poa pratensis* (Kentucky bluegrass or common meadow-grass) and some species of *Festuca* (fescue), which are native in the wild Scandinavian flora. For centuries they have regularly been harvested for hay and during the last 100 years they have been the target for intense breeding efforts here. The species have successively been domesticated, bred and cultivated in most of the agricultural land in the Nordic area. Also legumes, particularly the species *Trifolium medium* (red clover), *T. repens* (white clover) and *T. hybridum* (alsike clover), have extensive distributions in the Nordic region and these species, even if not directly domesticated here, are common elements in the wild flora and thus of great importance to preserve and utilize in breeding programs.

Other genera where Scandinavia houses important genetic resources are the temperate cereals wheat, rye, oats and barley (local landraces and older cultivars), black currant (*Ribes nigrum*), rhubarb (*Rheum rhabarbarum*), as well as many other fruits, berries and kitchen vegetables. The evolutionary process and natural selection for the area have over the years created a rich genetic diversity in our crops during the long history of agri- and horticulture.

The future of food supply and food security

Even if genetic diversity connected to our crops is large we are nevertheless rather vulnerable for the future food supply from the plant kingdom in a global context. Totally there are around 300 000 species of higher plants in the world. It has been calculated that around 7 000 of those can be used by man for food and other purposes and ca 120 species are of national importance.

Only 30 species stand for 90 % of human calorie uptake and, even more of concern, only three species – rice, wheat and maize – are used for 60 % of the global calorie uptake. If a serious pest or other external causes such as drought or flooding strike one of the major three staple crops, which actually has happened, it may result in a serious challenge for the food security in certain areas or globally. Richness in availability of genetic diversity within crops is the best insurance. The future will be complex with many new situations such as climate change, overpopulation, hunger and escalating environmental problems. We will need a new green revolution aiming at a sustainable intensification in agriculture with among other things increased urban or peri-urban cultivation. The continuous production of new cultivars of established major crops and better utilization of minor crops for all kinds of agricultural systems is necessary.

The large genetic diversity in our crops and wild relatives has been created over the whole history of man as a farmer. The 10 000 years of an ongoing evolutionary process in our crops will continue and hopefully contribute to further genetic variation. The present and future supply of new genetic material for breeding may however be vulnerable why collecting and preservation of genetic resources still is important.

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3

Strontium isotopes as a method of obtaining knowledge of mobility and trade in prehistory and historical times

Karin Margarita Frei

Abstract

Migration and trade are important themes, as they contribute to our general understanding of the dynamics behind socio-economic networks through time. In order to study migration and trade, the provenance of either the individuals or the artefacts being investigated must be known. As the archaeological material record is restricted and incomplete, the question of origin is not always easy resolvable. This article offers an overview of one of the scientific methods – the so-called strontium isotope tracing system – which keeps providing new ways in which provenance and origin can be investigated.

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Introduction

There are various methods of investigating past population mobility, identifying foreign presence in a given region and tracing trade of goods. In archaeology, the provenance of human remains can be investigated for example by looking at types of burial and grave goods. Similarly, ceramics and metals are often assigned a certain provenance on the basis of typological analysis. However, in the past decade, there has been a great increase in research projects that combine and integrate methods from the natural sciences with archaeological investigations in order to explore mobility and trade in prehistory in a whole new way. Hence we see that, more and more often, archaeological projects attempt to incorporate approaches like ancient DNA analysis, isotopic tracing analysis, trace element and main element analysis, with the aim of adding an extra dimension of information. Furthermore, there seems to be a clear pattern where archaeological research projects aim at performing multi-analytical investigations – that is, they wish to include several types of natural-science methods. Such interest is leading to a growth in the present, already broad palette of scientific methodologies. Additionally, some of the already well-established techniques are still being refined and improved. This article will concentrate on one of these methodologies, which continues to grow and develop further in providing information on provenance: the strontium (Sr) isotope system (Fig. 1).

Here, I wish to offer a general overview of the various ways in which this tracing system has been applied within archaeology, as well as a single modern example. The case studies come from a variety of regions as well as from different population groups and archaeological materials. The intention is therefore not to provide insight into the technique itself, but rather to inspire and to give an impression of what just one of these scientific methodologies can contribute to the field of archaeology. For insight information on the technique, several review articles can be recommended (Bentley, 2006; Frei, 2014; Montgomery, 2010).

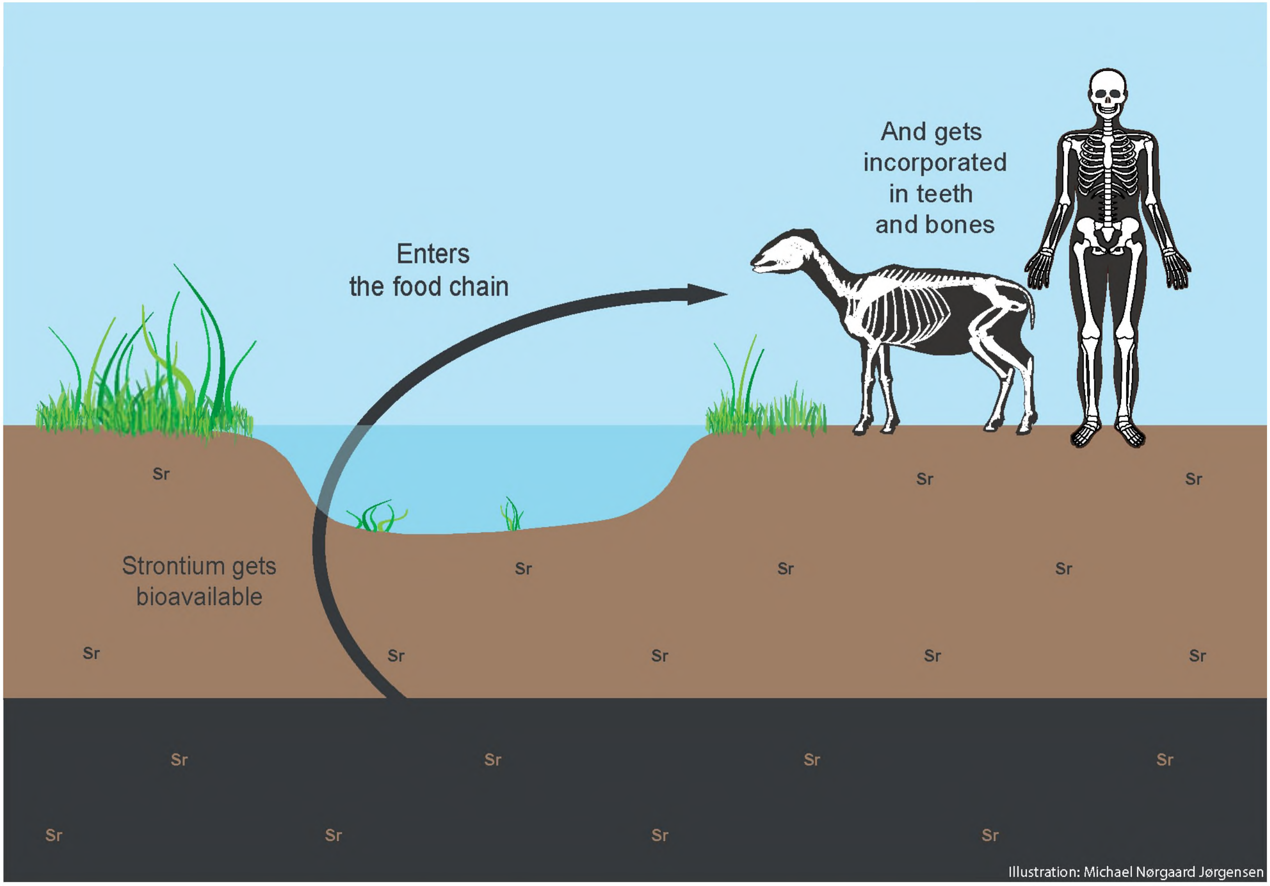

Figure 1. Simplified drawing depicting the strontium cycle. Strontium in the biosphere derives from the soil and underlying bedrock, i.e. the local geology. Strontium is very similar to calcium; hence it can substitute for calcium entering the food chain via plants, animals and drinking water. Consequently, strontium is naturally incorporated into the human and animal plant tissues. Because different lithologies show systematic isotopic variations which are traceable, the strontium isotope compositions of different human, animal and plant tissues can be tracked to a certain type of geology which can in turn be restricted to certain areas of origin. (Graphic by Michael N. Jørgensen, design by Karin M. Frei)

Mobility traced by the strontium isotope system

Mobility of humans in prehistory

In the field of archaeology, strontium isotope analyses are mainly known to have contributed to studies of migration in prehistoric periods. Probably one of the best known studies in which strontium isotopes were used is the investigation of the provenance of the Alpine Iceman "Ötzi" (Muller et al., 2003). Ötzi is a well-preserved human mummy that was discovered at the edge of a glacier in the Alpine region between Italy and Austria in 1991. He lived c. 5200 years ago during the European Neolithic-Copper Age and was approximately in his 40s when he died. Because of the uniqueness of this find, Ötzi has been studied with a huge variety of scientific methods in order to gain as much information as possible about him as well as the environment in which he lived. In order to establish his provenance, strontium isotope analyses, combined with lead (Pb) and oxygen (O) isotope analyses of tooth enamel from Ötzi, provided the necessary information for the authors to establish that the Alpine Iceman spent his entire life in an area south of the discovery site, most plausibly Feldthurns in Bolzano, Italy (Muller et al., 2003).

Figure 2. Sampling tooth enamel from the first molar of an individual dating back to the Bronze Age at the Danish Centre for Isotope Geology (DCIG) at the University of Copenhagen. (Photo: Karin Margarita Frei)

Figures 2 and 3 depict how tooth enamel samples are taken after previously being deeply rinsed; only a few milligrams of tooth enamel are necessary to conduct a reliable strontium isotope analysis.

Since strontium isotope analyses relate to the individual's geographic provenance, there is great potential for combining ancient DNA analyses -which provide information on the genetic provenance of the individual -, with strontium isotope analyses - which provide information on the geographical origin of the individual. One outstanding example of such a combination of methods is the investigation of four Stone Age multiple burials discovered in Eulau, Germany in 2005. The individuals buried at this site were men, women and children who lived c. 4,600 year ago. As their preservation was quite good scientists were able to extract ancient DNA, and at the same time they conducted strontium isotope analyses (Haak et al., 2008). Ancient DNA analyses revealed a direct child-parent relationship in one of the burials, which provided the oldest genetic evidence of a nuclear family. On the other hand, the strontium isotope analyses provided evidence of places of origin differing between men and children in relation to the women. The men and children seem to originate from the Eulau region, indicating that they were of local origin. In contrast, the women's strontium isotope signatures showed that they were of non-local provenance. The authors therefore argue that this could be interpreted as evidence of exogamy and patrilocality.

These types of provenance analysis have also proved useful for proto-historical and historical periods where written sources help to pinpoint the research questions to be put to the archaeological material. For example, we know from written sources that the Inca Empire performed human sacrifices called *capacocha*. Furthermore, these colonial documents indicate that this sacrificial rite involved the most beautiful children in the Empire and that these children were carefully selected from diverse regions within the Empire. Recently, excavations at Choquepukio, Peru, uncovered the human remains of seven children (aged 3-12 years, dating to c. AD 1410-1520), thus providing archaeological material for the investigation of this issue. The children were buried together, accompanied by highly elaborate, high-status artifacts. The strontium isotope analyses of the children revealed that at least two of them were of non-local origin, which seems to verify the statements of the colonial documents (Andrushko et al., 2011).

In Denmark such investigations have only recently been conducted. However, they have already uncovered new aspects of Danish prehistory. For example, the Viking Age site of Trelleborg (dating back to c. AD 980) – one of the large monumental circular fortresses erected by King Harald Bluetooth, located in the western part of the island of Zealand – proved particular interesting. These fortresses, which are unique to southern Scandinavia, are believed to have had a military character. During early excavations at the Trelleborg fortress between 1934 and 1942 by Nørlund from the National Museum of Denmark, human remains of 157 individuals, including men, women and children, were uncovered. Recent strontium isotope analyses of 48 of these individuals (Fig. 3) showed that nearly 50% of them were of non-local provenance (Frei et al., 2014; Price et al., 2011). This study has revealed the largest assemblage (to date) of non-locals in one single burial site in Denmark. Furthermore, the non-locals seem to originate from a variety of places, which might indicate that King Harald Bluetooth had a kind of mercenary military.

Mobility of animals

Animal migration is a phenomenon of great importance, as it provides insight into the biological mechanisms behind these movements. In archaeology, animal migration studies can also provide valuable information on trade networks and routes.

One example in which animals and trade in goods are closely connected is the case of elephant ivory. Elephant ivory is considered a very precious material, and consequently its value endangers the life of elephants. Efforts have therefore been made with the aim to find scientific methods that will enable us to identify origin of ivory (i.e. the elephants' area of origin) in order to combat potential illegal trade. Strontium and nitrogen (N) isotope analyses are among the methods that have been developed to trace the illegal trading routes. These investigations have shown that there are clear isotopic distinctions among different African elephant populations (Vogel et al., 1990). As a result these studies provide a good background for tracing ivory in prehistory and protohistory.

Another case study that illustrates how strontium isotope analyses can be used to trace animal mobility comes from the USA, where a group of scientists used strontium isotopes to reconstruct the migratory behaviour of mammoths and mastodons – members of the megafauna during the Pleistocene (c. 11.000 BP) – found in Florida. Their study revealed that the late glacial mastodons undertook migrations of at least 120 to 300 km. In contrast, the mammoths, which had previously been believed to have undertaken transcontinental migrations, had strontium isotope ratios that pointed to local feeding ranges (Hoppe et al., 1999). The authors therefore concluded that these mammoths did not migrate outside Florida.

In Denmark, a recent archaeological investigation from the Viking Age and Early Medieval site of Sebbersund (AD 700-1100) has uncovered that one of the animals found at the site has strontium isotope compositions that point to a non-local origin (Price et al., 2012). A total of six sets of archaeological animal remains from domestic pig, cow, sheep and horse as well as a mole were analysed for their strontium isotopic composition. Interestingly, most of the animals seem to be of local provenance; only the horse had a strontium isotopic signature that was too radiogenic to be of local origin. This indicates that this horse was probably traded from elsewhere, outside the region

Figure 3. Tooth enamel sample from one of the individuals buried at the largest of the three mass graves at the Trelleborg fortress, at the Danish Centre for Isotope Geology (DCIG) at the University of Copenhagen. (Photo: Karin Margarita Frei)

that is outlined by Denmark today (excluding the island of Bornholm).

Trade in materials traced by the strontium isotope system

There also are several examples where strontium isotopes have been used as provenance indicators for archaeological artifacts with the main aim of tracing trade.

A recent investigation of this kind used a combination of major element analyses with strontium and neodymium (Nd) isotope analyses on 33 colourless glass fragments retrieved from two Roman shipwrecks discovered in the northern Mediterranean (Ganio et al., 2012). Their aim was to identify potential glass trading routes across the Mediterranean. On the basis of the results of these multi-analyses, the authors could distinguish two compositional groups, suggesting the use of different raw materials. The authors concluded that the glass samples might have been produced in two separate workshops/factories.

Although hard, inert materials such as glass and metal constitute the majority of archaeological cultural remains thanks to their preservation characteristics, organic materials such as food and textiles have in some cases also been preserved as a result of specific climatic and soil conditions. For example, maize cobs were recovered from the pre-Columbian site of Pueblo Bonito (AD 850-1150) in Chaco Canyon, USA, because the very dry conditions there enabled their preservation (Fig. 4).

The find of these cobs is very important because maize was a dietary staple of most pre-Columbian so-

Figure 4. Image of the pre-Columbian site of Pueblo Bonito (AD 850-1150) in Chaco Canyon, USA. The very dry conditions at the site have enabled the preservation of maize cobs as well as wood beams, both of which have been investigated with the strontium isotope system to determine their provenance. (Photo: Karin Margarita Frei)

cieties. The Chaco people of Pueblo Bonito are known to have constructed monumental 'great houses' with roof beams as well as water-controlled systems for agricultural purposes and an impressive network of roads. Since the main function of the Chaco cultural system of 'great houses' and roads is not yet understood – there may have been economic, political or ritual reasons – a provenance study of the Chacoans' main food source could provide important information that would help to resolve this issue. A group of scientists therefore conducted strontium isotope analyses and elemental analyses of some of the cobs from the Pueblo Bonito site (Benson et al., 2003). The strontium isotope analyses revealed that the maize cobs were of non-local origin and that they came from a place at least 80 km from the Pueblo Bonito site. Moreover, the cobs were grown in several different areas. Benson et al. (2003) concluded that this was a finding fundamental "to understanding the organization of pre-Columbian southwestern societies" and that it "supports the hypothesis that major construction events in Chaco Canyon were made possible because maize was brought in to support extra-local labor forces".

Strontium isotope analyses specifically developed for ancient textiles have also recently shown that textiles made of plant and wool fibres were imported/traded (Frei, 2014; Frei et al., 2009a; Frei et al., 2010). A large one-piece tubular woollen garment from the pre-Roman Iron Age (500 BC – AD 0) recovered from the Huldremose bog site (Fig. 5) in Denmark was one of the first textiles investigated by this new method (Frei et al., 2009b).

Figure 5. Image of the Huldremose bog site, northeastern Denmark. At this site pre-Roman Iron Age (500 BC – AD 0) textiles have been recovered twice. One of the cases was the single deposition of a large tubular textile which proved to be made of a mixture of local and non-local wool. (Photo: Karin Margarita Frei)

This large textile garment (Fig. 6), was made of a very homogenously spun wool, and was woven in a technique indicating that the garment was of local origin. However, the 11 random wool samples showed that the wool of which this garment was made originated from sheep that grazed in several different regions, including regions outside mainland Denmark (defined as Denmark excluding the island of Bornholm). Hence, the authors argue that even though the textile might have been woven locally, the wool was gathered from several places, some of which were outside Denmark.

Figure 6. Sampling the Huldremose tubular garment at the Conservation and Natural Science Department of the National Museum of Denmark (on the right conservator Irene Skals and on the left Karin Margarita Frei). A total of 11 thread samples taken from both thread directions were analysed with the strontium isotope tracing system. (Photo: Karin Margarita Frei)

The last example also comes from the world of ancient textiles. Nettle, which we mostly know as a weed plant that stings when we come in contact with it, has been used in prehistory as a textile plant. The first strontium isotope provenance investigation of a nettle textile comes from the Voldtofte site in Denmark,

Figure 7. Image of the Lusehøj bronze urn which contained cremated human remains wrapped in a nettle textile from c. 2800 BC. The Lusehøj burial mound is one of the richest Bronze Age burials from Denmark. (Photo: Karin Margarita Frei)

Figure 8. A close-up image of the Bronze Age nettle textile found inside a bronze urn at the Danish site of Lusehøj, whose strontium isotope composition revealed a potential Austrian origin. (Photo: Karin Margarita Frei)

one of the most impressive centres of power during the Scandinavian Bronze Age. Voldtofte has several impressive burial mounds and the largest amount of gold from that period within Scandinavia has been unearthed there. One of the burial mounds, Lusehøj, which has been interpreted as a princely burial, contained a bronze urn (Fig. 7) with cremated human remains which were wrapped in a nettle textile from c. 2800 BC (Bergfjord et al., 2012; Frei et al., 2015).

The nettle textile was investigated using the new strontium isotope method for textiles (Frei, 2014), and surprisingly revealed that the textile was of non-local provenance (Fig. 8). Furthermore, the authors point to an area in Austria as the possible place of origin for the nettle, and this is in accordance with the archaeological/typological interpretation of the bronze urn (Frei et al., 2015). Both the bronze urn and the textile thus appear to have been imported goods of non-local origin. Currently, we are conducting further analyses to investigate whether the individual buried in the bronze urn (probably a prince or a person of very high status) was cremated locally or might have died and been cremated elsewhere.

General remarks

In order to investigate food resources and population dynamics in past societies, it is important to know the origin/provenance of the individuals and their foodstuffs as well as their goods. The strontium isotope tracing system has shown that it is an important scientific tool that can provide new information on archaeological research questions. The strontium isotope system adds an extra dimension to our understanding of the dynamics behind ancient human and animal mobility, as well as trade in food and a variety of other goods. Moreover, there is much potential in combining several scientific tracing systems, such as ancient DNA with strontium isotopes, as we have seen in the case of the Stone Age Eulau family. Finally, the development of new chemical protocols enables us to apply the strontium isotope system to new materials, as we have seen in the case of ancient textiles. With all scientific methodologies there are some limitations and the strontium isotope system is no exception. However, the combination of archaeological evidence with natural-science methods seems to continue to provide new platforms with which we can investigate the past.

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4

A history of animal diseases in the food supply of the United Kingdom since the nineteenth century

Peter Atkins

Abstract

Zoonoses are diseases that can pass between animals and humans. Emphasis in this paper is given to infections acquired through the food supply, with particular reference to the United Kingdom in the nineteenth and twentieth centuries. It is argued that the prion disease Bovine Spongiform Encephalopathy and the mycobacterial disease bovine tuberculosis are iconic examples of foodborne zoonoses that show how the veterinary public health system of the UK has failed. Zoonoses of this type are illustrative of the new types and scales of risk that have arisen in the Risk Society.

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Introduction

Zoonoses are animal diseases that can affect humans and this paper is about their mediation by the food supply. This might sound like a surprising topic since the proximity of people in wealthy countries to food producing animals has been greatly reduced over the last 150 years, and one might therefore reasonably expect the risk of infectious zoonoses to have declined. Yet we are told that of 1407 species of human pathogen, 58 per cent are zoonotic, and 73 per cent of so called emerging or re emerging pathogens are from animals.[1] The spread of disease from animals to humans is also sometimes claimed to be an increasing trend, as the result of a number of factors. For instance, at the beginning of the 21st century the greater intensity of modern livestock husbandry and the increased speed of connections worldwide have created hazards that are qualitatively different from, say, one hundred years ago.[2]

There are various classifications of zoonoses, for instance based on the life cycle of the pathogen, the type of causative organism (bacterial, viral, rickettsial, fungal, parasitic and protozoan), or the mechanisms of transmission.[3] For present purposes a relatively narrow definition will be adopted. We will be excluding any disease not mediated by the food supply, which will therefore rule out three recent high profile pandemics: Severe Acute Respiratory Syndrome (SARS)(2002-3) caused by a coronavirus in wild animals sold in markets in China but then passed largely from person to person; highly pathogenic avian influenza caused by subtype Influenza A (H5N1); and so called swine flu (subtype H1N1), which came to global prominence in 2009, was again an airborne infection between humans.[4]

Our focus instead will be on zoonoses with two vertebrate hosts, mainly humans and their domesticated farm animals, spread through the food chain (Table 1). There are many potential risk scenarios but

1. Woolhouse and Gowtage-Sequeria, 2005; Jones et al., 2008.
2. Greger, 2007; Coker et al., 2011.
3. Steele, 1979-82; Acha and Szyfres, 1987; Bell et al., 1988.
4. The related Spanish Flu (also H1N1) killed upwards of 50 million people 1918-20.

to simplify the present discussion we will choose three interesting situations: food poisoning, recent food scares, and the long run, quiet but devastating example of bovine tuberculosis. The emphasis will be historical, although it is worth noting from the outset that data is in short supply in most countries for the period before the Second World War. The quality even of the more recent data is questionable, as we will see.

Table 1. Principal foodborne zoonoses in Europe.

Salmonella
Campylobacter
Listeria
Verocytotoxigenic *Escherichia coli*
Mycobacterium bovis
Brucella melitensis
Trichinella
Echinococcus
Yersinia
Hepatitis E
Coxiella burnetii (Q fever)
Cryptosporidium
Viruses: calicivirus, rotavirus

Note: Not all serotypes of *Salmonella*, *Campylobacter* and *Yersinia* are zoonotic.

Zoonotic food poisoning

The European Food Safety Agency (EFSA) and the European Centre for Disease Prevention and Control produce regular joint reports on zoonoses, the most recent of which is rich in different ways of relating these diseases to the food supply. The overwhelming preponderance of notifications is for the agents of what we would normally call food poisoning. Between them campylobacteriosis, salmonellosis, verocytotoxigenic *Escherichia coli* and listeriosis account for 99.5 per cent of confirmed human cases of zoonoses in 27 EU countries, 97.9 per cent of hospitalizations, and 93.0 per cent of deaths.[5] Although campylobacteriosis is by far the most common zoonosis in Europe, the most deadly is listeriosis.[6]

Campylobacter is found most often in fresh broiler meat and milk, a staggering 31.3 per cent of EU poultry samples being positive for this bacterium in 2011. This average for the EU is dwarfed, however, by the over 50 per cent contamination in the slaughterhouses and meat cutting plants in the Czech Republic, Poland, Slovenia and Spain, and over 80 per cent at retail in Luxembourg. In human subjects campylobacteriosis is found most often in the Czech Republic, the United Kingdom, Luxembourg, Slovakia, and Sweden. The number of cases is increasing steadily.[7]

Salmonellosis is reported as the principal cause of serious foodborne outbreaks in the EU in 2012, especially serovars *Enteritidis* and *Typhimurium*. This is mainly via eggs and egg products, cheese and various meats. Salmanellosis is, however, on the decline in Europe, as a result of a concerted effort since 2006 by the EU to encourage better monitoring and regulation of conditions of production. The number of confirmed human cases in 2012 was one third lower than in 2008.[8]

Putting all of the zoonoses together, the EFSA report indicates that eggs and egg products are the causes of 22.0 per cent of outbreaks, followed by mixed food (15.6%), fish and fish products (9.2%). In terms of setting, outbreaks were most often (39.7% of cases) traced back to contamination in the domestic kitchen and 23.9% to a restaurant, cafe, pub, bar or hotel. How this relates to the number of food preparation events and therefore to risk is not revealed.[9]

It is often taken for granted that food poisoning and Infectious Intestinal Disease (IID) incidents generally increased during the twentieth century. This was a period of intensification of agriculture, a significant spatial extension and increasing complexity of the food system, and also a shift in lifestyles where

5. EFSA 2014. There were 328 deaths in 2012.
6. For instance in fish products and soft cheese.
7. EFSA 2014.
8. Ibid.
9. Ibid.

consumers relied less on their preparation skills and more on technologies of chilled or frozen storage and rapid heating. The data seem to bear this trend out, with increased reporting of food poisoning incidents, especially from the 1970s onwards. One does have to bear in mind, however, that data was incomplete. In England and Wales the first time *campylobacter* was linked to IID was as recently as 1972 and there was no official surveillance until 1982, when *salmonella* was also reported separately for the first time. Within just a few decades zoonotic food poisoning has risen to be a major burden of ill health. According to research funded by the UK's Food Standards Agency, the country has 17 million IID incidents a year, costing £1.5 to £2.0 billion a year in health resources and lost production.

The EFSA report referred to above has a series of maps of the incidence of zoonoses in Europe.[10] In a sense they are counter intuitive because they show high rates of human salmonellosis, campylobacteriosis and listeriosis in Scandinavian countries, which are known to be more scrupulous in their attention to food safety than the European average. Muller illustrates this by showing that Denmark has the highest annual self reporting rate in Europe at 1.4 incidents per person.[11] This does not mean that Denmark has the highest rate of IID; more likely it is due to heightened cultural awareness and an efficient recording system. Indeed this raises the issue of the 'burden of illness pyramid' that affects all morbidity statistics. A recent study in England found that only one in 17 IID incidents ever comes to the notice of a medical practitioner and only one in 147 is recorded in the national database.[12]

Zoonotic food scares

More informative about consumers' perceptions of ill health from food than self reported food poisoning is the recent history of zoonotic food scares. The classic example is outbreak of Bovine Spongiform Encephalopathy (BSE) that afflicted the UK for 20 years from 1986. BSE is a prion disease affecting the neurological system that can jump the species barrier, appearing as scrapie in sheep and New Variant Creutzfeldt Jacob Disease in humans. At the time of writing (December 2014) there have so far been 177 human deaths in the UK and the slaughter of 184,000 infected cattle at a cost of £5.0 billion in veterinary interventions and economic disruption. Under an intense media glare, beef consumption dropped by dropped 11 per cent in 1996 across the EU and there was also a dip in countries where there was neither a local problem of BSE nor much in the way of beef imports from Britain. It became a global food scare of truly astonishing proportions.

One interesting feature of the public response to BSE was the difference in reactions between countries. In the UK there was a 40 per cent reported drop in the consumption of beef in the first month after the official announcement in 1996 of a link between BSE and vCJD, but this was a brief pause and the purchase of better quality cuts actually increased thereafter. The negative reaction was greater in Germany in 2000 when BSE was found in 25 indigenous cattle, and the fear spread to other European countries that had previously felt safe. It seems that consistently across a wide range of food safety issues worries are higher in southern and eastern Europe than in Scandinavia, the UK and the Netherlands. This is paralleled by low levels of trust in the citizens of the southern and eastern countries in the ability of their governments to deal with food scares by comparison with relatively high levels of satisfaction with policy making in the north.[13] Trust and perceived risk are closely intertwined and the differences between the north and the south of Europe have deep socio cultural roots that are historical.

Bovine tuberculosis

Our final example of a zoonosis is less headline grabbing than food poisoning or food scares but over a long period it has been amongst the most serious for

10. EFSA, 2014.
11. Muller, 2012.
12. Tam, 2012.
13. Mullet et al., 2005; Kjaernes et al., 2007; Kjaernes, 2010.

mortality. This is bovine tuberculosis (bTB), which between 1850 and 1960 is estimated to have been responsible for at least 0.5 million and probably 0.8 million deaths in the UK.[14] We know about the airborne version of TB (*M. tuberculosis*) and the mortality of 7 million in the same period but less has been written about the foodborne bacterium, *M. bovis*. This spreads readily in raw milk and therefore remains a public health hazard in those countries in the Global South where pasteurization has yet to be adopted as a precautionary measure. In Europe bTB remains a theoretical risk, with 125 cases in 2012, but this is small by comparison with the other zoonoses.[15]

There are no reliable published morbidity or mortality data for bTB in humans in the nineteenth and early twentieth centuries. It was possible to distinguish between the human mycobacterium, *M. tuberculosis*, and the bovine mycobacterium, *M. bovis*, by bacteriological laboratory analysis but this was time consuming and expensive and was never adopted as a matter of routine. Instead we have to use the vital statistics for tuberculosis to make an estimate on the following lines.

For the British Isles we have the *Annual Reports* of the Registrars General of England and Wales (from 1838), Scotland (from 1855), Ireland (1864-1921), Northern Ireland (from 1922), and the Republic of Ireland (from 1922). These record tuberculosis deaths attributed to the disease at various bodily sites, usually by age and by sex. The detail varies through time but in broad terms we can recover data in seven categories: respiratory; central nervous system; abdominal; bones and joints; genito urinary; skin; and cervical and other sites. Not all of the tuberculosis at these sites was caused by *M. bovis*, however. We know this because of the extensive experimental bacteriology undertaken by researchers such as Stanley Griffith and others in the first half of the twentieth century. Their conclusion for the UK was that *M bovis* can be credited with only 2.1% of deaths from respiratory tuberculosis in England and Wales, but 26.7% for the central nervous system, 64.7% for abdominal TB, 15.0% for bones and joints, 18.8% for genito urinary TB, 48.5% of the skin disease, and 56.8% of cervical and other cases of TB.[16]

Bringing these two datasets together we can now estimate mortality for the whole period. A simple calculation suggests over 800,000 bTB deaths in the British Isles in the period 1850-1960. There are several warnings that need to be attached to this figure, however. One is that the registration of the cause of death was not compulsory until 1874, with inevitable consequences for data quality, especially where a physician did not attend the person who died. The most important doubt though is that clinical diagnoses in the Victorian period were often vague and inconsistent, notably where more than one cause might plausibly have been attributed to the symptoms. The most often quoted example was infantile tuberculosis, which was frequently certified as tabes mesenterica but shared symptoms with marasmus.

Like BSE, bTB was a problem principally of the British livestock industry. Other countries with high rates of the cattle disease, such as Germany, habitually boiled their milk and therefore the transmission to humans was limited. The domestic heating of milk was less common in the UK and Scandinavia and the risk therefore remained as long as the milk supply was unpasteurized.

In the UK the milk supply of London was the first to be protected by heat treatment, although candidly this was a cynical ploy by the milk trade to increase the shelf life of their product rather than protect the public. 95% of the capital's milk was heat treated by 1932 but it took another 30 years for the rest of the country to be protected to the same degree. Pasteurization of milk has never been made compulsory in England and Wales and the slow pace of change was due to a reluctance by successive governments in the twentieth century to engage with food safety as a political issue. There were three reasons for this. First, in the 1920s and 1930s the peak of zoonotic TB meant that 40% of dairy cows were infected, and the poten-

14. Atkins, 2000a.
15. EFSA, 2014.
16. Atkins, 2016.

tial expense of compensation for farmers was off putting. When area based eradication did at last happen in the 1950s it cost in today's values about £2.65 billion to slaughter 110,000 animals. Second, no government was willing to take on the National Farmers' Union, a lobby group of legendary negotiating strength that had fellow travellers in the Ministry of Agriculture. Third, the heat treatment of milk was stridently and vigorously opposed by a number of different groups, to a degree that in retrospect is difficult to comprehend.[17]

Denmark has always taken the issue of foodborne zoonoses more seriously and for more than 100 years it has been well organized in its public health interventions. N.J. Fjord in the 1870s was among the first anywhere to apply Pasteur's ideas to the heating of milk and for the next 30 years it was Danish and German machinery that was at the forefront of pasteurization technology.[18] The so called Danish Heater was the first to be applied on a large scale to drinking milk, in New York in the 1890s, and it was the Danes who first made pasteurization compulsory, in a law passed in 1898, for the portion of their milk production that was used for feeding pigs and making butter. The rationale was that eliminating disease from foodstuffs was vital for the Danish economy, which at that time was dependent upon agricultural exports. Pasteurization therefore minimized the risk of reputational damage. Denmark was also home to Bernhard Bang (1848-1932), one of the world's most distinguished veterinarians and the originator of an influential method of monitoring and voluntary control of bTB in cattle. Although Bang's approach was eventually abandoned, the Danes were relentless in their desire to rid their country of bTB, which they eventually did in 1951.[19] By contrast there has been a recrudescence in British herds to the extent that 30-40,000 infected are still being slaughtered annually at a cost of £150 million pounds.

17. Atkins, 2000b.

18. Frederiksen, 1919; Westhoff, 1978.

19. Francis, 1958.

Conclusion

In conclusion it is fair to point to a British exceptionalism with regard to diseases which can pass from animals to humans. While all European countries have their challenges, particularly on the food poisoning front, it is the UK, both historically and in the modern era, that has suffered the largest scale, most dramatic and most costly outbreaks of zoonotic foodborne disease. BSE and bTB are indicative of the country's serious political and administrative failings, not to mention the Foot and Mouth Disease outbreak in 2001, which was a further vast though non-zoonotic embarrassment. We can suggest that the intensive nature of British livestock agriculture puts its farm animals at greater risk than experienced in other European countries but this is clutching at straws. The most obvious conclusion is that the successive crises of zoonotic foodborne are somehow a marker of a polity maladjusted to the veterinary public health needs of its farmers and other actors in the food supply chain, along with the consumers of the food produced.

Ulrich Beck and the other Risk Society theorists suggest that such food scares define a new phase in history.[20] They acknowledge that there have been many concerns expressed about food quality and food safety in the past but here we have something altogether different. The 'dread risks' represented by BSE are on a scale of catastrophe that is said to be beyond anything previously witnessed. Their impact has been global, crossing international borders, with the authorities seemingly powerless in the face of this aspect of globalization. As a result, the authority of science and of the political process has been undermined, to the extent that in many countries there has been a serious loss of credibility in official public health messages.

Foodborne zoonoses are not just a historical curiosity then. They have been in the past and remain a source of significant public health risk, and the regular emergence of novel zoonoses is a concern for the

20. Beck, 1992.

future. Ebola, a zoonosis originating in fruit bats devastated the west African countries of Liberia, Sierra Leone and Guinea caused worldwide anxiety in 2014. It is not a foodborne epidemic but it is conceivable that the future may see the emergence of new threats mediated by food and drink. Past successes in controlling zoonoses must therefore not be allowed to breed future complacency.

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5

A landscape of early modern mortality: Spatial perspectives and methodological thoughts on eighteenth century diseases

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SCI.DAN.H. 4 · 7 · FOOD, POPULATION AND HEALTH – GLOBAL PATTERNS AND CHALLENGES
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Abstract

Based on data gathered from church records in two Swedish counties, this study shows that it is possible to conduct relatively detailed spatial analyses of epidemics in the 18th century. The outbreak of two diseases, smallpox (1751-52) and dysentery (1772-73), are in focus. They differ in several ways (e.g. various microbes transmitted in different ways), as did the counties (e.g. population density, topography), but nonetheless there is a striking similarity between the outbreaks. Long, low intensity initial phases with a few local epidemics were followed by an intensive diffusion phase where the diseases gained an epidemic character in a few weeks. In both counties the diffusion pattern was irregular with epidemics in parishes located far apart. Their spread was moderated in the winter but then had a renewed impetus in their second year. In several cases the infection spread to neighbouring parishes from those affected early on. Still, we can barely see any obvious traces of epidemic "roads" or "waves". One reason for the irregular patterns is probably that the diseases are mapped out through mortality instead of morbidity. But it may also be that this, albeit roughly, is actually the main pattern of early modern epidemic diffusion. The assumption of expected epidemic "roads" or "waves" may be incorrect. People interacted more, and moved over greater distances than one readily believes.

When the British physician John Snow plotted the cholera victims in the area surrounding London's Broad Street in in the early 1850s, he was not breaking new ground. Attempts to spatially identify epidemics had been made for decades, but gained both speed and attention during the cholera epidemics of the 19th century.[1] Snow's map garnered a great deal of attention later, however, and today it often features in lectures as an early example of a spatial analysis created with the aim of revealing the elusive causes of diseases.

Mapping became a common way to describe and analyse epidemics, especially in the 19th and 20th centuries. In terms of the 17th and 18th centuries, however, the spatial interest in crises and epidemics only created limited interest among the historians, not least in Scandinavia. This is something of a paradox as supply crises and infectious diseases on a Western Euro-

1. Cliff, A, Haggett, P, Smallman-Raynor, M, *World Atlas of Epidemic Diseases*, 2004, p. 11: Koch, T, *Cartographies of Diseases. Maps, Mapping, and Medicine*, 2005, ch. 2.

pean level in the early 19th century sharply affected the mortality levels of these countries.

This article is based on pilot studies in a larger ongoing project.[2] The aim is to draw some primary conclusions on diffusion patterns for two of the early modern era's most severe diseases while discussing empirical challenges and methodological issues related to spatial compilations of diseases in the 18th century's demographic regime.

Are there reasons to talk about the "waves" and "roads" that are so often brought up when it comes to epidemics? The very word "epidemic" implies speed, and one can easily imagine how pestilence swept between villages and cities. But *how* quickly did they spread? In the following we will tackle two classic infectious diseases from the 18th century, bacterial Dysentery and the notorious viral disease Smallpox, but first some methodological decision making must be covered.

Dusty church records and digital tools: Some methodological issues

Firstly, there are no simple ways to conduct spatial compilations of 18th century epidemics. A major difficulty is the scarce availability of sources and statistics, and a first withdrawal must be made when considering what we actually want to measure. Disease diffusion is contamination and should ideally be studied via its *morbidity,* but such data from the 18th century is very unusual, and therefore the disease specific mortality must become a proxy. The next problem concerns the balance between time and space. Despite not being able to use morbidity as an instrument, it is clearly possible to make maps that annually follow, for example, the 18th century plague or the rumbling ways of 19th century cholera over various parts of the world.[3] For Sweden and Finland it is also possible to use a rather unique source material, the early national statistics, "Tabellverket", which were already being kept in 1749 and provide information on population, births, marriages, number of households, deaths and causes of death, etc., both annually and at a parish level. This, and later corresponding materials in other countries, makes it possible to study a range of demographic variables over long time spans with a relatively high spatial accuracy.[4] But if we will study an epidemic's diffusion closer to the ground – in order to reveal connections to human behaviour in further detail – then things become far more complicated. Maps based on annually summarised disease mortality data can provide good information about distribution and regional differences, but they do not tell us how quickly diseases spread or which pattern the diffusion had. Thus, it is essential to break down the year into smaller longitudinal units. In doing so we must leave the excellent national

2. The research on crises has many components and specializations – i.e. demography, climate, diseases, and politics – and has become difficult to overview. New approaches have been needed for a long time (Devereux, S, *Theories of Famine*, 1993, p. 29; Sarracino, F, *Explaining Famines: A Critical Review of Main Approaches and Further Causal Factors*, 2010, pp. 2), not least research that reaches over and diminishes the boundaries between different disciplines. Spatial studies is one method, but when it comes to the early modern era the efforts have only just begun (in Scandinavia i.e. Jutikkala, E, "Spridningsmönstren hos smittkopporna under andra hälften av 1700-talet i Finland", *Festskrift til Kristof Glamann*, 1983: Sköld, P, *The Two Faces of Smallpox. A Disease and its Prevention in Eighteenth- and Nineteenth-Century Sweden*, 1996: Castenbrandt, H, *Rödsot i Sverige 1750-1900. En sjukdoms demografiska och medicinska historia*, 2012). The present article emerges from pilot studies carried out in *After the Wars*, a project dealing with the 18th century Swedish mortality crises, which is funded by the Swedish Research Council.

3. Several examples in Koch 2005.

4. The data from Tabellverket is digitized and accessible at the Demographic Database, University of Umeå (http://www.ddb.umu.se/databaser/tabellverksdatabas/), 2014-12-23. A good overview of the Tabellverket and its stumbling initial years in Sköld, P, *Kunskap och kontroll. Den svenska befolkningsstatistikens historia*, 2001. Peter Sköld, historian at the Umeå universitet, also studied smallpox in his doctoral thesis, *The Two Faces of Smallpox*, 1996. When it comes to the geographical implications of smallpox, Sköld draws important conclusions about regional differences in many aspects on country and county level, but the patterns of diffusion at a local level are only sparsely examined (see chapt. III.6 and the example of Uppsala county).

statistics and collect the data from ecclesiastical burial records where the dates of the epidemic victims' deaths were written down.

The Swedish church records are, although photographed, not digitized. Compared to using the national statistics, the labour required to obtain data thereby increased significantly and greatly limited the area we wanted to map; it would have been easy to end up with a study limited to a single parish.[5] However, as the aim was to compile and analyse the geographical pattern of epidemic movements this level has proven to be somewhat problematic. The villages and individual data on residency in the burial records must be transcribed and positioned in today's landscape, a challenging and time-consuming process which can be misleading due to biases created by the gap between actual morbidity and our measured mortality.[6] A larger area, however, can reduce the problem of "the morbidity-mortality gap" and give a more reliable picture of contamination patterns.[7] In this study the mapping has therefore been made at the county parish level where the dates for epidemics were collected from burial records, parish by parish, in two different counties.

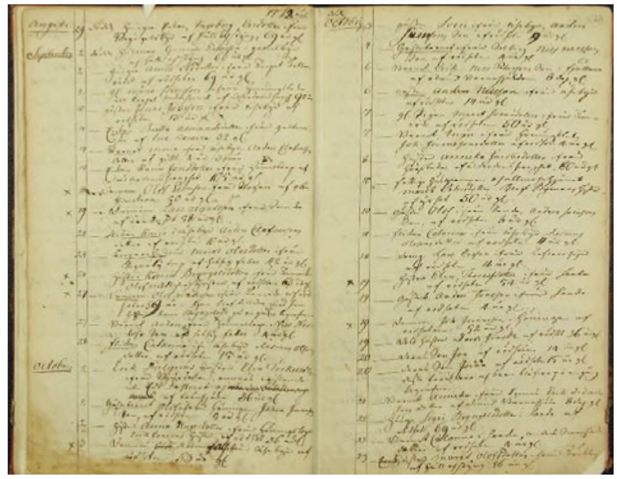


Fig. 1. Typical church record, Sillerud parish, Värmland County, Sweden, 1772.

Disease diffusion at the local level in the 1770's and 1750's

Dysentery, Värmland, 1772-73

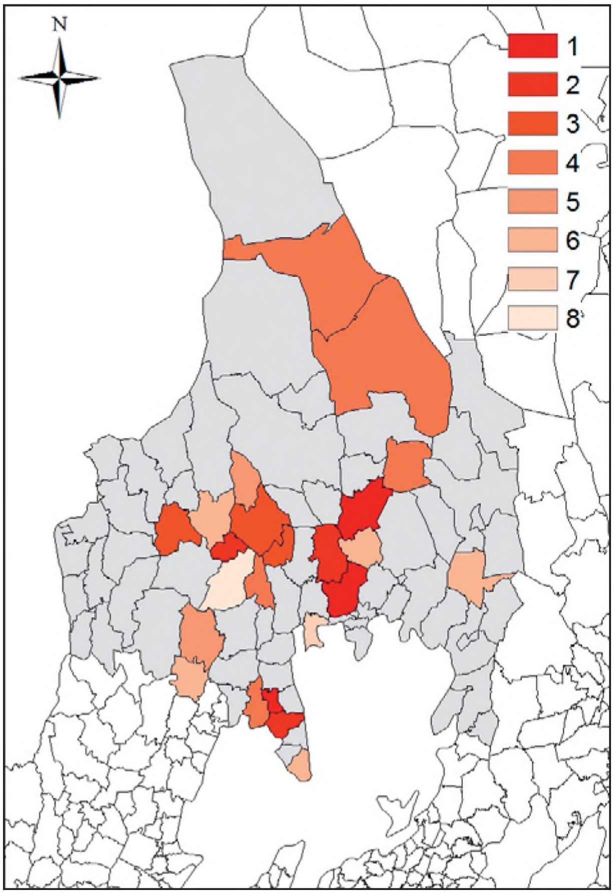
During the severe mortality crisis in the early 1770s, Sweden was hit by brutal outbreaks of dysentery. The crisis, which was basically a supply crisis due to crop failures that affected much of Northern Europe, led to hard restrictions on trade in cereals, not least from the German ports. As epidemics broke out the mortality rose, and the import dependent and politically troubled Sweden of 1772 was particularly exposed in comparison to the rest of Europe. The governmental remedial measures entered too late; in 1773 the mortality rate rose to 52 pro mille for the country as a whole, roughly double the normal level. With the exception of the plague in 1710-11, it was the highest level recorded in Sweden during the 17th, 18th and 19th centuries.[8]

5. At the parish village level there are of course other fine possibilities to draw conclusions from, e.g., the risk of infection through interaction in the local community (e.g., via kinship, baptisms, funerals, households etc.). A good example in Persson, E B, *Pestens gåta. Farsoter i det tidiga 1700-talets Skåne*, 2001, ch. 10.

6. The burial records usually tell us where people lived, not where they were when they died. We must expect a rather significant (spatial contamination) impact from the individuals who were sick but didn't die at the parish village level. A majority of those who died during epidemics certainly died in their homes, not least children, but many did not. There are numerous examples in the burial records of people that where found "dead, lying beside the road to …", or "was found in the woods …" especially during times of starvation and epidemics. James Wilsons study of smallpox in Isokyrö parish, Finland, 1822, shows the problems related to the use of mortality as a proxy for morbidity, see "Mapping the Geographical Diffusion of a Finnish Smallpox Epidemic from Historical Population Records", *The Professional Geographer*, 1993, pp. 276-286.

7. "At micro scales of analysis, mapped mortality should not be used as a surrogate for tracking the geographical movement of epidemics. When broader scales are used, mortality may be satisfactory for plotting spatial trends in the epidemic diffusion process." Wilson 1993, p. 285.

8. Cf. mortality levels in Palm, L A, *Livet, kärleken och döden fyra*



Map 1. The weekly order of dysentery outbreaks during the intense phase in August and September 1772, parish level, Värmland County, Sweden.

An area that was particularly hard hit was the county of Värmland. It is located along the border to Norway in western Sweden and has an area of about 17,500 km² (about 160 kilometres on the east-west axis). The population density was mainly low, in 1810 there were only 8 people per km² of land, with scattered villages and farms throughout wide, hilly forest areas.[9] The dysentery was – although somewhat forgotten in modern overall disease historical handbooks – one of the truly great infectious diseases in Scandinavia before the 20th century.[10] The lethal epidemics were caused by bacteria (Shigella dysenteriae. There was also an amoeba variant, but it was much less terminal). The incubation period ranges from one day up to a week. Infected humans got a stomach ache, fever and bloody stools. The bacteria spread via feces, water and food, but could also infect directly. It usually broke out in late summer and early autumn. The bacterium does not last long outside the human body, but unlike e.g. bacterial cholera, small doses are sufficient to cause symptoms of infection, and the carrier could infect long after recovery.[11]

The dysentery in Värmland initially spread slowly, starting with a few, low intensity local epidemics in the southern part of the county in February.[12] They went on without any further diffusion until May, when a small number of other parishes were hit. A far more intense epidemic phase started in August. In a few late summer and early autumn weeks the number of parishes with registered dysentery deaths increased from a handful to c. 30. The peak of dispersion took place in November.

The intensive diffusion in the late summer of 1772 established dysentery in several locations in the county, but the epidemic weakened during the winter months after its peak in November. In the second intense phase in August 1773 it seems that the disease mainly spread to parishes neighbouring those who were hit the year before. But what about the intensive phases? A closer look at the late summer of 1772 shows that the spread was quite asymmetric. Map no. 1 il-

uppsatser om svensk befolkningsutveckling 1300-1850, 2001. Norway was also badly affected, while Denmark didn't see any sharp increase in mortality, probably thanks to distribution of grain and controlling and restricting people's mobility, Post, J D, "The Mortality Crises of the Early 1770s and European Demographic Trends", *Journal of Interdisciplinary History*, 1990, 49 pp.

9. SCB, 1923, Tab. 1, and 1969, Tab. 11.

10. Castenbrandt 2012.

11. Niyogi, S, "Shigellosis", *Journal of Microbiology,* 2005, pp. 133–143: Castenbrandt 2012, 15 pp.

12. According to Tabellverket, Värmland County contained of 52 parishes at the time. In 1772 there is information about dysentery in 43 of them, 38 of which have contributed data to the maps here (5 parishes just had one or two dysentery victims or are missing information due to shortfalls, absence of notes on cause of deaths or because they have joint church records with other parishes). 1773 corresponds to figures 50, 41 (and 9).

lustrates the order of affected parishes in August and September 1772 (no. 1 is the first week of August, no. 2 the second week and so on). It is difficult to see any pattern at all, except for a tendency towards epicentres in the central and southeast areas of the county.

When the outbreak died out in the late autumn of 1773, it did so with a few lasting local epidemics in parishes which were located far from each other.

Smallpox, Skaraborg County, Sweden, 1751-52

Finally, an outbreak of smallpox in the early 1750s is mapped out. The area covered is Skaraborg, a county located just southeast of Värmland between Sweden's two largest lakes, Vänern and Vättern. The county's northern and eastern parts are characterized by mixed terrain with considerable densely wooded areas. The central and southern parts are marked by plain areas with large and populous villages. The county's area amounted to a little more than 8000 km² of land (ranging on the east-west axis between about 100 kilometres in the south, and 20-70 kilometres in the north), with a population density of c. 17 persons per km² land in 1810.[13] Smallpox causes a characteristic rash and raised fluid-filled blisters in later stages. People were familiar with the disease because it had been around for hundreds of years and there were quite regular outbreaks; an average Swedish parish in the 18th century had to deal with smallpox every fifth to seventh year.[14] Smallpox affected mainly young children as they had generally not been exposed to the virus in the past and thus had no immunity. The virus is mainly transmitted from person to person and does not last long outside the human body. It could, however, be spread in the air to the immediate environment and was therefore a distinct epidemic disease that needed previously unaffected human hosts.[15] The incubation period was one to two weeks, with the disease only becoming transmissible after its onset.

The epidemic started with an outbreak in a few parishes in the southwest part of the county in January 1751.[16] The spread – or, more accurately, the outbreaks in various locations throughout the county – slowly took place throughout 1751. The epidemic then continued with a slight slowdown over the winter, and reached a more intense diffusion in January, February and March with its culmination in the spring of 1752.

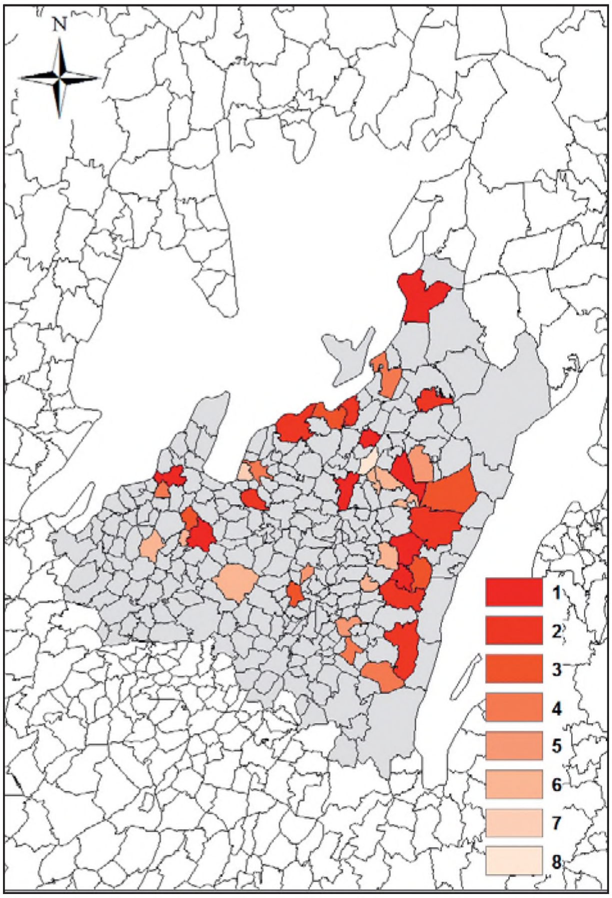
In the intensive phase in January and February the disease spread in different directions from parishes in different parts of the county. More parishes were affected in the county's mixed landscape in the north and east than in the densely inhabited central and southern plain areas, but on map 2 (where no. 1 corresponds to the first week of January, no. 2 the second week and so on until no. 8, the last week of February), there is no single core area or main direction for the contagion, there are several.

Several of the parishes with smallpox during week no. 1 of the epidemic, however, are the same as the year before and in several cases it was their neighbours, or neighbours' neighbours who were affected.

The initial phase of the smallpox epidemic in Skaraborg was similar to dysentery in Värmland. It was slow, but at a certain stage – in this case in January and February 1752, it was followed by a more intense diffusion when the number of affected parishes rapidly grew from about 10 to 36. Thus, the geographical culmination was also late in Skaraborg, over a year from the first outbreaks. When the epidemic faded out in the late autumn of 1752 it did it with the same pattern as the dysentery: ongoing local outbreaks far from each other.

13. SCB, 1923, Tab. 1, and 1969, Tab. 11.
14. Larsson, D, *Den dolda transitionen. Om ett demografiskt brytningsskede i det tidiga 1700-talets Sverige*, 2006, p. 103.
15. Crosby, A W, "Smallpox", *The Cambridge World History of Human Diseases*, 1993, p. 1009. Sköld 1996 is also a well-known study of smallpox in Sweden.

16. According to Tabellverket, Skaraborg County contained 157 parishes at the time. In 1751 there is information about smallpox in 64 of them, but only 29 have contributed data to the maps (data from 35 parishes is missing, mainly due to a widespread use of joint church books at the time, and fewer due to shortfalls, cf. note 12. 1752 the corresponding figures are 128 and 66 (and 62).



Map 2. The weekly order of smallpox outbreaks during the intense phase in January and February 1752, parish level, Skaraborg County, Sweden.

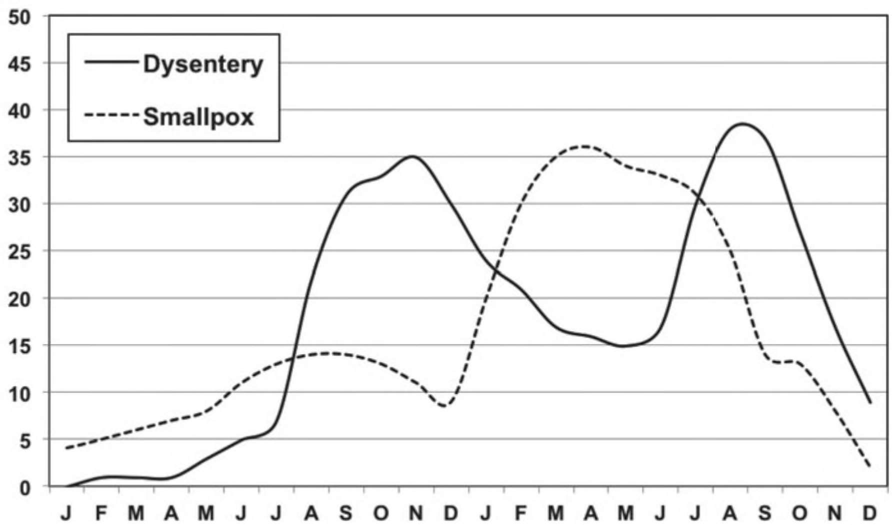
Conclusion

Spatial descriptions and compilations tend to generate more questions than they answer, not least when dealing with conditions 250 years ago. The lack of good maps, sometimes ambiguous and rough ecclesiastical records and time-consuming data collection sharply reduce the possibilities. In this pilot study, diffusion patterns of two of history's most severe infectious diseases, smallpox and dysentery, have been in focus. A number of methodological problems have come to light enabling conclusions to be drawn from them. Finding a balance between time and space is vital. The earliest national statistics at a parish level are from the mid-1700s (Sweden), but are summarised annually. A prerequisite for studying epidemic geographical movements more precisely however – underlined by the smallpox and dysentery's intensive dissemination in the winter of 1751-52 and late summer of 1772 respectively – is a more sufficient time subdivision, and data therefore has to be gathered from church records forcing us to analyse smaller areas than desired, normally villages or single parishes. Thus, a main point of this study was to expand the area to a county level, and at least tentatively determine what knowledge could be gained from this.

The similarity between the outbreaks of dysentery and smallpox in this study is remarkable. The two diseases are caused by various microbes, which are transmitted in different ways resulting in different symptoms and generally affecting different age groups. The two counties in focus were also quite diverse – not geographically, but in terms of population density, the actual supply situation, village structure and topography. Although there are huge gaps in the preserved church records from Skaraborg in 1751 (35 parishes with smallpox had to be removed) the epidemics in both Värmland and Skaraborg had long, low intensity initial phases with a few local epidemics that were followed by an intensive diffusion phase where the diseases – expressed by disease mortality – gained an epidemic character in one or two months. In both cases the spread was somewhat moderated in the winter but had a renewed impetus in their second year (smallpox in January and February, and dysentery in late summer).

The diffusion pattern was irregular with epidemics in parishes located far apart in Skaraborg as well as in Värmland. In several cases the infection later spread to neighbouring parishes from those affected early on. Still, we can barely see any obvious traces of epidemic "roads" or "waves". Missing church records are probably not the answer to this. One important reason is probably that we have mapped out the disease distribution through mortality, and not through morbidity, meaning that the "mortality-morbidity gap" also affects compilations at the county level. Another interpretation to the irregular patterns may also be that we, albeit roughly, are actually seeing the main

Fig. 2. The number of affected parishes (Y-axis) per month (X-axis) during the dysentery epidemic in Värmland County 1772-73 and the smallpox epidemic in Skaraborg County 1751-52.



patterns of early modern epidemic diffusion. The counties studied cover large areas of land and, additionally, the assumption of expected "waves" or "roads" may be incorrect. People were moving more and over greater distances than one readily believes. In the burial records we find numerous examples of how people on the move spread diseases.[17] So next to structural factors such as the supply situation, population density and the longitudinal distance to previous epidemics (smallpox), it's likely that patterns of movement and a series of factors that are hard to recognise in the source material played an important role in the epidemic's outbreaks and diffusion: which and how many people did travellers met along the way? What type of contact took place? Which stage of the disease did you or the people you met have? And how far had you planned to go? A week long incubation period may have allowed sick people - although feeling quite well - to move relatively far, crossing perhaps three or four parishes, at least, before they became ill or developed symptoms.

The study has identified a number of conditions that are both necessary and possible to investigate further. How does the mortality curve for each epidemic match the diffusion curve in a weekly or monthly perspective? Can we find the longitudinal character of the outbreaks by looking at e.g. the smallpox epidemic that we know took place in Värmland in 1772-73, or the dysentery epidemic which broke out in Skaraborg in 1772? And what about the length of the epidemics and the correlation with population size and population density? Some parishes had epidemic mortality for several months, others not. What did these severely or moderately affected parishes have in common? And moreover, is it right to define the long, low intensive periods prior to the actual epidemic explosions as "starting phases"? Much seems to indicate that it was just normal conditions; both the smallpox virus and the shigella dysenteriae seem to have been present every year not only in the country as a whole, but also down to the (normal sized south or middle Swedish) county level.[18]

17. During the cholera epidemic in 1834 we know several examples of rapid diffusion due to people's movements, see also a number of good, earlier examples from southern Sweden in Persson 2001, pp. 135-37.

18. A quick glance in the national statistics Tabellverket tells us that smallpox was also present in Skaraborg in the years surrounding 1751-52, and that dysentery was in Värmland in the years prior to 1772-73 and 1775 (1774 is missing in the records), although not with a mortality rate on a magnitude similar to that of 1772-73.

When it comes to cholera we have identified both its worldwide pandemics as branched epidemic routes in different countries. But when it comes to the other great scourges, like typhoid, dysentery and smallpox, we have much left to explore. The problems are many and several questions must be left unanswered, but there is much to gain from further attempts.[19]

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19. Not least do the international Early modern epidemic diffusion patterns need to be examined, e.g. on the Scandinavian Peninsula and the countries around the Baltic Sea.

6

Studying socio-economic differences in mortality in nineteenth century cities with individual level data: The Copenhagen Historical Population Database

Bárbara Revuelta-Eugercios

Abstract

The effect of industrialization and urbanization in the appearance of socio-economic differences in mortality is still a heated topic in scholarship. Reliance on contemporary accounts and data published by statistical offices has only given us a static and broad, impressionistic image of how the working classes lived and died. Enormous efforts aimed at bypassing these limitations have consisted on reconstructing the life courses of complete historical populations, similarly to what has been done for contemporary populations, through linking administrative registries. In the case of cities, precisely where the main effects of industrialization were felt, the sheer amount of work needed to attain these types of projects has prevented much work being devoted to them. This article shows how, the historical sources for the city of Copenhagen can be utilized in the face of the challenges of contemporary research in historical demography and, particularly, in the study of socio-economic differences in mortality and deepen our understanding of the circumstances that influenced people's life courses.

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The role of industrialization and urbanization on the presence of socio-economic differences in mortality during the 19th century is still a contested topic in the scholarship. Until recently, contemporary accounts and data published by statistical offices had been the only sources available for researchers, while the study of population counts and information on vital statistics made the reconstruction of general mortality trends possible, uncovering the existence of socio-economic differences in some geographical areas. The image these sources at the aggregated level offer is, however, a bit broad and impressionistic, and we are far from having a clear idea of how different life and death were for different social classes or socio-economic groups in the past.

In fact, such sources are not particularly well suited to study socio-economic differences in mortality for individuals. For instance, finding associations between wealth and health in an area does not necessarily mean that wealthy individuals experienced lower mortality risks when compared to other, less wealthy, individuals, as pointed at by current modern epidemiological, demographic and sociological research. Indeed, research in these fields has showed us the complexity of the interaction between social, demographic and contextual factors (age, gender, marital status, place of birth, place of residence, etc.), on the one hand, and measures of socio-economic status or class (however it is measured, i.e. education, occupation, income, etc.) on the other, in buffering or heightening mortality risks.

In order to address these limitations, contemporary research has partially shifted its focus from the aggregated figures to the individuals that comprised the populations under study, taking advantage of the availability of individual level data originated from administrative records. By linking individuals' information through different registries, scholars are able to collect individual and household information over time, as well as individual reproductive, migration, health and labor market histories. In historical research, the same path has been taken. Reconstructing life courses for whole populations is, however, a much more daunting challenge, albeit one that has garnered much scholarly attention.

The community of family historians and historical demographers started in the mid-1960s (Henry 1953, Henry 1956) to reconstruct the population history of villages and parishes through the use of parish registries, census information, population registers and vital statistics. Their work has unraveled a fascinating history of life and death in the Ancient Regime, reaching also the early 20th century, although mostly in rural areas as, so far, relatively less work has been done for cities[1], mainly due to the sheer amount of effort required in producing this type of databases. However, these areas are particularly relevant to the debate on the origin of socio-economic differences in mortality, as it was in cities and, in particular industrial and capital cities, where industrialization and urbanization first manifested and took hold. Cities were the motors of the sweeping economic, political social and demographic changes that transformed the Western world.

This article will illustrate how Denmark and, in particular, the city in Copenhagen, is a particularly good context to address this debate. Here, the construction of the *Copenhagen Historical Population Database* (CHPD) will offer the possibility of studying in depth one of the most pervading issues in 19th century historical research: the origin and presence of socio-economic health and mortality differences.

The debate on the onset of socio-economic differences in mortality

A seemingly pervading view on the historicity of socio-economic differences in mortality, often found in modern-day research, is the claim of its universality across time and space. The almost ubiquitous presence of differences in mortality according to socio-economic status -often meaning occupation-, has given credence to the "historical inevitability of social class differences in mortality" (Link and Phelan 1995, Wilkinson and Marmot 2003, Marmot 2004).

This assumption seems quite sensible, as it finds support in the collective imagery of 19th century industrializing cities. The long working hours, the hot, damp, dusty, and overcrowded environments and the poor food that characterized the "dark Satanic mills" of the Industrial Revolution, according to contemporaries and reformers (Chadwick 1842, Engels 1845), seem to be connected to a higher susceptibility to disease among the working poor and a consequent higher death toll. Moreover, it is not difficult to picture the same large inequalities in access to food, shelter and, in general, living conditions, also before the Industrial Revolution, between peasants and noblemen, serfs and masters, all the way to the first manifestations of social stratification. However, when looking carefully at the actual scholarship documenting socio-economic differences in mortality in the past, evidence of this consistency is nowhere to be seen, particularly as we go far back in time.

One of the most cited references against this hypothesis is Antonovsky's divergence-convergence scenario, which stated that socioeconomic differences did not exist prior to 1650, but that they did afterwards: there was a process of divergence between 1650 and 1850 and a process of convergence since then (Antonovsky 1967). Scholarship has found no consistent evidence of convergence within the last century, but rather clear signs of a widening of socio-economic dif-

1. Among some of the early efforts undertaken for cities, it is important to note the work of Thestrom (1973) in Boston in 1973, who reconstructed the lives of a sample of men across different censuses between 1880 and 1958.

ferences over the last decades (Woods 2004, Strand, Grøholt et al. 2010, Mackenbach, Kulhánová et al. 2014). As for the earlier period, historical demographers have consistently casted doubts on the existence of large mortality differences in pre-industrial Europe. Indeed, empirical evidence has found non-existent or even inverse gradients (i.e. the rich were much more likely to die than the poor) in many historical settings prior to late 19th century (Henry 1956, Hollingsworth 1981, Woods 2004).

The seemingly straightforward and universal association between low socio-economic status or class (differently defined according to disciplines, authors and data availability (Elo 2009)), deteriorated living conditions, higher prevalence of disease and higher mortality that would explain a long-term trend of mortality inequality needs to be challenged. The interaction between biological and social factors that accounted for the variability of disease experience is a very complex one. On the one hand, poverty is generally associated to deficient living conditions (nutrition, housing, hygiene, etc.), but these conditions do not necessarily translate into mortality differences. Nutrition plays a part in health measures like height, that show socio-economic differences, but insufficient nutrition, although linked to decreased immunological resistance, is only linked to higher mortality beyond the threshold of severe malnutrition, such as in famines (Livi Bacci 2000). In fact, before the early 20th century, mortality was driven by infectious diseases (comprising up to three fourths of all deaths), and no real preventive or curative measures were differentially available to the wealthy, so mortality depended mainly on the exposure to disease (Bengtsson and Van Poppel 2011).

On the other hand, cultural or contextual practices determined particular relationships between wealth and health in different time periods and areas. For instance, infant mortality was higher for the wealthy in 19th century Denmark, as "luxury" substitute foods were given to infants instead of breastfeeding, thus increasing their susceptibility to disease and, in turn, creating an inverse gradient (Løkke 2002). Another example is doctors in 19th century Great Britain, who experienced higher mortality risks than other groups with lower status, which is easily explained by their increased exposure to infection (Woods 2004).

The interaction between the social/cultural and the biological is thus not just an isolated phenomenon but a common finding, also in contemporary societies. In developing countries, the wealthy have been shown to be the first to benefit from public health investments, but also the first to modify cultural practices and adopt "more modern", but sometimes riskier, behaviors that can create inverse gradients: unhealthier diets and habits that lead to a higher level of obesity, cardiovascular disease, and risky behaviors, sexual and otherwise, that cause an inverse gradient in HIV infections and accidents (Rossier, Soura et al. (in press)). Although the debate is still ongoing, most scholarship in historical demography agrees that the process of divergence towards the current wealth/status and health association started around mid-19th or early 20th century, but the specific moment it happened seems to have varied according to many biological and social factors. Geography, which many scholars have found to be more important than class, also plays a great role, nationally and internationally, with a large emphasis on the urban/rural differences (Szreter and Woolcock 2004, Woods 2004).

How do we measure socio-economic differences in mortality?

Historically, the process of socio-economic differentiation in mortality has been studied using mainly published statistics and contemporary sources, which have been essential for discovering trends in the past. However, as our hypotheses become more refined, and our questions not only concern populations, but also the individuals living and dying in them, aggregated sources are no longer sufficient to answer them.

One of the main problems related to the use of aggregated sources is the danger of the ecological fallacy, i.e. interpreting associations found at the population level as indication of associations at the individual level. This mismatch was first identified in the scholarship in the 1950s by Robinson (1950). He showed that the association found between higher rates of literacy and higher rates of immigration in certain US states, according to the census of 1930, was not the result of higher literacy rates in migrants. It hid, in fact, the opposite situation: migrants had lower literacy rates but were attracted to the states with higher literacy rates, thus producing a higher-level correlation (for states) that was completely opposite to that found for individuals.

Unfortunately, in the absence of individual level data for historical periods, the scholarship has often been reduced to discussing associations of health and wealth across neighborhoods, district, municipalities, provinces, states, etc., not always emphasizing the differences between inference at the individual and the aggregated levels.

The dangers of aggregated data do not only fall in the realm of interpretation but also in its computations, especially if the registration practices responsible for the production of the data are not able to properly capture the dynamics of the societies under study. This is a particularly relevant problem in the study of socio-economic differences in mortality. For instance, if migrants arrived to the cities to make use of health and charity institutions and died shortly after, estimations of mortality would include their deaths but not their presence as residents. The same would occur with deaths of seasonal migrants, hardly likely to have been reported in the population counts. Both cases would imply overestimating mortality and misjudging any mortality differences studied (Mooney, Lucking et al. 1999, Ramiro Fariñas 2007). And in fact, the sensitivity of estimations to both types of mis-registration have been systematically found for southern Europe (Revuelta Eugercios and Ramiro Fariñas forthcoming).

Lastly, aggregated data and mortality computations derived from aggregates can only tell us about the average of individuals, that sometimes do not even reflect real individuals or only comprise a minimal part of the population. In real world populations, individuals are exposed to different risks and, thus, endure different experiences of disease and mortality, with risks factors potentially contributing differently to the explanation of their mortality. These reasons varied across age, sex, socio-economic differences, etc. In some cases, contemporary doctors or officials in charge of statistics may have computed sex, age or socio-economic specific mortality rates, but the tabulations offered are not sufficient to help us comprehend the diversity of the population experience. Thus, we are forced to think of them as part of a homogeneous group made up of interchangeable units, even if we are well aware that particular groups can be more vulnerable than others -single women, children, the elderly, etc.

The promise and challenge of individual level data

The limitations posed by aggregated data can and have been already overcome by the reconstruction of the individual lives and circumstances of entire populations. So far, and mostly in pre-industrial small populations, extraordinary databases have been collected, providing insights to individuals in their contexts, families and societies.

Historical demographers and family historians first engaged in family reconstitutions (i.e. linking births, marriages, and deaths of individuals through parish registries) in the 1950s, and then more intensely in the 1970s, to cover periods for which no published data or official statistics were available, leading demographers to produce their own aggregated population measures (Henry 1956, Laslett 1965, Thestrup 1972). Population registries and other nominal sources, including censuses and vital statistics, were incorporated later, linking people through administrative records. Soon, analyses extended from the earliest parish registries up to the 20th century. Additionally, accompanying the sweeping changes in the social sciences around the importance of the individual within his/her context, the attention also shifted to the individuals themselves and their life courses, as in Alter's early work (1988), connecting with the growing life-course approach paradigm in its sociological or epidemiological incarnations (Kuh and Ben-Schlomo 1997, Elder, Kirkpatrick Johnson et al. 2003). The focus turned to the examination of people's life events, i.e. the milestones of human life –i.e. birth, marriage, parenthood, work engagement and social mobility, migrating, death-, studied not only as aggregated numbers, but also as possible "outcomes" for individual life courses. The likelihood of experiencing one or other can be partially explained by people's own characteristics, their family situation, their circumstances and previous experiences, e.g. sex, age, marital status, migrant status, place of residence, household composition (Alter and Gutmann 1999).

Besides demographic interest, these efforts have also shed new light on the history of the people without history: how they lived and how they died and to what extent their circumstances shaped not only their own life courses but also those of their offspring. In fact, the potential of this new approach for history and demography has made the linkage of all sorts of social, economic and demographic data, for complete populations at different points in time, and even following generations evolving over time, a staple of historical demographic research in recent decades.

Where they exist, population registries are used to track individuals' life courses. Where there are none, researchers collect data on individuals from parish records (birth, marriage, reproductive life and death), censuses (household composition, occupation, income, rent, etc.) and a myriad other records (tax rolls, land registration, business lists, conscription rolls, etc.).

Examples of such undertakings are found for many places of the world. One such is the *Historical Sample of the Netherlands*, that collects information on the life courses of 0,5% of the Dutch population during the 19th and 20th centuries (Mandemakers 2000). There are many similar undertakings in Sweden, Belgium, Italy, Spain, Scotland, France, etc. Recently, the *European Historical Population Sample Network* has brought together some of these scholars to create a common format for databases containing non-aggregated information on individuals, families and households[2]. Collaboration on joint projects has a long history. The *Eurasia Project* was a joint effort to compare data from several European and Asian contexts from the 18th century onwards, providing enormous insights into life and death in the past (Bengtsson, Campbell et al. 2004, Tsuya, Feng et al. 2010, Lundh, Kurosu et al. 2014). Other efforts have been the *North Atlantic Population Project* (Ruggles, Roberts et al. 2011) and the *Mosaic Project*[3], which have collected census data that includes non-Western European regions, and there are other ongoing projects also creating databases for African (Walters 2008) and colonial contexts (Kok 2013).

Research using these unparalleled databases has allowed us to understand many local communities better and, particularly, has shown the variability of the historical experience of socio-economic differences in mortality. For instance, in a recent number of the journal *Explorations in Economic History*, eight settings in continental Europe and North America (predominantly rural or small cities under 22,000 inhabitants) were examined in relation to the question of the study of socio-economic differences in mortality during the 19th and early 20th century, and researchers found that industrialization and urbanization were unconnected to the onset of socio-economic differences. Some contexts did show a socio-economic gradient before the onset of any industrialization (Breschi, Fornasin et al. 2011, Schumacher and Oris 2011), while little or no trace of it could be found in other studies until much later (Bengtsson and Dribe 2011, Edvinsson and Lindkvist 2011), once more underlying the importance of the 'place of residence' in shaping the health patterns of different socio-economic groups (Woods 2004, Szreter 2005).

However, the full extent of the variation in the geography-class interactions is still unknown, as we are still missing large urban contexts. Even though urban populations only accounted for a small share of national populations in the 1850s, capital and industrial cities were the motors of change in the 19th century, and the places where the full extent of industrialization and urbanization processes was felt. Moreover,

2. See http://www.ehps-net.eu/content/about.

3. See http://censusmosaic.org

their changing mortality patterns make them exceptional places for research: first considered literally "graveyards"(Sharlin 1978), they would later become pioneers in mortality improvements through changes in sanitation, sewage, water, etc. (Woods 2003). Accounting for this gap is thus particularly important in the literature on mortality, as rural areas, provincial towns, industrial cities and capitals most likely experienced very different scenarios of inequality. However, the burden of the of work involved in this large-scale urban population reconstruction projects, requiring large amounts of financial and human resources to see them through, has prevented projects until recently from focusing on cities.

The Copenhagen Historical Population Database

The development of urban databases has been slow but steady in the last decade: there are available samples for Antwerp (Matthijs and Moreels 2010), ongoing projects of full coverage for Stockholm, the *Roteman* database (Geschwind and Fogelvik 2000), and Madrid (Bosque González, García Ferrero et al. 2010). There are also large-scale efforts involved in full national coverage digitation for Norway (Thorvaldsen 2011) and Scotland (Huang, Razzell et al. 2012), as well as samples, such as the already mentioned *Historical Sample of the Netherlands* and the *Historical Population Database of Transylvania*. *The Copenhagen Historical Population Database* will join these efforts for Denmark, continuing the pioneering efforts in Odense by Prof. Johansen (1994).

Denmark and, in particular, Copenhagen around 1880, are extraordinary settings for the development of such database. There are two main reasons that explain this relevance: first, the role of the city as capital, port and industrial center characterized as a scenario of rapid change; and, second, the availability of extraordinary sources for the city.

Copenhagen, as the capital city, comprising 12% of the total population (234,850 inhabitants in 1880), was an important port and, as such, was a center not only of communication, but also of political, economic and social activity. The 1880s were a period of economic and demographic growth in the city (Hyldtoft 1984), characterized by a growing socio-economic stratification, the most diversified labor market (Johansen 2002) and a population in strikingly poor health. Still suffering from the initial effects of urbanization, albeit engaged in a process of improvement, infant mortality rates were double that of the rest of the country (Løkke 2002).

Along with the wealth of data available for Denmark, in the form of parish registration of vital events (births, marriages, deaths) that goes as far back as the 16th century and decennial national censuses (starting in 1801), there are additional sources available only for Copenhagen. Faced with the revolutionary currents across Europe, Danish authorities made keeping the peace their priority, mainly in the form of police control via censuses of adults every 6 months, of incoming and outgoing migration through the port of Copenhagen, and additional population censuses. From 1840 onwards, the capital also implemented the requirement of a medical certification of death prior to burial, which allowed the publication of statistics of cause of death. These sources allowed a very early adoption and application of historical demography techniques (Matthiesen 1970, Thestrup 1972, Johansen 1975), and will now permit the creation of a database for the city of Copenhagen to study socio-economic differences in mortality, as well as the patterns and changes of individual behavior in relation to partner choice, fertility, migration, etc.

A strong genealogical community, amateur historian circles and enthusiasts of family reconstitution, noted and took advantage of this wealth and availability of sources, starting to gather data already in the 1970s and 1980s, to be then followed by the enthusiastic effort of hundreds of volunteers cooperating in its digitization from the early 1990s, under the coordination of the Danish Data Archive (Floor Clausen and Jørgen Marker 2000). These projects, now hosted at the *Danish Demographic Database*, have all made the construction of *The Copenhagen Historical Population Database* possible.

However, even under these unparalleled favorable conditions, the reconstruction of a population of roughly a quarter million of inhabitants for a number of years will involve a great effort in terms of time and funding. The first step towards the full construction of *The Copenhagen Historical Population Database* is the ongoing construction of a dataset for a five-year period, 1880-1885. The project is a two-year plan funded by a Mobilex Fellowship under the name: *A tale of two cities: inequality in death in Copenhagen and Madrid in late 19th and early 20th century*, co-financed by the Danish Council for Independent Research and the FP7 Marie Curie Actions-COFUND (DFF-1321-00136).

A longitudinal database, following all residents in the city for a period of 5 years, will be constructed from censuses, that normally offer a cross-sectional perspective, the population at a given moment in time, and vital registration and police records that record events at particular points in time (births, deaths and migration). The dataset will provide a short window of observation between 1880 and 1885, taking advantage of the wealth of available sources, either digitized in scanned format, or available from the Danish States Archives (*Rigsarkivet*) in Copenhagen. The population present in the 1880 census (236,000 individuals) will be linked to their information in the special census of 1885, which was only undertaken in Copenhagen. Additionally, those not found in 1885 will be linked to the death and migration records from between 1880 and 1885. Finally, in order to study infant-child mortality (a difficult task, as censuses tend to underestimate the number of infants), births that occurred in 1880 will be linked to the parental information in 1880 and their own (potential) 1885 census, death and migration records. This will allow to assess whether each individual living in the city survived to the next census, or died or migrated within that period (see figure 1).

This endeavor will be possible because its two main sources, which offer the basic individual socio-demographic and economic information, have already been fully digitized and are available through the *Danish Demographic Database* at the *Rigsarkivet*. Each census page lists the information by household (head of household first and then rest of family members with their position in said household), including address, name, surname, age in completed years, place of birth, occupation, possible handicaps, number of rooms of the apartment, rent, number of children alive in the household - and also of previous child deaths-, etc.

In addition to the two censuses, the migration records kept by the police in Copenhagen on people moving in and out the city will also be used, as found in the *Dansk oversøisk udvandring 1868-1900* records. These have also been fully digitized and are now part of the *Danish Demographic Database*. They include information on the name, surname, age of the person emigrating, last residence (parish and county) and destination, as well as the date of registration. Finally, these sources will be complemented by the undertaking of the digitation of two more sources: deaths for the period 1880-1885, and births for the year 1880.

Information on death is available through parish books (*kirkebøger*), but for deaths a unique source, available only for Copenhagen, will be used: the death certificates issued by doctors (*dødsattester*), which offer unique information on cause of death and medical treatment that is not available in the parish books. These certificates are available in paper and in microfilm at the *Rigsarkivet*, and will be photographed and transcribed for the period 1880-1885. The information included in these certificates includes: name and surname of the deceased, sex, age, marital status, occupation, place of residence and place of death, cause of death, medical treatment prior to death and doctor authorized to certify. A team of student assistants is currently transcribing these records. A similar effort will be undertaken for birth certificates and included in the database, using the scanned images of parish books made freely available at the *Rigsarkivet*'s webpage. These give information on the births occurring in each parish about: birthdate, baptism date, given name and surname of the child, name and surname of parents, age of the mother, marital status of the mother (if unmarried), occupation of the father, address, name and additional information on godparents.

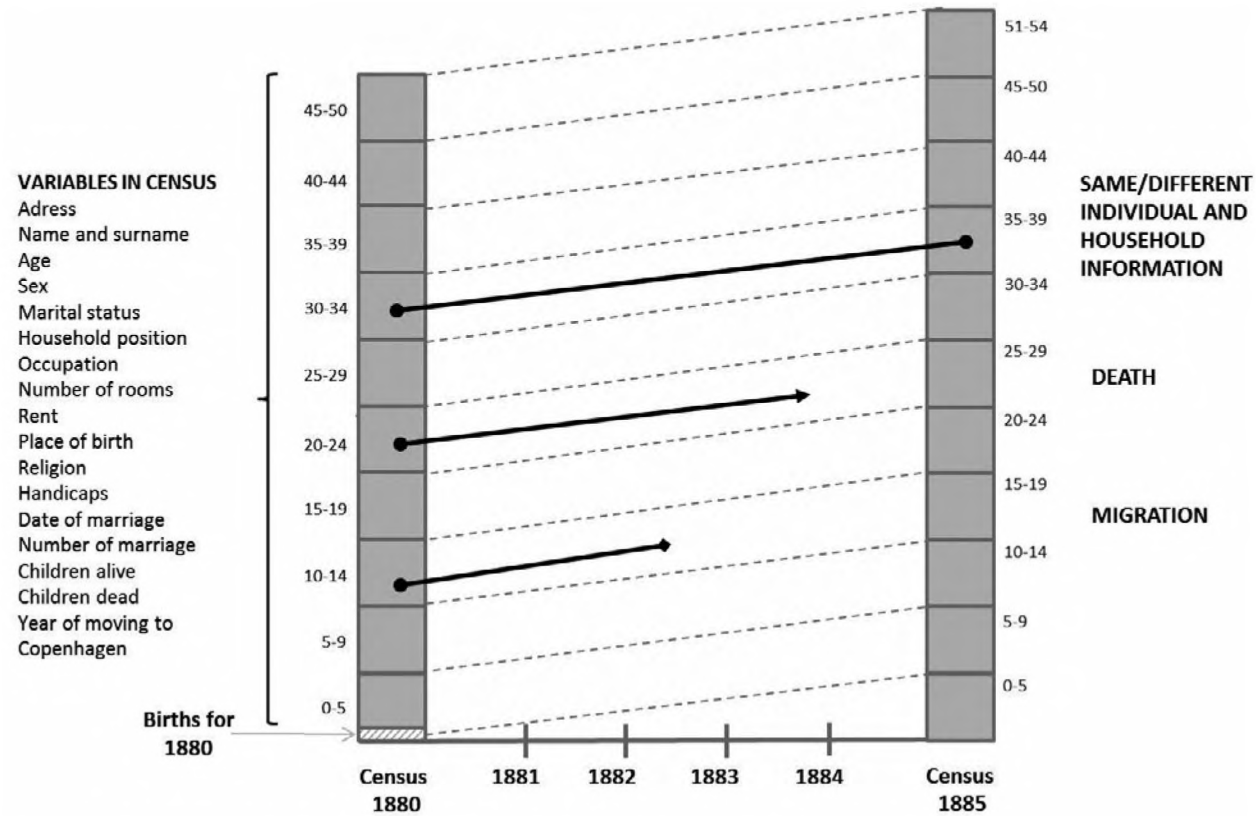

Figure 1. Reconstruction of partial life courses in Copenhagen, 1880-1885.

All the sources will be linked using the names and identifying details of individuals. Data cleaning and standardization will be built on the efforts already taken by the *Danish Demographic Database* at the *Rigsarkivet* (Floor Clausen 2015) and the most current practices in historical population reconstruction (Bloothooft, Christen et al. 2015) developed by other European countries. Standardization and variations lists will be created and made available to other researchers to ensure transparency and further follow-up efforts. The linkage will be undertaken through the software freely available (Febrl) developed by the National Australian University (Christen 2008), that has been tested for other Scandinavian countries, such as Norway (Thorvaldsen 2011). Indexing, record pair comparison by several methods, classification, and evaluation will be undertaken in order to obtain the best quality of linkages. The most recent recommendations on data matching, especially the seminal work by Christen (2012) will be followed. In particular, especial attention will be devoted to the establishment of reliability criteria for the linkages established, involving clerical work.

Conclusion

This article has shown how Danish historical sources and, particularly, those of the city of Copenhagen, can be utilized in the face of the challenges of contemporary research in historical demography and, in particular, in the study of socio-economic differences in mortality. The wealth and availability of the Danish data, especially that for Copenhagen, will clearly be able to overcome the limitations and biases of aggregated statistics that are usually experienced by historical demographers and will deepen our understanding of the circumstances that influenced people's life courses.

By taking advantage of these unparalleled conditions, of which the size and characteristics of the city of Copenhagen is not the least, it will be possible to create a database similar to those already being developed elsewhere. The lives of individuals being born and living in Copenhagen around 1880 will be reconstructed up to 1885, allowing the careful study of mortality differences in the same way they are studied in contemporary epidemiological research, offering simultaneously a uniquely rich perspective on the lives and experiences of the people living in the city. The resulting scientific contributions will shed light on socio-economic differences on mortality for children, adults and the elderly, as well as on gender differences, especially those of particularly vulnerable groups: single women, the residents of poorhouses, etc.

Once this initial window of observation into the city is completed, the scope for extension in time, size and representation is gigantic. In the near future, provided adequate funding, *The Copenhagen Historical Population Database* could become a comprehensive source on the lives of inhabitants in the city, leading to the inclusion of even more sources, linking any kind of material coded with a date and a name or address. The database will become public, at the disposal of the buoyant historian and genealogical community, as well as the student body at both gymnasium and university levels, compounding the social relevance of this momentous public endeavor.

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Reduced mortality – increased morbidity? Morbidity in relation to the emerging system of sickness funds 1890-1960

Helene Castenbrandt

Abstract

In recent decades, worldwide life expectancy has increased by as much as ten years. However, also the time spent with ill health increased, and not only among the aging population. This so-called health paradox is also reflected in the fact that women are generally more ill but lives longer than men. Previous research suggests that the earlier decrease in mortality in Europe, during the 1800s and the early 1900s, also led to an increased morbidity. This project aims to increase our knowledge concerning changes in morbidity and changes in what was regarded as an illness in relation to the emerging welfare system in Europe. Sweden is in focus – the Swedish source material offers unique opportunities to study changes in morbidity. Both women's and men's health will be analyzed and the study has a clear gender perspective. With the industrial revolution the system of sickness funds expanded, which gave laborers with membership compensation for sick leave. Archive material from these sickness funds and official statistics constitutes appropriate source material. The question of how the insurance system affected the perception of illness will be studied with the help of journal articles, government investigation material etc. By adding to the knowledge that already exists about changes in mortality with knowledge on morbidity, this project intends to provide a new understanding of the differences and changes in public health.

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In December 2012, *The Lancet* published a comprehensive study in which risk factors for ill health were evaluated. It showed that the average life expectancy worldwide has increased by a full ten years since 1970. However, the time people are living with illness has also increased and not only among the aging population (GBD 2012). This so-called "health paradox" is also reflected in the fact that women are generally more ill than men but live longer (Smirthwaite 2007). This paradox has been explained in two ways. One emphasises that risk factors for ill health are made up more and more of non-communicable diseases such as cardiovascular disease, cancer and mental disorders; the other highlights that our perception of morbidity has changed.

This health pattern varies in different parts of the world and today's health conditions have historical roots. In Europe, the major mortality decline in infectious diseases took place during the 1800s and continued into the 1900s. Did this reduced mortality result in a similar increase in morbidity as that shown in current global trends? Were the patterns of women's health different from those of men then as well? Or was there perhaps a change in how illness was perceived? This issue becomes extra interesting in the light of the fact that a system of private health insurance societies, so-called friendly societies or sickness funds, emerged during the same period.

This article will present a recently started project, financed by the Swedish research council. The aim is to study on the one hand changes in morbidity and on the other changes concerning what was regarded as an illness in relation to the emerging welfare state in Europe. Chronologically, the focus is on the turn of the century 1900 and the first half of the 20th century. Sweden is at the core of the study, as the Swedish source material offers unique opportunities to study shifts in ill-health and morbidity. From a public health perspective, this period is of great importance as it marks the breaking point between a time when mortality in the western world was dominated by infectious diseases and a time when mortality more and more became dominated by non-communicable diseases. This shift is usually called the epidemiological transition. Previous research has concluded that this change took place at the same time as mortality rates declined sharply; however, it is unclear as to what impact these changes had on actual morbidity. Since morbidity is a relative concept, this study will emphasise the tension between actual and perceived illness. Unlike previous research, this study will highlight both women and men's health. In addition to putting Sweden on the European health map, a gender perspective will shed new light on European development. At the same time, present-day health patterns will be given a historical perspective.

Previous studies on morbidity

Historical analysis of the improved health in Europe has mainly been based on mortality statistics. This is particularly evident in Swedish research, due to the fact that the Swedish source material is unique in terms of its magnitude and details concerning mortality and causes of death. The consequence is that relevant Swedish historical research to a large extent lacks an understanding of actual morbidity. However, it is clear that changes in the perception of disease and morbidity occurred around 1900, as well as that these changes varied according to gender (see for example Johannisson 1990, 1998). Nevertheless, it has not been studied how these changes related to the emerging scheme of sickness insurance. Internationally, research exists that has studied changes in actual morbidity. These studies are based primarily on data from the payments male workers received for sick leave from British friendly societies. Swedish researchers have studied the Swedish sickness insurance system, but mostly by examining changes in laws and regulations not by studying morbidity (see for example Lindqvist 1990; Berge 1995; Andersson 2000; Olofsson and Edebalk 2000; Johansson 2003).

Previous research has revealed an increase in morbidity by the turn of the century 1900, but opinions differ as to what this really meant. Historian James C. Riley argues that a consequence of the reduction in mortality rates was that more frail people survived, resulting in increased morbidity around 1900 (Riley 1987a, 1987b, 1989, 1997). Demographer Robert I. Woods and economist John E. Murray instead argue that increased sick leave was more an indication of a changed view on health and on when taking sick leave is legitimate – not an indication of an actual increase in morbidity. They point out, however, that morbidity needs to be studied in much more detail than in Riley's research. For example, one needs to take better account of age-specific mortality (Woods, 1997; Murray 2003).

Historians Bernard Harris and Martin Gorsky have studied age-related illness and found that morbidity does not seem to have increased, but instead remained at the same level (Gorsky & Harris, 2004; Gorsky et al. 2006, Harris et al. 2011). Nevertheless, the contemporary debate in late 19th-century England assumed that claims from friendly societies had increased. Contemporary commentators argued that the legitimate reasons for staying home from work were changing. They argued that the increase in friendly societies resulted in a growing distance between the societies and their members, which is why control of cheaters had become a central issue (Harris et al. 2011).

Furthermore, the Swedish historian Anna-Karin Frihs has shown that the debate on morbidity did not always reflect reality. In about 1900, the perception of young women changed from the stereotypical image of a frail, sickly young woman to the notion of a happy and healthy young woman – without a corresponding change in actual morbidity (Frihs 2007). Therefore, Frihs' research somewhat contradicts Harris and Gorsky's results regarding an increased morbidity observed by contemporaries. This discrepancy is interesting as increased medicalization and the expansion of the sickness insurance system in this period have traditionally been considered to have had an expanding influence on the number of disease diagnoses.

The philosopher Ian Hacking provides a possible explanation for the discrepancy between actual morbidity and a changed view of morbidity. Strongly influenced by Foucault, Hacking believes that how we categorize, mention and debate different phenomena also helps to redefine them. New systems, therefore, have a direct impact on human thought and behaviour (Hacking 1986, 1995). Thus, the development of a sickness insurance system can be seen as linked to the fluctuating perception of morbidity.

Three arguments summarise the state of research and serve as a foundation for this study: 1) An increased registration of morbidity corresponded to an actual increase in sickness. 2) The registration of morbidity increased, but was caused by a changed view of morbidity. 3) The registration of morbidity did not increase. Contemporary debate about increased morbidity was rather put forward by the expansion of the sickness insurance system.

Three different ways to study morbidity through sickness funds

With the onset of the industrial revolution, the system of sickness funds expanded. It offered an opportunity for the working population to receive compensation for sick leave through membership. The Swedish system of sickness funds soon became partially government funded, even though the Swedish sickness benefit system in the early 1900s was organized in private sickness funds. The number of sickness funds in Sweden increased after 1870 and in 1891 a new law was passed that meant that the government partially provided subsidising to registered funds under the new legislation. More reforms followed until compulsory health insurance was introduced in 1955. Moreover, the Swedish welfare system developed gradually during the first half of the 1900s, reforms that had a great impact on society.

In order to follow morbidity in relation to the development of the sickness insurance scheme and the general welfare system, the study's period of investigation has been set to approximately 1890-1960. The study is comprised of three parts: a statistical analysis of the changes in sickness benefit claims on a national level, a qualitative assessment of the perception of morbidity in relation to the emergence of sickness insurance and a case study of morbidity using two sickness funds. The latter part contains sensitive personal data from individuals who may still be alive. The study has therefore undergone an ethical review to ensure good handling of the data.

In summary, all three parts of this study are required in order to gain knowledge about morbidity and to provide new perspectives on the epidemiological transition. In the following description of the three sub-studies, references are made to the results of my pilot studies; however, considering the complexity of the source material, they are largely preliminary.

National statistics on sickness funds

In order to provide an overview of the changes in morbidity, published statistics on sickness funds will be used. Due to the fact that the Swedish system was partially state-funded since 1892, sickness funds were required to submit certain statistics annually. Thus, certain types of data are available from all registered funds. This fact demonstrates one of the main advantages in using the Swedish source material. These statistics provide an overall picture of the use of the insurance in relation to changes in membership, the gender of membership, age distribution among mem-

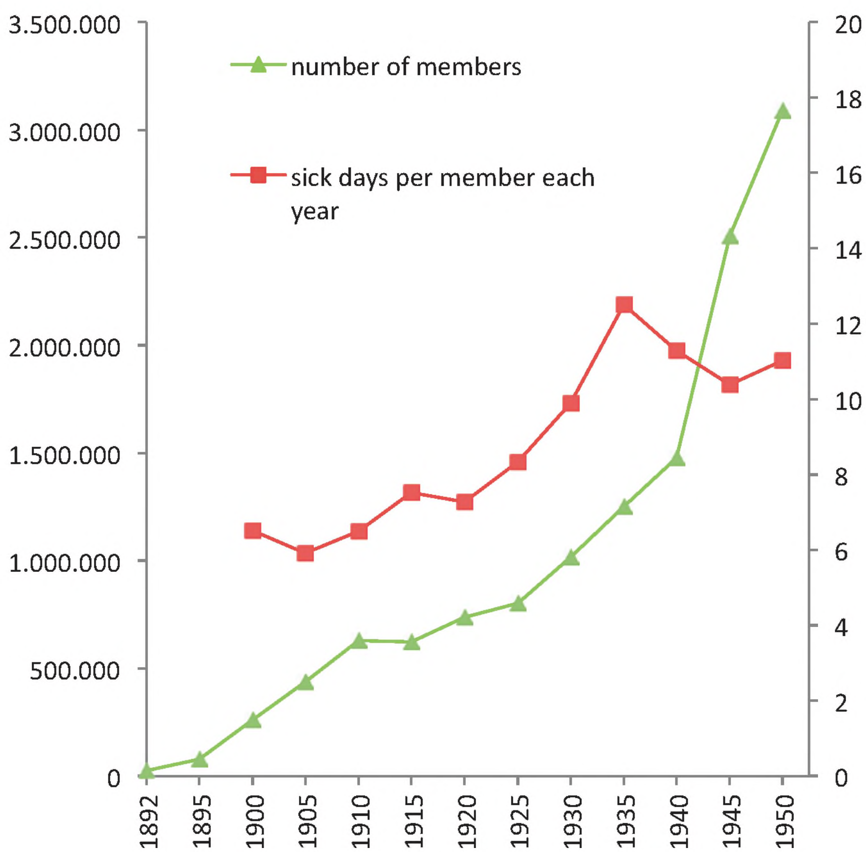

Figure 1 The number of members and the number of sick days per member every fifth year in Swedish sickness funds, 1900-1950

Source: Published national statistics: Kommerskollegium. Afdelningen för arbetsstatistik, *Arbetsstatistik. B, Registrerade sjukkassors verksamhet*, Stockholm (1905-1912); K. Socialstyrelsen, *Sveriges officiella statistik: Registrerade sjukkassor*, Stockholm (1915-1936); Riksförsäkringsanstalten, *Sveriges officiella statistik: Erkända sjukkassor*, Stockholm (1940-1957).

bers, the number of sick days and the cost of sickness, particularly at the national but also at the county level. The processing of these data is intended to provide a solid foundation of knowledge about changes in claims from sickness funds.

In Figure 1, statistics from every fifth year for the period 1900 to 1950 are shown. It shows a general increase in the number of sick days claimed per member during the period 1905-1950, with a »hump« around 1935 with an extra high number of sick days. By examining national statistics, therefore, an increase in sickness withdrawals can be identified. The chart raises several questions. Does this increase persist if the statistics are made age-specific? What were the differences between women's and men's sickness claims? What changes in the welfare system may have influenced changes in morbidity? A deeper statistical analysis within a larger context is therefore needed in order to make an adequate interpretation. It is clear, however, that along with the rise in the number of members, the general increase in sick days per member successively raised the costs for this partly government-funded system. These increased costs brought about a debate concerning both the benefits of this insurance and the concept of disease.

Changes in the perception of sickness

Normative perceptions of illness will be studied by means of examining the debate brought about by the expansion of the sickness funds. Some of the issues discussed were: "is old age a disease", "are all types of illness eligible for compensation" and also how sickness funds should deal with the incapacity to work caused by a member's alcohol consumption (Svensk Sjukkassetidning, June 1910). Before the new legislation that was passed in 1931, several doctors expressed their concern at the proposed changes. With the expansion of the insurance system, cheaters were assumed to have increased, while physicians expressed a fear of being forced to act as policemen for sickness funds. Moreover, the problem of providing accurate diagnoses was raised, which included the question of how to assess a patient's ability to work (Socialmedicinsk tidskrift, 1930 and 1931; Svenska läkartidningen, 1931). These examples make it clear that there was a lively debate concerning the cost of the health insurance system, disease assessments and problems related to how the system had expanded.

With regards to source material, journals such as *Svensk Sjukkassetidning*, *Socialmedicinsk tidskrift*, and *Svenska läkartidningen* will be used, as well as *Riksdagstryck*, *Committee Reports* for the legislative changes regarding sickness insurance conducted in 1892, 1910, 1931, 1955 and *Government Official Reports*. The debate on the assessment of illness will provide a deeper understanding of the context in which compensation was granted and diagnoses stated. The following section describes the part of the study in which member's sickness claims and disease diagnoses will be studied in more detail.

Individial sickness experiences

The analysis of how sickness claims and diagnoses changed during the investigation period in relation to factors such as gender, age and occupation will be based on studies of two sickness funds from Gothenburg. They are *Sömmerskornas Sjuk- och begravningskassa* and *Sjuk- och begravningskassan Redbar*. These two sickness funds provide good opportunities to study the disease experience for both men and women from the 1890s until 1955. The former was founded in 1898 and had only female members working in the needlework or textile industry. The second was established in 1891 and most of the members were men from various occupations such as carpenters, bricklayers, factory workers, blacksmiths and tailors. Both of these sickness funds had about 200 members around 1900 and many remained loyal members for 30 years or more. Therefore, their membership numbers can be considered normal for that time. In addition, they both had a stable flow of members which forms a good basis for the study. In both cases, registers over paid sick days are well-structured allowing the monitoring of illness experiences for each member. It contains information pertaining to name, address, occupation, date of birth and so forth. In addition, information about the illness benefits applied for by every member is provided. It states the date of application, number of sick days, the amount of compensation the member received and the illness or accident for which the member received compensation. Therefore, individual case histories can be created for each member. These records give us a unique opportunity to monitor illness experiences for thousands of men and women during their working lives.

The following two examples clarify the historical value of what these archives contain. The list of members and medical records for *Sjuk- och begravningskassan Redbar* contains, for example, a male member whose sickness benefits can be followed from 1889 to 1932. Over the years, he was paid compensation on eleven different occasions, both for occupational accidents and diseases such as diarrhoea, flu, pain in the knee and stomach problems. From *Sömmerskornas Sjuk- och begravningskassa*, an unmarried woman, whose benefits can be followed for the period 1898 to 1933, will serve as an example. She received compensation on ten separate occasions, several of these for longer periods of illness caused by eye problems combined with what was termed "neurological disease". The two examples provide a stereotypical image of the nerve-sick woman and the man with concrete diagnoses such as joint pain and stomach problems. It is possible that the examples describe differences in morbidity between men and women; however, it could also be an example of the difference in how men and women's morbidity was described, interpreted and named (for a discussion of the non-obvious and changing boundaries between physical and mental disorders, see for example Figlio, 1982). Although these questions are difficult to answer, this study enables the highlighting and discussion of gender differences.

In the context of this project, the illness experiences of members will be analysed based on age, occupation, gender, where they lived and with regard to changes over time. In this way, the study will seek to explain both the changes in the experience of disease, as well as the differences among diverse groups' encounters with illness.

Conclusion

The Swedish sickness funds annually reported certain data which gives unique national statistics on sickness claims from 1892. Unlike previous British studies which have measured morbidity solely by the claims made by male members, the Swedish material offers the opportunity to study both men and women. The fact that current statistics show that women's and men's morbidity differs in terms of extent and diagnoses highlights the need to complement and problematize previous research. A gender perspective is, therefore, essential. The age aspect is also important: Were the elderly sicker than the young? Therefore, by using a variety of sources and by looking at both male and female sickness experiences, this study will add to our knowledge on sickness during the mortality transition. By adding new knowledge on morbidity to existing facts about changes in mortality, the project will provide a better understanding of the differences and changes in public health. Furthermore, the project will introduce a broader time perspective to the current debate on morbidity and health issues. An historical illumination on how arrangements such as insurance systems affect our perception of sickness can provide a valuable perspective on similar issues in present day society.

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8

Height and health – in the Danish case

Jesper L. Boldsen

Abstract

This paper reviews (mostly) Danish data with bearing on stature differences within a population both in a synchronic and in a diachronic context. In studies of individual life history, it is shown from data on medieval skeletons that stress in childhood affect body proportions differently in women and men. In women, stature and body proportions were independent on indices of childhood stress where as in men, childhood stress distorted body proportions but did not affect adult stature. Relationship between (nearly) adult female stature and parental stature in late 20th century Great Britain indicates a maternal effect that could epigenetically played a role in shaping the pace of stature increase during the rapid secular trend through the last 150 years. In community level studies it is shown that contemporary Danish children at all ages are taller than medieval Danes were, and that the poorest medieval community was subject to selective mortality for height possibly causing the surviving members of this community to be more than 5 cm taller than members of other communities from the same period. Further it is shown that Gross Domestic Production (GDP) did not explain any of the secular increase in Danish stature during the 20th century. However, GDP did affect the variance for stature, indicating that parts of the variation for income did play a part in formation of adult stature in subgroups of society.

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Introduction

Ever since Quetelet (1835) published his extensive observations on the variation of human height there has been an intense interest in data on and correlates of (male) stature. The principal finding of this early study has been reiterated extensively in recent studies (Eveleth and Tanner, 1976; Steckel, 1995; Bogin, 2001; Steckel and Rose, 2002; Varela-Silva, 2012; and Boix and Rosebluth, 2014). Many of these studies demonstrate beyond doubt that stature both during growth and as adults shows high correlation with in order social, economic and nutritional indicators. In spite of the fact that only few studies (e.g. Bogin 2001 and Varela-Silva, 2012) actually has demonstrated the effect of specific environmental factors on human growth both on the individual and group level, it is nearly universally assumed that mean stature and to a certain extend variance for stature can be used as indicators of socio-economic conditions and well-being.

Danish researchers were relatively quick to pick up on Quetelet's (1835) early study (Thune, 1848; Trier, 1855; Det Statistiske Bureau, 1859, Gad, 1890; and Hansen, 1893). In the more recent past, Boldsen and colleagues have reanalyzed some of these 19th century data (Boldsen, 1995, Boldsen and Kronborg, 1984, Boldsen and Søgaard, 1998). These studies have been extended to include both older data (Boldsen, 1990a, 1997, 1998) and more modern data (Hasle and Boldsen, 1990, Boldsen and Søgaard, 1998).

Konigsberg et al. (1998) have pointed out some of the difficulties in comparing height estimated from skeletal remains. In order to overcome the problem, regression formulae for stature estimation must be population specific. Based on a combination of archaeological and anatomic work, Boldsen (1984) developed a method for measuring living stature on the skeleton during the excavation before it was removed from the ground. These data were used to develop a regression formula, which he hoped could be used for medieval Danes. However, later research has shown that samples from sites in use during the same centuries and situated less than 50 km apart gave statistically different regression formulae (Boldsen, 1990b). This finding must lead to the conclusion that in comparison between ancient skeletal heights with modern measured heights, the only unbiased ancient data come from stature measured in the grave before removing the skeleton.

Following Fisher (1918) the general understanding is that the variation of stature is primarily/nearly exclusively determined by genetic factors. Although this might be the case in a specific population in a specific time horizon, it cannot be the case over time when, as in many countries, mean stature has increased more two standard deviations in less than two centuries. Accepting that such changes can only be brought about by environmental factors, this paper takes a critical look at the assumptions about a causal relationship between stature and specific environmental factors like income, nutrition and disease based on diverse sets of data primarily from Denmark.

Individual level studies

In a paper primarily aimed at developing a regression formula for estimating stature from femoral length for the medieval Tirup population, Boldsen (1990b) analyzed the distribution of the regression residual and found that it was not normally distributed. In fact it was found that the residual for males had a bimodal distribution. The same and more data from Tirup were subsequently analyzed (Boldsen, 1998) to show that the bimodality of the residual distribution in males was associated with linear dental enamel hypoplasia (LEH). LEH is generated when in childhood calcification of the enamel is disturbed due to the disease, hunger or perhaps even psycho-social stress (Gamble, 2014). In such episodes of ill health the bioavailability of calcium and/or phosphorus is decreased, but tooth growth continues as it is genetically determined. Thus, LEH is often taken as a non-specific indicator of childhood stress.

Figure 1 illustrates the simultaneous distribution of femoral length and stature measured in the grave for females from Tirup. As expected, there is clear association between femoral length and stature for these women. It is also clear that neither femoral length nor stature is associated with LEH. The relevant statistics are summarized in Table 1.

Figure 2 illustrates the simultaneous distribution of femoral length and stature measured in the grave for males from Tirup. Again as expected, there is clear association between femoral length and stature for these men; the association is even stronger than it is for women. But here LEH is much more common in men who were tall relative to their leg length. The relevant statistics are summarized in Table 1.

There are three important messages to infer from the analysis of the Tirup stature, femoral length and LEH data. The first one is that disease or other kinds of important biological stress in childhood has no effect on adult stature in either sex. The second is that the events leading to LEH affect females and males differently. And the third is that boys when recovering from their stress episode undergo disproportional catch-up-growth viz. they catch relatively more up in their upper body than in their legs.

There are also individual level modern data of relevance for the understanding the dynamics of human growth; but these data are not Danish. They come from the British National Child Development Study (NCDS), which is a very large and rich set of data that has been and continuing can be analyzed in many ways. Figure 3 illustrates the effect of differences in parental height on the stature of their daughters at age 16. It is obvious that women who are very tall relative to their husbands become mothers to taller

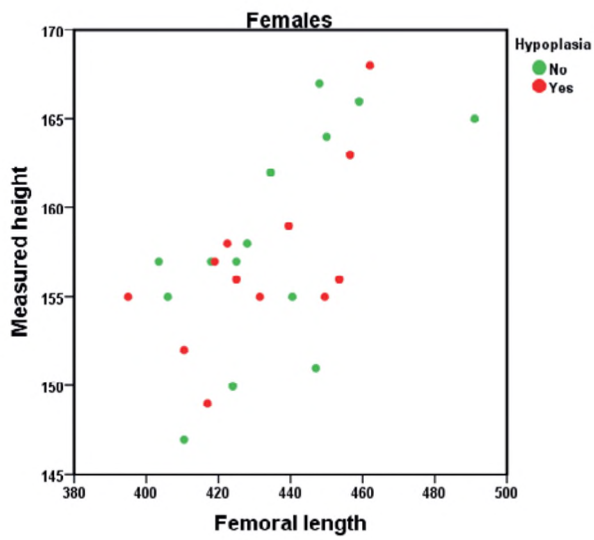

Figure 1: Simultaneous distribution of femoral length and stature measured in the grave for females from Tirup. Green circles women with no LEH on the upper canines, red circles women with LEH on the upper canines (data: Boldsen, 1998).

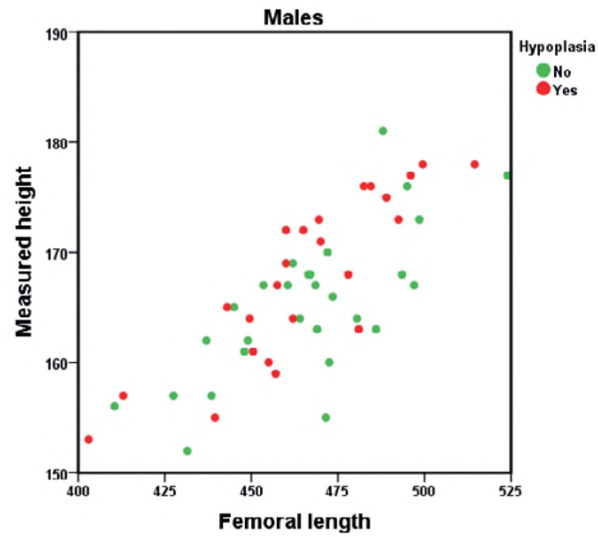

Figure 2: Simultaneous distribution of femoral length and stature measured in the grave for males from Tirup. Green circles men with no LEH on the upper canines, red circles men with LEH on the upper canines (data: Boldsen, 1998).

Table 1: Coefficients and tests for the regression of stature on femoral length (cm stature per mm femoral length) and LEH (cm for positive for LEH)

	Females		Males	
Number of cases	26		52	
	estimate	t-test	estimate	t-test
Femoral length	0.161	3.96**	0.222	9.13***
LEH	-0.553	-0.32NS	2.699	2.21*

daughters than women who are very short relative to their husbands. In the middle of Figure 3 it appears that fathers' relative height is more related to the daughters' height. This is expected as fathers share slightly more genes with their daughters than mothers do. This means that the maternal effect on 16years old girls' stature is an epigenetic effect that could be part of the explanation, why mean stature in Denmark has not increased at a constant rate over the form the onset of the rapid increase around 1900 to the end of it around 1980 (see figure 4).

Group level studies

Due to prehistoric data on height are cross sectional in their nature, it is impossible to follow longitudinal growth in the past. Therefore, the growth curves in Figure 5 are based on cross sectional data. The medieval growth curves were based on measurements of length in the grave to avoid the bias introduced from reconstruction of stature from long bone measurements. They show that modern Danes are taller at all ages (except at birth) than medieval children and adolescents. This is not all that surprising as mean adult

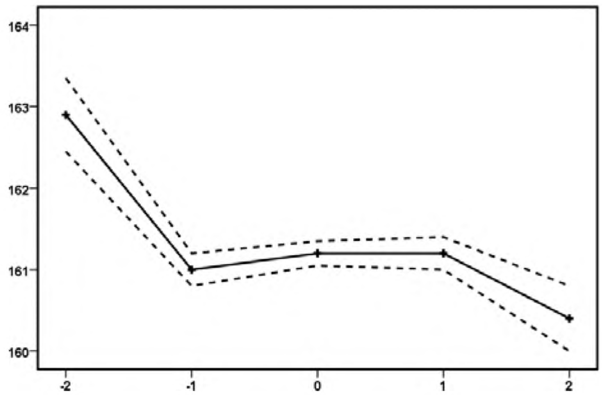

Figure 3: the effect of the normalized parental height difference on the mean stature of 16years old girls from the National Child Development Study. Relatively tall mothers are to the left (with negative parental hight difference scores) and relatively short mothers are to the right, with positive scores. The dotted lines indicate the 95% confidence limits for the estimates. (Data: Boldsen and Mascie-Taylor, 1990).

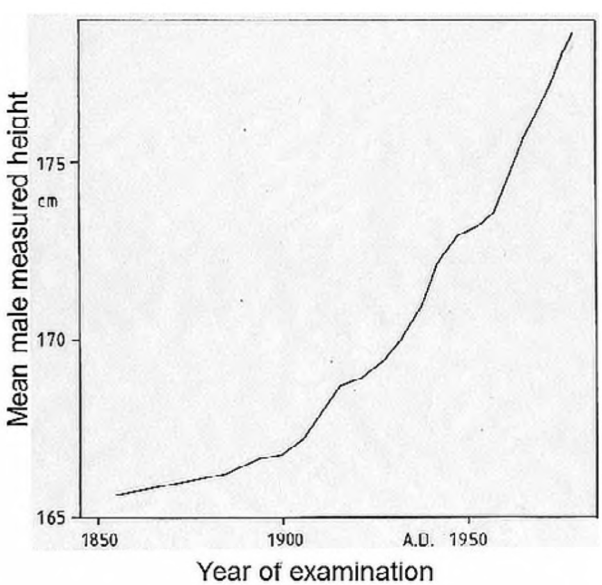

Figure 4: Five year average of male stature by year of examination prior to conscription. There are episodes of relatively slow increase of mean stature in the 1890s, 1920s, and 1950s. These episodes all come just after an episode of relatively rapid increase in mean stature. It is noteworthy that these oscilations has a wavelength more or less corresponding to the time between successive generations.

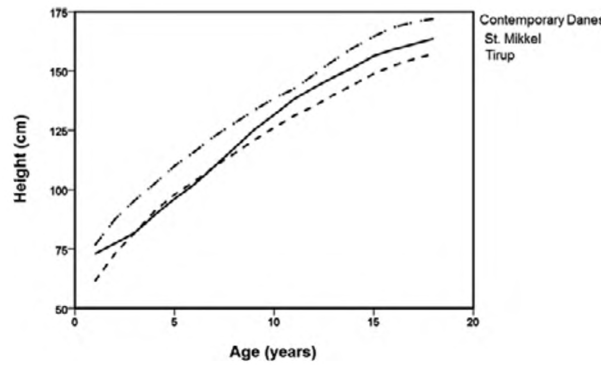

Figure 5: Stature by age for children and adolescents from contemporary Denmark, the lower class St. Mikkel community in medieval Viborg and the Eastern Jutland village community Tirup (Data: Boldsen and Søgaard, 1998).

stature in the medieval period was 7-15 cm less than it is today (Boldsen and Søgaard, 1998). However, it is surprising that it appears that babies in the socially challenged St. Mikkel community (Petersen, et al., 2004) were born more or less the same size as are modern Danes, whereas the socially less challenged rural peasant babies were born significantly smaller and remained short throughout life compared to modern Danes. The growth curve that really stands out is the one for the poor people of St. Mikkel. It is strange their infants are born bigger than infants from the better off Tirup community. It is clear that there must have been selective mortality for size in the St. Mikkel community particularly in ages 2 - 6 years when catch-up-growth seems to have set surviving children back on a growth trajectory more or less parallel to the two others and halfway between them. Following the argument Wood et al. (1992) the greater adult stature in the St. Mikkel community compared to the Tirup community could be an effect of more children between ages 2 and 6 died prematurely compared to their peers; but given the large size of the St. Mikkel infanta it is possible that this population was simply larger from some unknown, perhaps genetic reason.

Modern stature data are much more abundant that ancient data; but in some aspects they are not as

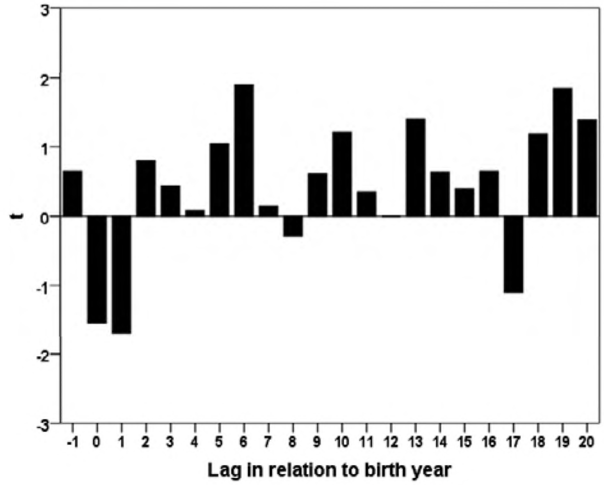

Figure 6: Tests for short term associations between mean stature in birth cohorts and GDP at different lags. The test value (t) follows a t-distribution and none of the tests reach the level of significance (over 2 or under -2).

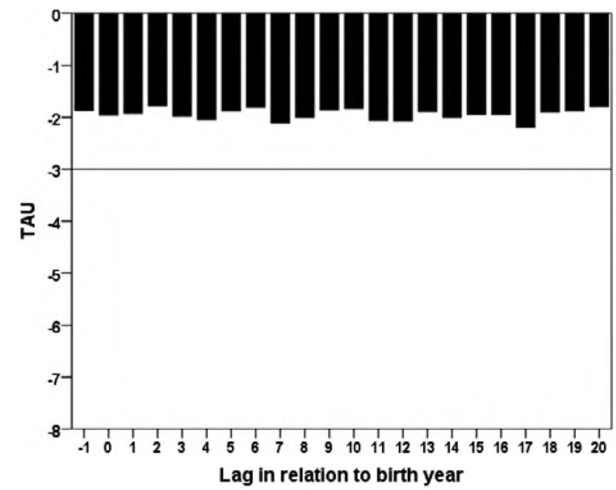

Figure 7: Tests for long term associations between mean stature in birth cohorts and GDP at different lags. The test value (TAU) has a critical value at -3 (See Boldsen and Søgaard, 1998 for details). None of the tests are statistically significant.

rich as the older individual skeletal observations. However, what the modern collective data lack in individual richness they compensate by abundancy and precision of dating. Boldsen and Søgaard (1998) utilized the large sample size and reliable temporal data to carry out a study of co-integration of economic (gross domestic product deflated to 1980 prices per capita – GDP) and stature time series. The stature data, from measurements prior to conscription, used in these analyses were rearranged so they were ordered by year of birth rather than by year of examination. During the period (1915 – 1964) covered by these analyses age at the examination decreased from 20 to 18 years reflecting the secular trend towards earlier maturation during the 20th century. In the middle of the 19th century age of examination was actually as high as 22 years and even at that age, final adult stature was not been reached (Det Statistiske Bureau, 1859).

Even though the distribution of stature in large national samples is not perfectly normally distributed (see e.g. Boldsen and Kronborg, 1984) summary statistics (mean and variance) have been analyzed as if they came from normal distributions. The large number of observations (totally more than two million) compensates for the deviation from normality of the distributions.

'Time confounding' is one of the most important factors confusing the debate about the importance of specific environmental factors on parameters of stature distribution. Time confounding is a consequence of the fact that two time series undergo more or less linear development through a historical period necessarily must be highly correlated. One very funny example of such spurious, time confounded, correlations can be found on http://www.tylervigen.com/. Among several other weird associations it is reported that the correlation between Divorce rate in the state of Maine and per capita consumption of margarine in the United States is 0.993 in the period 2000 to 2009. However, if time series are causally related the association must also be significant if the time series are detrended by looking at the difference from year to year rather than at the raw data.

Figures 6 and 7 illustrate tests for possibly causal association between GDP and mean stature in birth cohorts in Denmark from 1915 to 1964. The result of these tests is very clear. No causal association between GDP and mean stature is indicated for this period

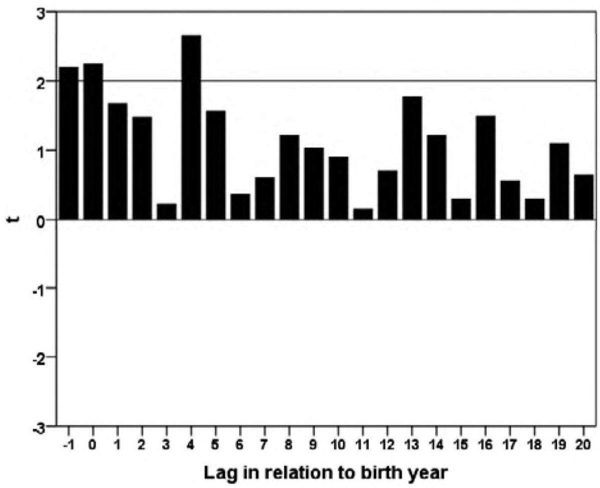

Figure 8: Tests for short term associations between variance stature in birth cohorts and GDP at different lags. The test value (t) follows a t-distribution and the tests reach the level of significance (2 or -2) of the year before birth (the year of pregnancy, the year of birth and the year of age 4).

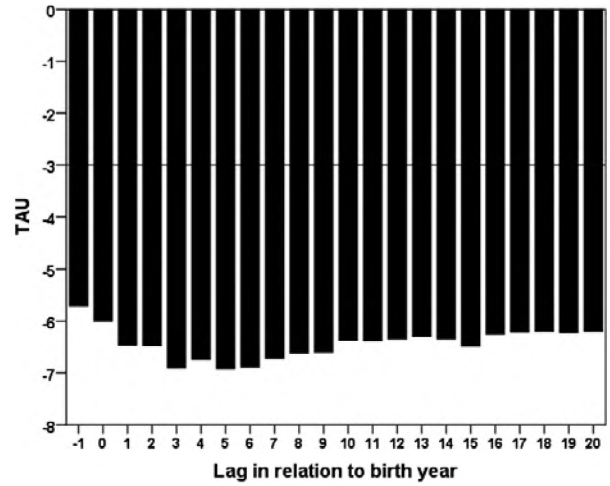

Figure 9: Tests for long term associations between variance for stature in birth cohorts and GDP at different lags. The test value (TAU) has a critical value at -3 (See Boldsen and Søgaard, 1998 for details). All of the tests are statistically significant. This means that economic growth in the long run does affect the variance for stature.

that saw the most rapid increase of mean stature in Danish history (cf. Figure 4).

Likewise, Figures 8 and 9 illustrate tests for possibly causal association between GDP and variance for stature in birth cohorts in Denmark from 1915 to 1964. These figures clearly demonstrates the fact that whereas mean stature is unaffected by changing developments in GDP the variance for stature is clearly dependent on it. In periods with growth in GDP the variance for stature also increases. If, as usually has been the case, that social inequality has grown in periods with rapid economic development, then this can be seen as a direct effect of social inequality on stature.

Conclusions

Several conclusions can be formulated based on the analyses and data presented above:

1. We can be certain that it is environmental changes that brought about the two standard deviations increase in mean male stature in Denmark during the last 5 - 6 generations; but we cannot know which environmental factors have been important for this change and which have not. General income increase definitely does not explain it.
2. Most of the associations between indicators of well-being and stature that are so convincingly presented in the literature are due to confounding with time and/or general social status.
3. Stature is not nearly as genetically determined as is usually assumed. Fisher's (1918) result is partly due to the fact that the data were collected as the population was undergoing a secular increase of mean stature.
4. The environment acts differently on different segments of humanity (females and males), and it seems that it only is part of an environmental spectrum of variation that affects stature.

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9

Height as a measure of the nutritional status and health of a population

Stefan Öberg

Abstract

The average height has increased dramatically in many populations over the last two hundred years as a result of improved nutrition and living environments. It is difficult to disentangle the exact underlying causes of the increase since the number of factors that are known to influence growth and height is so large and the analyzable variation is low. We can still learn much about living conditions, nutrition and disease exposure in the past by studying the historical developments of heights, especially if we use individual level data. This is important also for understanding the long-term increase in longevity. The trends in height and in longevity most likely share some underlying causes but they were also affected by unique, unshared factors. Mortality and height are not interchangeable measures of human health or living conditions. We should therefore not be expecting to always find the same results when we analyze the two different outcomes.

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Macro level associations and micro level influences

The average height of people in Western Europe today is at least 12 centimetres – almost two standard deviations[1] – taller than it was two hundred years ago (Garcia and Quintana-Domeque 2007; Hatton and Bray 2010).[2] The populations in present-day high income countries were shorter in the eighteenth and nineteenth centuries than almost any population even in low-income countries during the twentieth century (Floud, Wachter and Gregory 2006[1990], fig. 1.1). Variations in height among individuals are largely determined by influences that are not environmental, including genetics, but systematic differences among social groups, populations and differences over time are the results of environmental influences (e.g. Mueller 1976; Silventoinen et al. 2000; Silventoinen 2003; WHO Multicentre Growth Reference Study Group and de Onis 2006). The increases in average height

1. The standard deviation of adult height in a population is almost always between 6 and 7 centimeters. The Clio Infra project (2015) has published a collection of 706 decadal observations of average adult male height and "height gini" from 125 countries from between 1810 and 1989. The standard deviation can be derived from this information through the following transformation; standard deviation = ((height gini + 33.5) / 20.5) * height / 100. The average (and median) standard deviation in this sample is 6.3 cm. The distribution of standard deviations has in itself a standard deviation of 0.59.

2. The discussion of the secular trend in height and influences on growth and achieved height presented below is further developed and is more thoroughly referenced in Öberg (2014a, Introduction).

over time have also been too fast to have been caused by genetic factors, and must therefore reflect environmental influences on growth. A large number of factors are known to influence growth and achieved height, including nutrition, disease, toxins and pollutants, and stress (see Öberg 2014a, pp. 20-34 and references there for further discussion).

Information on the average height of populations and groups therefore provides some insight into their standards of living and health status. Investigating trends in height enables us to gain some knowledge about changes in living conditions and health for historical populations when this kind of information is scarce. Knowledge of historical heights also makes it possible to compare their development with the development of mortality rates and to discuss how improvements in living conditions have contributed to the mortality decline (e.g. Floud et al. 2011). From the differences in height among groups and over time we learn about living conditions linked to growth and achieved height. To use this knowledge to inform our discussions on the influence of living conditions on changes of longevity, we need to assume that the same factors influence both height and longevity. It will be argued here that even if some of the influencing factors are common to both growth and height, and health and longevity, there are also factors that influence them in different ways or that influence one but not the other. We can still learn a lot from studying these trends separately and jointly, but we should not consider them to be interchangeable measures of the living conditions or health status of a population.

To know how we should interpret the secular trend in height we need to try to establish the causes behind the increase in height and their relative importance. We have no reason to expect the secular trends to be results of any single cause, but the relative importance of different causes still has implications for how we should interpret the trend and its relation to other contemporary fundamental changes, such as the mortality decline. It is difficult to analyse the underlying causes of a linearly trending variable, such as the average height in Sweden and other high-income countries during the last 100–200 years, since the number of factors that are known to influence growth and height is so large and the analyzable variation is low. Societies experiencing increasing average heights were changing dramatically in many ways during the same period, with industrialization, increasing productivity, rising real wages, changing consumption patterns and diets, and falling mortality rates (see e.g. Easterlin and Angelescu 2012). The average height among conscripted men in Sweden from the early nineteenth until the late twentieth century is extremely closely correlated with a large number of indicators of the social and economic development of the country (Pearson's correlation coefficient for height with: urbanization rate, r = +0.993; GDP per capita (log), r = +0.963; fertility rate, r = -0.945; infant mortality rate, r = -0.983). The extremely close associations in the macro-level data prevent most meaningful statistical analyses of the aggregated trends.

Some of the associations, even the very plausible ones like the association between the average height and GDP per capita or the infant mortality rate, do not hold up in all contexts. There is a close log-linear association over time between average income and average height in European countries as well as across countries (see Öberg 2014a, pp. 24-26 and references there for further discussion). But there is no similar close cross-sectional association in samples of low- and middle-income countries, and the effect of the average income level on the prevalence of undernutrition in these countries is not very strong (Deaton 2007). Countries that have made rapid progress have made interventions specifically targeting the nutritional status of the population (Bhutta et al. 2013, p. 471). Hatton (2014) also questions the seemingly close association between average income and height historically in Europe, and argues that the average height is better predicted by the infant mortality rate than the income level. But the association between the infant mortality rate and adult average height is again less strong in populations in present-day low- and middle-income countries (Deaton 2007; Akachi and Canning 2010).

Several of the suggestions in the previous literature on associations between height and environmental influences, and the causes of the secular trend in height, can only be tested using individual-level data covering a long period. For my dissertation I linked information from lists from universal conscript inspections to a sample of men in the Scanian Economic Demographic Database born between 1797 and 1950, who were inspected in 1818–1968 (Öberg 2014a). In this way I could combine the data on the heights with detailed information on the family background and community context of these men.

The secular trend in height in Sweden

Figure 1 summarizes what is known about the development of the average height of men in Sweden born in the nineteenth and twentieth centuries from conscript data (see also Hultkrantz 1927; Sandberg and Steckel 1997). The secular increase in average height in Sweden started among men born in the second quarter of the nineteenth century. Universal conscription had already begun for men born in 1791, but the published national statistics unfortunately only start with the men born in 1819. We therefore do not know if the lack of a clear trend seen for the Scanian data for men born in the period 1797–1818 is representative of the country in general.

Sandberg and Steckel (1980) took part in pioneering historical research on heights by collecting information on recruited soldiers in Sweden born in the eighteenth and nineteenth centuries. They did not find any clear trend in the average height during the eighteenth century (Heintel, Sandberg, and Steckel 1998). What is known about the even earlier trend is mostly based on estimating heights from skeletal remains. Even though the heights estimated from skeletal remains are uncertain and cannot easily be compared with measured heights, it seems that there was no clear trend in the average height in the nine centuries before 1700 either (Gustafsson et al. 2007). The secular increase in height in Sweden therefore seems to have started among men born in the second quarter of the nineteenth century, about the same time as real wages started to increase in southern Sweden (Bengtsson and Dribe 2005).

The large difference in average height among men born around 1850 in the SEDD parishes compared with the national trend is most likely a consequence of the differences in who is included in the data. The Scanian data include the height of men who were shorter than the minimum height requirement, while the national series is then based only on men accepted for conscription. The subsequent linear trends are very similar for the Scanian parishes and for Sweden. The median height of the Scanian population shifts abruptly a couple of times, especially in the early nineteenth century. This is due to lack of precision in the measurement – heights were measured in inches, not centimetres – and random variation in combination with small sample sizes. The underlying trend in the population height was as gradual as the national trend. This is clearer when we use more fine-grained but less robust techniques to estimate the trend (Öberg 2014b, fig. 1).

Some of the increase in average height was the result of earlier physical maturation of the inspected men. When growth is slowed during infancy and childhood, people can also continue to grow for a longer time and reach their final adult height later (see Öberg 2014a, pp. 31-34 and references there). Today most men reach their final adult height in their late teens. In the early nineteenth century people continued to grow into their twenties. Improved conditions for growth result in both taller average stature and faster physical maturation. Parts of the increase in the average height during the nineteenth century are therefore a result of earlier maturation with an increasing share of the inspected men having reached their adult height at inspection. The estimated height presented in Figure 1 is therefore not an estimate of the average *adult* height in the population. The average adult height of the men is likely to have been one or a few centimetres taller than the average at the conscript inspections during most of the nineteenth and early twentieth centuries. The increase still reflects an improvement among the factors influencing heights but might not reflect changes in the final adult height in the population.

The secular trend in height slowed down in Sweden among men born in the 1950s. There was no

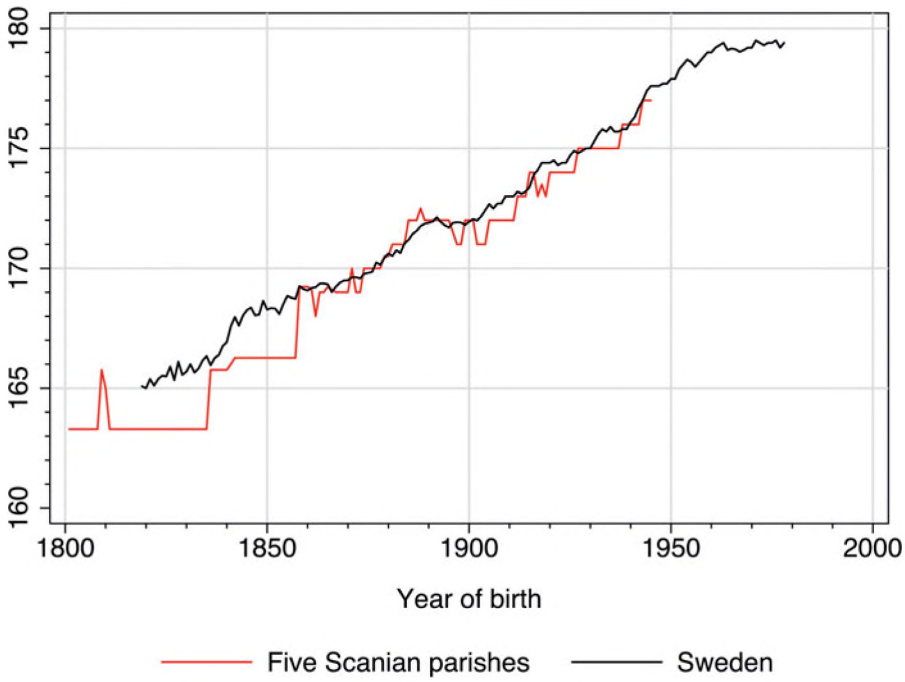


Fig. 1 The secular trend in height in Sweden among young adult men born between 1797 and 1978.

Note: The figure shows the median height among all inspected men in the five parishes in the Scanian Economic Demographic Database (Bengtsson, Dribe, and Svensson 2012; Öberg 2014a). The median was calculated for 145 samples, each including men born within a moving ten-year period. The national height series includes, as far as possible from the published data, only men born in one year. The series for Sweden are: for men born in 1819–1906 the median height of men accepted for conscription, and for men born in 1907–1978 the average of all inspected men. For sources on the national series see Öberg (2014b, fig. 1).

change in the median height among young adult men born in 1953-1978 even if the average increased slightly (Värnpliktsverket/Pliktverket 2013). The slowing-down or cessation of the secular trend in the mid- and late twentieth century has also been observed in Norway, Denmark, the Netherlands and Italy, while heights otherwise continue to increase in today's still shorter populations in eastern and southern Europe (Larnkjær et al. 2006). It is still not yet clear whether this is a result of a maximum achievable average size of humans, even if this seems likely.

Heights as a measure of nutritional status

Heights are interesting for social scientists because, to some degree, they reflect nutritional status. *Nutritional status* must be "clearly distinguished from nutrition, which is the amount and nature of energy ingested in the form of food and drink" (Floud et al. 2011, pp. 11, see also 41-42). Nutritional status is a result not only of the intake of energy and nutrients but also of the expenditure of these. The body needs energy and nutrients to function, maintain and repair itself. Quite naturally it also needs energy and nutrients to be able to grow. It is intuitive that the body needs energy for growth and physical work, but most energy is actually used in less obvious ways, such as for keeping organs working, keeping the body warm, digesting foods and for the brain. If the balance between inputs and requirements is not sufficiently positive the growth slows down and if the negative influences, such as undernutrition or disease, are repeated, severe or prolonged, they will result in a shorter adult stature.

Nutrition affects growth and achieved height both through the amount of food consumed and through the composition of the diet (see also Öberg 2014a, pp.

27-28 and references there). Intakes of energy and macronutrients (i.e. protein, carbohydrates and fats) need to be adequate for the body to function well and grow. But the quality of the food consumed seems to have at least as strong an influence on growth as the quantity. Some specific micronutrients are also important, such that deficiencies can result in shorter height (see also Bhutta et al. 2013). Heights may therefore have increased historically both because of an increased and more stable supply of food and because over time diets became more diverse, with a higher content of animal products, fruits and vegetables. Children growing up in families with a more variable diet are on average somewhat taller than others (see also Marriott et al. 2012). Monotonous, largely vegetarian, diets may be deficient in vitamins and minerals even when they provide sufficient energy. This situation may be aggravated, as the diet may influence the nutrients that are actually accessible for the human body. A diet consisting of coarse whole-grain cereals may limit the ability to absorb micronutrients such as zinc and iron (e.g. Schneider 2013). The monotonous, coarse and largely vegetarian diets consumed by the majority historically may therefore have contributed to their short stature even in situations where energy intake was sufficient.

The protein content of diets, especially from animal sources, is likely to be especially important for growth (Silventoinen 2003, 273-274; Hörnell et al. 2013). Cow's milk also seems to increase growth, even independently of being a nutritious food and source of protein (Hoppe, Mølgaard, and Michaelsen 2006). The seeming importance of intakes of animal proteins for growth can be a result of both the protein content and the accessible micronutrients in these foodstuffs.

That access to animal proteins, meat and milk, was also important for growth historically has been indicated in several studies. Baten (2009), for example, finds that access to milk explains much of the regional variation in height in nineteenth-century France, Prussia and Bavaria. Steckel and Prince (Steckel and Prince 2001; Prince and Steckel 2003) show that the indigenous population in North America, living on the prairies hunting buffaloes, were among the tallest people in the world in the nineteenth century. Komlos (2003) comments on their findings and shows that tall stature was a common feature of populations with good access to foodstuffs, including meat and milk. These populations have historically also lived in less densely populated areas. This makes it harder to conclude that their taller stature was a result of better access to nutrients and not of the more favourable disease environment they lived in. Even if it is not possible to exclude an influence from disease, several results indicate that the taller stature of people in less densely populated areas is a result of their better access to foodstuffs (Sunder 2004).

The influence of diseases on growth is not uniform either, but can vary depending on the disease, its severity and duration as well as the living conditions of and care provided for the person who is ill (see Öberg 2014a, pp. 28-30 and references there). Disease affects growth in several ways. It can prevent or reduce food intake because of loss of appetite. Some diseases, especially gastrointestinal ones, can lead to direct losses, or to impaired absorption or transportation of energy and nutrients in the body. The body's reaction to disease, for example as a result of fever and other immune system responses, also requires extra energy. Most historical studies can only provide "strong circumstantial evidence" of the influence of disease on growth (Hatton and Martin 2010, 513). That even people from resource-rich backgrounds were short by modern standards is an indication that diseases were an important influence on growth historically.

Studies of present-day populations in low-income countries have shown convincingly that disease in childhood slows growth in children (Checkley et al. 2008). They have also shown that any infections, even subclinical ones, worsen nutritional status and slow down growth. Checkley and co-authors (2008) estimated that about 25% of stunting among children in low- and middle-income countries can be attributed to having experienced five or more episodes of diarrhea before the age of 2 years. Well-designed studies of the effects of improving water quality, sanitation and hygiene also show positive effects on child growth even over short follow-up periods (Dangour et al. 2013 [1996]). The influence of disease on growth depends on the nutrition, general living conditions and care provided to the person who is ill (Tanner 1990, chap. 9; Golden 1994; Boersma and Wit 1997; Scrimshaw 2003; Silventoinen 2003, 273–274). The influence of disease on growth is therefore weaker in high-income populations, but can still be shown (Dowd, Zajacova, and Aiello 2009).

Disease and living conditions in general, and nutrition in particular, influence not only growth and achieved height, but also health and longevity. Most of the association between nutrition and mortality today is most likely to be found among children in lower-income countries and is generated by the synergistic effects of nutritional status and disease (Black et al. 2008). The sensitivity to and severity of infections is influenced by nutrition (Chandra 1997; 2002; Scrimshaw 2003; Schaible and Kaufmann 2007) even if different diseases are affected differently by the nutritional status of the host (Rice et al. 2000; Chandra 2002; Scrimshaw 2003; Caulfield et al. 2004). This is an important reason why general living conditions influence the effect of exposure to disease on growth. There is no doubt that disease influences nutritional status, but the influence of disease on growth and achieved height comes from frequent, severe and prolonged diseases, especially gastrointestinal ones, and especially in combination with suboptimal nutrition.

Social bodies: Family and community level influences on height

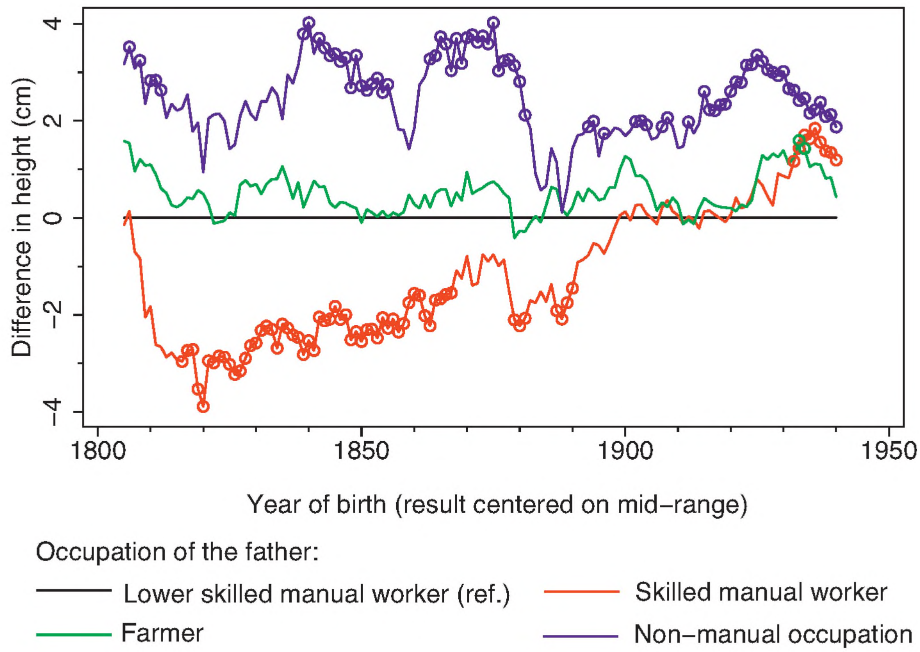
I investigated the influences on height that could be affected by access to resources, i.e. nutrition, housing standard, hygiene, workload etc., by analysing social differences in height in my study population and how these changed over time. There were always socioeconomic differences in height in the studied population (Öberg 2014b; see also Åkerman, Högberg, and Danielsson 1988). The magnitudes of the differences varied over time, but they also show a tendency to become smaller (Figures 2a and 2b). Economic and social changes along with improvements in living conditions over time were important for reducing the socioeconomic differences in height. Improvements in living conditions over time also reduced differences in height depending on the number of siblings (Öberg 2015b). Men with many siblings present during childhood were shorter than others during the nineteenth century and early twentieth century, but not in the mid-twentieth century.

These results show that material resources and factors that could be changed by access to resources were important for growth and achieved height. Still, most of the secular trend in height was shared by all groups in the society studied (Öberg 2014b, fig. 4). All social groups were positively affected as the economy gradually grew, markets and infrastructure improved and society in general developed.

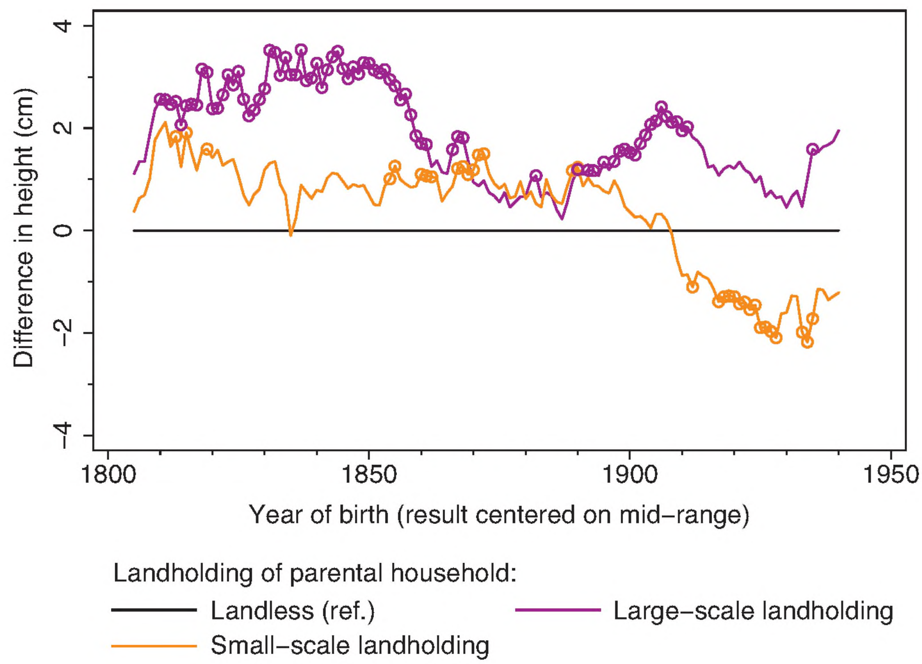
The secular increase in height has been gradual in all populations, with increases per decade of about 2 centimetres at most. The multitude of influences on growth and the long growth period will work to reduce the impact of any sudden changes. But it is also likely that the gradual increases in height reflect the fact that the improvements in living conditions over time have historically been gradual. Healthy growth also seems to require sufficiently good conditions across several different factors. It has been estimated that almost universal (90%) implementation of ten evidence-based interventions to improve nutrition in the worst-off countries would only reduce the prevalence of stunting among children by about 20% (and reduce child mortality by 15%) (Bhutta et al. 2013). That different conditions improve in parallel can also be seen in low- and middle-income countries today. The change between the year 2000 and 2010 in child mortality from diarrhea and pneumonia is very highly correlated across 74 countries (Walker et al. 2013, fig. 2) despite the fact that these diseases are caused by different pathogens and have different ways of transmission. That different influences work in interaction may also be a reason why average income is in many cases a good predictor of average height (e.g. Steckel 2008). Income can affect several different influences on growth, e.g. food availability and diet, but also disease exposure through housing and hygiene conditions.

Figure 2 Socioeconomic differences in height among young adult men in southern Sweden born between 1797 and 1950.

A. Differences in height related to the occupation of the father.



B. Differences in height related to the landholding of the parental household



Note: Estimates from a rolling regression, i.e. 135 separate regressions each including men born within a 20-year span. Circles on the lines indicate that this group was statistically significantly (90% CI) taller or shorter than the reference category. The results are centred on the year in the middle of the 20-year range used. Data from the Scanian Economic Demographic Database (Bengtsson, Dribe, and Svensson 2012; Öberg 2014a.

The influences on growth, height and weight in historical populations were most likely similar to those in present-day populations. The influences were multifaceted and complex, then as now. Different economic and social developments most likely improved the preconditions for healthy growth prenatally and during infancy, childhood and adolescence at different times and in different ways. The important influence from nutrition was not just a matter of the number of calories consumed; the quality of the food and the diet also played a role. The influence from disease came from common and frequent infections interacting with the nutrition. Other influences, for example housing conditions and behaviours, are also likely to have played a role in gradually allowing healthy growth and improving health.

The association between height and longevity

We can learn much about living conditions, nutrition and disease exposure in the past by studying the historical development of heights. But we need to acknowledge that growth is a complex and specific process and that adult height is the net outcome of a multitude of influences, including random genetic variation. The multitude of environmental influences on growth and achieved height, and the long period during which the body is sensitive to these influences, make achieved height a good summary measure of overall life experiences, but a poor proxy measure of separate influences. While the environmental influences on growth are consistent and theoretically and substantially important, the associations are all quite weak when measured empirically in individual-level data. The multitude of influential factors, the long growth period and genetic variation always work to reduce the associations between separate environmental exposures and achieved height. Height therefore cannot be used as a proxy measure of single or specific experiences, such as exposure to disease around birth (Öberg 2015a). For the same reasons it is a very poor measure of health status or human capital at the individual level.

Growth, height, health and longevity are all influenced by factors that come under the crude headings nutrition and disease (Figure 3). The factors and outcomes also interact and influence one another in different ways. Nutritional factors and exposure to disease contribute to the secular trends in both height and mortality. The two trends therefore most likely share some underlying causes. Still, I think that we also need to investigate the two trends separately. Nutrition is likely to have had a stronger influence on growth than on resistance to disease, which in turn affected mortality rates. Diseases have also had an important influence on growth and achieved height, but mortality has also been influenced by the exposure to and virulence of diseases that are likely to have left little mark on growth (e.g. Öberg 2015a).

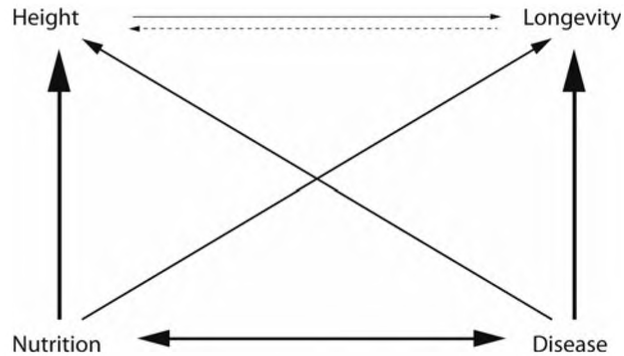


Figure 3 A simplified model of the associations between nutrition, disease, height and longevity.

Influences from nutrition and disease that are shared by height and longevity work as confounders to increase a positive association between the two. Height is indeed positively associated with longevity. The association is consistent and well established for both adults (Alter 2004; The Emerging Risk Factors Collaboration 2012) and children (Olofin et al. 2013). The association is theoretically very important and provides insights into influences on health and longevity (Floud et al. 2011). But the association is weak and height only explains a fraction of the variation in longevity at the individual level. The Emerging Risk Factors Collaboration (2012), for example, finds that an increase in height of one standard deviation is associated with a 3% reduction of all-cause mortality risk. Height also had a very low independent predictive power for individual mortality risk in The Emerging Risk Factors Collaboration data (personal correspondence with David Wormser, Senior Epidemiologist/Applied Statistician, Cardiovascular Epidemiology Unit, University of Cambridge, Oct. 29, 2013). Ganna and Ingelsson (2015) tested the (univariate) predictive ability of 655 measurements of demographic characteristics, health, and lifestyle for five-year all-cause and cause-specific mortality among the participants (aged 37-73 years) included in the UK Biobank. Height is not among the very few variables that have any useful predictive ability. Nor is it among the variables with the least predictive ability; it is typical of the majority of the tested variables in having very little predictive ability.

The association between height and longevity does not seem to be a result just of confounding (Özaltin 2012). That the association is weak therefore means that most of the influences from nutrition and disease on height and longevity not are shared, or that there are factors that affect height and longevity in opposite ways. There are some factors that seem to have clearly different or opposite influences on height and longevity. Acute epidemic infectious diseases have had a strong influence on mortality rates, but less effect on heights (Steckel and Prince 2001; Prince and Steckel 2003; Oxley 2006; Öberg 2015a). A larger exposure to disease early in life will result in shorter stature and worse overall health but can at the same time reduce the risk of dying from later exposure to pathogens. This is shown by the different death rates of soldiers in the US Civil War (Lee 2003; Smith 2003). Men born in the US, from rural areas, and especially farmers, were, for example, on average healthier and taller than foreign born men from urban areas (Haines et al. 2003). But the US born rural farmers had higher risk of dying from disease while serving in the Union Army. This increased risk of dying from disease was a result of an increased risk of acquiring diseases. The case fatality rates were independent of the previous exposure. Alter and Oris (2005) find similar results for rural-to-urban migrants in nineteenth century Belgium where the migrants with a rural background were especially vulnerable during epidemics.

Protein, especially cow's milk, increases growth (Silventoinen 2003, 273-274; Hoppe, Mølgaard, and Michaelsen 2006; Baten 2009; Hörnell et al. 2013), but animal proteins, and again especially cow's milk, do not seem to have any corresponding positive influence on health and may rather be harmful (Katz and Meller 2014; Michaelsson et al. 2014).

The model presented in Figure 3 is clearly highly simplified. But this model shows us that it is very difficult, perhaps impossible, to accurately estimate the effect on and relative importance of nutrition and disease for height and longevity using crude summaries like this. Historical research therefore also has to move beyond the averages and crude trends with regard to the development of both influences and outcomes. Increases in the quantity of food consumed have probably contributed to rising average heights and to the reduction of mortality rates, but the quality of the diet could have contributed just as much. Rising dietary diversity and refinement, and the share of animal products in the diet could for example have contributed to improvements in nutritional status both through more adequate provision of nutrients and by making them more easily accessible to the body. Reduced deficiencies of micronutrients could very well have contributed to both the secular trends in height and to declining mortality.

Because mortality and height are influenced by different factors they are not interchangeable measures of human health or living conditions. We should therefore not expect always to find the same results when we analyse the two different outcomes. The results in my dissertation from analysing height are, for example, quite different from what has been found by analysing mortality in the same population. Socioeconomic differences in adult mortality emerged only at the time when the socioeconomic differences in height declined substantially (Bengtsson and Dribe 2011; Öberg 2014b). Nor did socioeconomic differences in infant and child mortality change in parallel with the corresponding socioeconomic differences in height (Bengtsson and Dribe 2010; Öberg 2014b). Sibship size was negatively associated with height but the share of children in the household had no strong influence on the mortality risk of children in the mid-nineteenth century (Bengtsson 2009 [2004]; Öberg 2015b). Infant mortality in the year of birth had no direct influence on achieved height, but has been shown to influence mortality in later life as well as, for example, the fertility outcomes of women (Bengtsson and Lindström 2000; Bengtsson and Broström 2009; Quaranta 2013; Öberg 2015a).

Systematic variations in height show how the human body is literally shaped by its living conditions. We need to learn much more about this, and studying historical differences and trends in height can contribute to this. Acknowledging the complexities and specificities of how nutrition and disease affect growth and height, and health and longevity, will help us learn.

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The lowest possible infant mortality rates in prehistoric and medieval populations discussed in the light of nineteenth-century northern European experiences

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Abstract

New historical demographic studies show that the infant mortality rates (IMR) were not uniformly high in the eighteenth and nineteenth centuries. The variability was huge. In some places the level was as high as 80 deaths in the first year of life per 100 live births; while the minimum observed was merely 7. This chapter discusses how this best practice was achieved and if it could have been equaled in prehistoric times. It concludes that exclusive breastfeeding the first five to six months followed by several years of combined breastfeeding and other sustenance were the essential elements when achieving this minimum IMR. Some prehistoric populations may have done that even if ideas about how to breastfeed correctly most probably have differed as much in prehistoric times as in the nineteenth century.

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It is common knowledge that in the bad old days before the hygienic and medical revolutions of the early twentieth century, infant mortality was excessively high. Therefore, whenever archaeologists excavating prehistoric and medieval burial places find only a low proportion of infant skeletons, they have to wonder why. Of course, infant skeletons may be missing for many reasons including easier dissolution of small, fragile skeletons and the disposal of dead infants in different places. However, the expectations as to the correct number of infant skeletons are often based on the high national averages of infant mortality rates (IMR) during urbanization in the late nineteenth and early twentieth centuries and on the descriptions of infant mortality in former times used by medical doctors in the middle of the twentieth century, when they looked back on declining mortality as one of the great triumphs of modern medicine. Their narratives often implicated a uniformly high infant mortality becoming even higher the further back in history one delved.

However, new empiric studies, carried out by historical demographers and historians during the last twenty years have shown that this familiar narrative does not comprehend the history of levels, trends and variables in infant mortality in the eighteenth and nineteenth centuries. The image that emerges now is much more complicated and less linear. More and more examples of local populations with unexpectedly low levels of IMR come to light. Norway and Denmark are countries which both have high quality data and are rich in low infant mortality regions during the nineteenth century.

In this article I shall discuss whether the more detailed knowledge of the existence of low infant mortality regions in the nineteenth century side by side with regions with much higher levels of infant mortality have insights to offer researchers working with infant mortality in pre-statistical times. I shall focus on three questions:

- How low was the lowest level of infant mortality in nineteenth-century northern Europe on a regional level before circa 1880, when modern knowledge about pathogenic microorganisms began to be integrated into birth assistance and infant care practices?
- How was this best practice carried out?
- Could this best practice have been performed in prehistoric times and could the resulting IMR have been as low as in the nineteenth century?

Background: The infant mortality rate (IMR)

The infant mortality rate (IMR) is the statistical tool used by statisticians and historical demographers to measure the frequency of infant death in a given population. It is defined as the number of deaths in the first year of life among 100 (or 1000) infants born alive. It is a very powerful concept, as it allows direct comparison of infant deaths between different populations, as the population at risk is always the same: the infants born alive and thus running the risk of dying. The invention and use of this concept was one of the most important stimuli to the onset of public health interventions to reduce infant mortality.[1]

It is important to keep in mind that in pre-parish register populations we almost never have access to the number of live- born babies. Therefore it is not possible to make a direct calculation of the IMR. Where the sources are burial places alone, it is only possible to calculate the distribution of age among the deaths. That is a quite different concept, which does not offer the possibility of comparing the frequency of infant death between populations, as the percentage of infant skeletons among all skeletons will differ according to the number of adult skeletons, even when the IMR is the same. Thus a high percentage of infant skeletons may be due to the fact that some of the adult members of the population had been buried elsewhere, as is often the case with warriors or sailors.[2] The proportion of infant skeletons at a burial place will also change when the birth rate in the living population increases or decreases, even if the IMR are constant. Thus a low number of infants buried could be due to few births just as well as to a low infant mortality.

Nevertheless, the age distribution among skeletons is the best available information we have for pre-register populations and valuable knowledge can be gained from it. However, in order to proceed from age distribution among the buried to infant mortality rate, some serious modelling is necessary. This includes careful methodological considerations about the fertility, mortality and burial patterns for the whole population. Such models have been made and have been used to calculate IMR[3], but some of the most-used models were calculated twenty-five years or more ago[4] or have used twentieth-century national aggregated level data.[5] They have therefore not had the possibility of including the more recent historical demographical studies in the great variability in IMR in the nineteenth century.

The infant mortality rate was not uniformly high in the past

The one most important result of the many recent historical demographic studies about IMR in the past is that in the two centuries preceding the onset of the large early twentieth-century decline all over Europe, the variability in the IMR was huge. IMRs varied from place to place both locally within countries and

1. Løkke, "No Difference without a Cause. Infant Mortality Rates as a World View Generator".

2. Løkke, *Døden i barndommen*.

3. Boldsen, "Patterns of childhood mortality in medieval Scandinavia".

4. Gejvall, "Westerhus. Medieval population and church in the light of skeletal remains", 38f; Boldsen, "Two methods for reconstructing the empirical mortality profile".

5. Gage, "Variation and classification of human age patterns of mortality: analysis using competing hazards models".

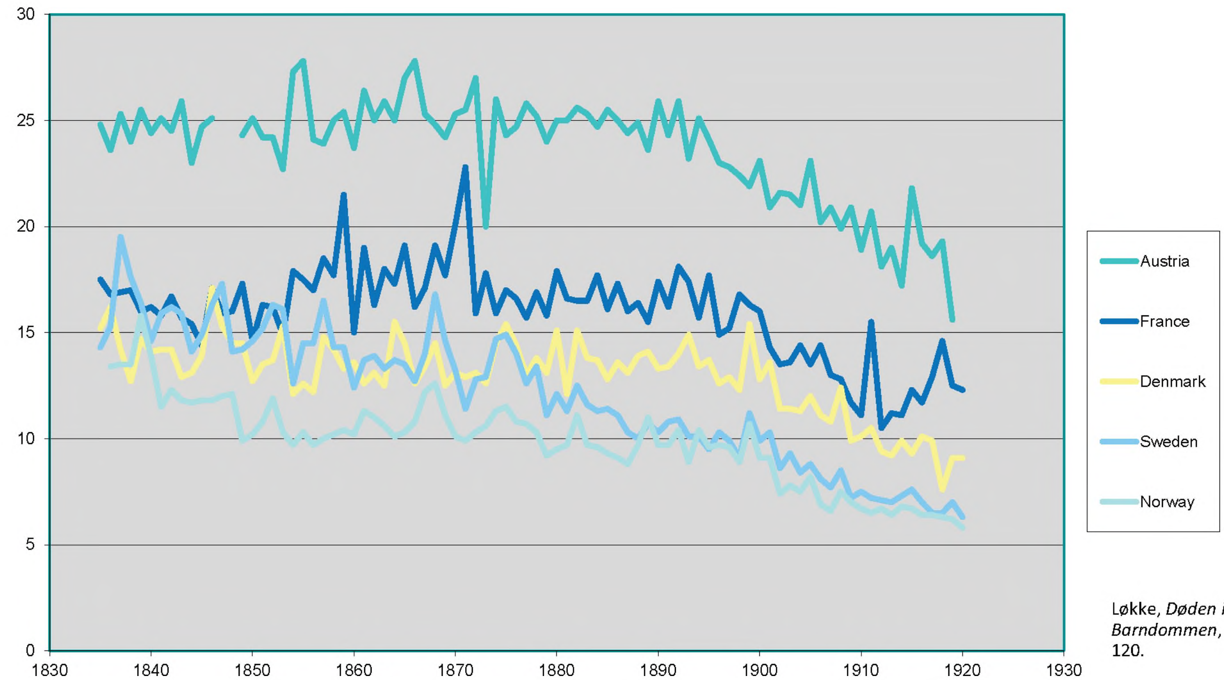

Figure 1. Deaths in the first year of life per 100 live births 1835-1920.

between countries. It varied between cities and countryside, between different cities and between different localities in the countryside. It differed between legitimate and illegitimate infants and between the social classes – most often in disfavour of the poor, but even that was not always the case.[6] Thus, when the twentieth-century decline sat in, it was not only a decline but just as importantly a transition from great variability to lesser variability.[7]

During the nineteenth century European regions existed where 50 percent or more of the live-born infants died before their first birthday and at the same time there were regions which kept the IMR down to 10 percent decade after decade.[8] Examples of places with very high IMRs are seen, in the eighteenth century, in northern Sweden[9] and in the marshlands in South-East England.[10] In the early nineteenth century Iceland[11] and Bavaria[12] had excessively high IMRs. Such high IMRs could also be found among illegitimate infants in Copenhagen in the 1860s and 1870s, where the IMR peaked at 55 percent, while infants born in wedlock in the same decades had a level at 20 percent.[13] Even higher levels, 70 to 80 percent were found on the island of Vestmannaeyjar in Iceland[14] and among illegitimate infants left at the Royal Foundling Ward in Copenhagen (*Den Kongelige Pleje-*

6. Edvinsson, Garðarsdóttir and Thorvaldsen, "Infant mortality": 463, Løkke, *Døden i barndommen*: 145, Wrigley, *English population history from family reconstruction 1580-1837*: 218-219.

7. Løkke, *Døden i barndommen*: 229-231.

8. Knodel and Van de Walle, "Breast Feeding", Løkke, *Døden i barndommen*: 157-179.

9. Brändström, *De kärlekslösa mödrarna*.

10. Dobson, *Contours of Death and Disease in early Modern England*: 340.

11. Garðarsdóttir, *Saving the child*.

12. Knodel and Van de Walle, "Breast Feeding".

13. Løkke, *Døden i barndommen*: 219-224.

14. Guttormsson and Garðarsdóttir, "Public Intervention to Diminish Infant Mortality from Neonatal Tetanus in the Island of Vestmannaeyjar (Iceland) during the First Half of the Nineteenth Century".

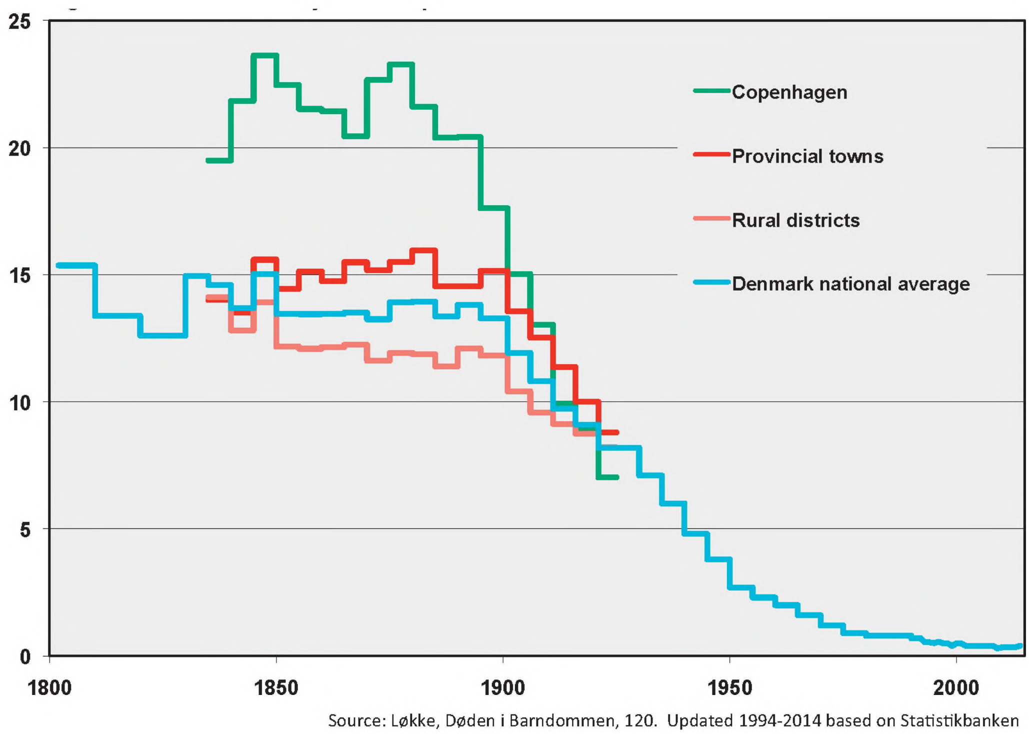

Figure 2. Death in the first year of life per 100 live births in Denmark 1802-2014. Copenhagen, Provincial towns, Rural districts, The whole of Denmark.

stiftelse)[15], as well as at the Madrid Foundling Hospital (*La inclusa*).[16]

The lowest known relatively stable regional levels of IMR are found in some rural areas in Norway and Denmark throughout the nineteenth century. These levels are reliable, as both Norway and Denmark had established and well-kept registration practices. The lowest level of IMR in Denmark for decades in regions the size of Danish *herreder* (which normally consisted of six to ten parishes) remained at 10 percent for the whole population and 7 percent among the infants born in wedlock. [17]

The national IMR levels masked to some degree the regional variability, but even so also the national levels showed differences in a scale unseen in our time. During the nineteenth century the national average IMRs in Norway, Denmark, and Sweden were the lowest in Europe, although the registration there was among the most reliable. Norway held an absolute low with a national average IMR at 10 to 12 deaths per 100 live-born 1840-1880 and 9-11 percent for the rest of the century. Denmark held a level at 13-15 percent throughout the century, while France (and England and Wales) held levels a little higher at 15-17 percent. In Europe the high position was occupied by Austria, Bavaria and Iceland, which held IMR averages of 25-27 during most of the nineteenth century. Only Austria is shown in figure 1.

The infant mortality has varied over time in non-linear ways.

During the late nineteenth and the twentieth century the IMR at the aggregated national average for most countries presents itself as a continuous decrease. This may give the impression that the IMR in the

15. Løkke, *Patienternes Rigshospital 1757-2007*: 45.
16. Revuelta-Eugercios:, “Surviving the bottle: feeding practices and foundlings’ health in 20th-century Madrid””, in *14th ICREFH Symposium. Food and life span in Europe 1800-2000.*
17. Løkke, *Døden i barndommen*: 137-147.

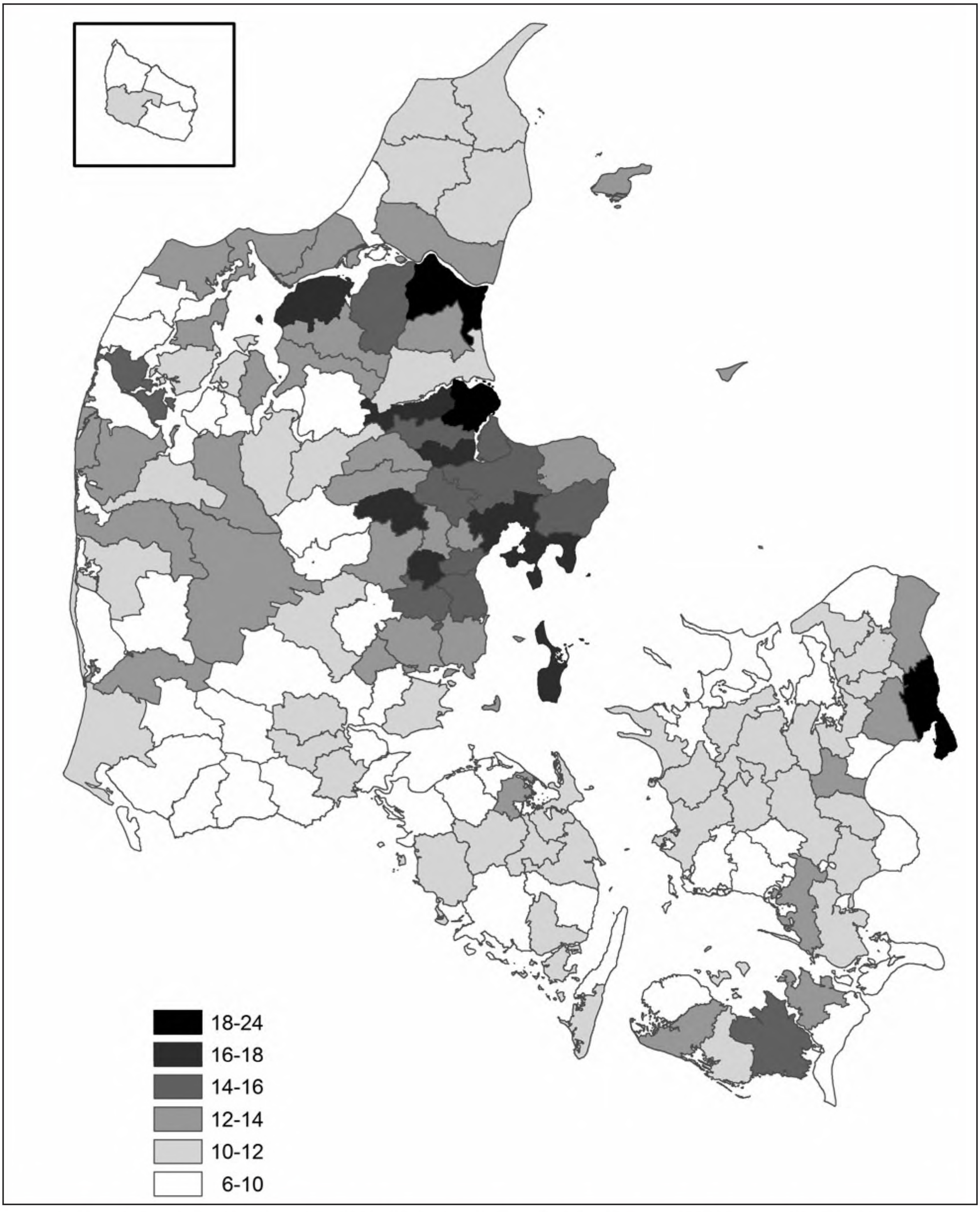

Figure 3. Danish rural districts 1850- 1854 divided into *herreder.* Death in the first year of life per 100 live births.
Source: Løkke, *Døden i Barndommen:* figure 2.10 144 II and appendix 2.3b. Map redrawn by Peder Dam/www.digdag.dk.

more distant past was as high as in the late nineteenth century or most probably higher. Recent studies show, however, that the IMR has been highly variable before the great early twentieth-century decline. This is not easily understood, as the aggregated national level often masks several increases and decreases at regional and local levels for different reasons.

An example of this is the Danish case (Figure 2): The stable national IMR of around 14 percent between 1850 and 1900 is not homogenous when subdivided. The stable national IMR masks that the rural districts had a lower level with a slow decrease, the provincial towns a slightly higher level with a slow increase and that Copenhagen, Denmark's only metropol, went through a rather turbulent development at a much higher level with two steep increases followed by decreases. Such increases in big cities were common all over Europe and are explained as a crisis of urbanization, when the population increased rapidly while sanitation remained miserable. Also in Copenhagen investments in clean-water supply, more hygienic dealing with night soil, the building of an underground sewerage system and introduction of prevention and control measures related to food-borne hazards have all played a part in the declines.[18] Rapidly growing cities in the nineteenth century seem nearly everywhere to have experienced increases in their IMR.

However, even the low IMR in the rural areas varies considerably from place to place from 6-10 percent in the *herreder* with the lowest IMR to 18-24 percent in high IMR *herreder* (figure 3).

The levels and time trends in the IMR are generally not known for periods earlier than the nineteenth century. To establish knowledge further back in time, IMRs have to be calculated from parish registers, which involves a huge work load and is thus not yet universally done. An impressive study, however, has been made in this way by Wrigley et al., who have studied the long-run trends in IMR in England and Wales among legitimate infants from 1580 to 1837. They see for sub periods during this time several increases and decreases: Rising from medium to medium high, decreasing to medium again, and then decreasing to medium low.

Table 1:

	Number of deaths in the first year of life per 100 live-born in England
1580-1679	16,4 (of these 1620 to 1649 as low as 15,5)
1680-1749	19,0 (of these 1680-9 and 1710-9 were above 20)
1750-89	16,3
1790-1837	14,1

[19]

A more detailed analysis of the distribution of deaths over the first year of life shows that the number of deaths in the first month of life went down, while in the second half of the first year the mortality in 1825-37 more than doubled compared to the level before 1675. This means that different variables had been involved in the composition of the IMR at different times.[20]

What is influencing the level of infant mortality?

Many studies have shown that a broad range of variables influence the level of IMR, among them economy, feeding practices, climate, population density, hygienic environment, illness panorama, legitimacy, order of birth, confession, age of parents, and many, many more. Several attempts have been made to order factors known to influence the IMR in a hierarchy, but they seem to escape that kind of ordering, as there are nearly always many factors at work at the same time, and they often produce a synergetic effect.[21]

To comprehend the interlinked nature of the variables influencing the level of the IMR, I have argued

18. Løkke, *Døden i barndommen*: 201-204.

19. Wrigley, *English population history from family reconstruction 1580-1837*: 218-219.

20. Wrigley, *English population history from family reconstruction 1580-1837*: 223.

21. Løkke, *Døden i barndommen*: 125-127.

that a model that analyzes the level of the IMR as an unstable balance between resistance and exposure is fruitful, as this model makes it clear that the same level of IMR in two populations does not have to be caused by the same factors. The same build-up of resistance will give a different IMR output if the exposure is changed and vice versa.[22]

Very high levels of infant mortality show up in empirical studies, when the resistance build-up was minimal and the exposure to one or more high risk factors was great. The minimal resistance build-up is most often caused by no breastfeeding at all right from birth.[23] Other factors known to hamper resistance build-up in infants are severely under- or malnourished mothers during pregnancy and a high incidence of pre-term infants for example as a result of hard workloads for the mothers during pregnancy. Exposure can be increased in many ways. Among the most fatal in nineteenth-century northern Europe was infant diarrhoea caused by unhygienic urban environments and unclean feeding utensils and sustenance[24]. Epidemic diseases such as measles, whooping cough and diphtheria played a part[25] as well as endemic illnesses. Endemic tetanus kept the IMR over 70 percent in the early nineteenth-century Icelandic island of Vestmannaeyjar and malaria caused the high levels in the English marshlands.[26]

How was the minimum level of Infant Mortality achieved?

The Norwegian and Danish minimum levels of IMR in the nineteenth century were achieved in regions, where the exposure was minimal according to the standards of the time and the resistance build-up was maximized.

The concrete processes involved were several. The minimum exposure was found in rural districts which were then called healthy areas. This means that severe illnesses such as malaria or tetanus were not endemic, that the panorama of less malign infectious diseases was relative stable so the mothers had a high probability of having gained immunity from them and that epidemics malign for infants did not have easy access to the place. That was often the case where no larger town or city was nearby and no main road or trafficked harbour was within easy reach.

In addition vaccination against smallpox was very widely accepted in Denmark from the early nineteenth century, so the exposure to smallpox of infants not yet vaccinated was thereby reduced.

It was also the case that in minimal IMR-regions the prevalence of restricted pelvis hampering births as a result of rickets in the childhood of the mothers, was less than in high mortality regions, so births were easier and less dangerous for the infants (and the mothers).[27]

And as a last variable reducing IMR, a network of educated, authorized midwives, midwives free of charge for the poor and used by rich and poor alike, was introduced in Denmark from the early nineteenth century and in full function in the 1840s. The midwives were trained to keep the birth normal so as to avoid procedures dangerous for mother and infant. The result was a significant decrease in perinatal and maternal mortality that remained lower than in most other countries until antibiotics were introduced worldwide in obstetric care from the 1930s.[28] There are sources telling of a singularly competent midwife at one place or another from many periods in history, but it was not until the late eighteenth century that

22. Løkke, *Døden i barndommen*: 128-129.
23. Knodel and Van de Walle, "Breast Feeding", Løkke, *Døden i barndommen*: 157-179, Garðarsdóttir, *Saving the child.*
24. Løkke, *Døden i barndommen*: 62-64.
25. Løkke, *Døden i barndommen*: 196.
26. Dobson, *Contours of Death and Disease in early Modern England* 340, Guttormsson and Garðarsdóttir, "Public Intervention to Diminish Infant Mortality from Neonatal Tetanus in the Island of Vestmannaeyjar (Iceland) during the First Half of the Nineteenth Century".
27. Løkke, *Døden i barndommen*: 139-183.
28. Løkke, "The antibiotic transformation of Danish obstetrics. The hidden links between the decline in perinatal mortality and maternal mortality in the mid-twentieth century", Løkke, "Did midwives matter? 1787-1845".

there were organized endeavours to train every midwife in best practice.[29]

But even with the minimal exposure possible in the nineteenth century the IMR could vary greatly. The minimum IMR levels of 7 percent were only reached for infants born in wedlock in populations who carried out breastfeeding in a special way.

The maximum resistance needed for the minimal IMR was carried out by extended breastfeeding with well-timed introduction of complementary feeding

Breastfeeding can be carried out in many ways with different results for the resistance build-up. The local populations in nineteenth-century Denmark who maintained the minimal IMR, breastfed exclusively for five to six months. That means that nothing but women's milk direct from the breast was given to the infant until it was old enough to sit on a grown up's lap and grab its food for itself. Then followed two, three or more years in which the infant continued to suck but also received complementary food from the table.

In the Danish high IMR regions breastfeeding was also almost universal, but it was carried out in another way. The crucial difference was the timing of the introduction of complementary feeding. In the populations which gave complementary foods alongside the breast right from birth the IMR was doubled to a level of 18-20 percent even in healthy areas. The breast/food combination, which is healthy for infants six months old, can be fatal for a new-born baby.[30]

The description and understanding of these nineteenth-century infant feeding cultures has been complicated by the early to mid- twentieth- century medical doctors, who did not use a language that was able to distinguish between exclusive breastfeeding and breastfeeding with complementary sustenance. They found the long period of combined breast and food disgusting and prescribed breastfeeding followed by, what they called "weaning", by which they meant a period not longer than a month going from breast milk only to no breast milk at all.[31] This has in turn given a lot of misunderstandings in the research about breastfeeding both in medical science and among historical demographers. The problems have until recently been that very often it has been impossible to see whether the word breastfeeding was used for "exclusive breastfeeding" or for "breastfeeding with complementary feeding" or for both. The word "weaning" too has been used for at least three different processes. As a long period of breastfeeding with complementary feeding is today seen by paediatricians as the best for infants over six-months-old, the concepts used now are "exclusive breastfeeding", "breastfeeding with complementary feeding" and "no breastfeeding". The term "weaning" is avoided because of its lack of precision and lack of recognition of the desirability of a long period of breastfeeding with complementary food.

Today pediatricians explain the better survival of infants who are exclusively breastfed for the first six months of life compared with entirely artificially fed, everything else being equal, with four points:

- The breast milk shall not be handled. So it is not exposed to contamination on its way from breast to baby.
- The breast milk meets automatically the nutritional needs of young infants, also the ones science have not discovered yet.
- The breastfed infants do not receive substances harmful or useless for it.
- Through the breast milk the infant gains access to the immune system of the mother and the development of the infant's own immune system is stimulated.[32]

The excess mortality of artificially fed infants is highest where the hygienic conditions are worst, where knowledge of suitable substitution is poor and where poverty places obstacles to the obtaining of such substances.

29. Løkke, "The 'antiseptic' transformation of Danish midwives, 1860-1920".
30. Løkke, *Døden i barndommen:* 130-34.
31. Løkke, *Døden i barndommen:* 259-73.
32. Akre, *Infant feeding*: 31.

Experiences from early twentieth- century pediatricians as well as later tropical pediatricians agree that exclusive breastfeeding for the first six months followed by extended breastfeeding alongside other sustenance for some years is a very effective way of preventing high IMR in poor populations living in unhygienic environments.[33] The Swedish state was organizing public health interventions based on knowledge about this as early as the late eighteenth century, when midwives and a physician were sent to Nedertorneå in Northern Sweden to teach the mothers how to breastfeed in order to bring down the excessively high IMR. The local tradition was to give the infants milk from animals served through a cow's horn. The campaign succeeded as the IMR went down, but the mortality among children from one to four years old went up.[34] A development pointing to the possibility of mortality regimes in the past with life tables as different from the European twentieth-century life tables as the ones found by Gage in African and Asians populations in the middle of the twentieth century.[35]

To sum up – the level of infant mortality can fruitfully be seen as a balance between exposure and resistance. A major part of the resistance build-up is determined by nutrition. In nineteenth- century Denmark and Norway the minimal IMR of 7 percent was reached by exclusive breastfeeding during the first five to six months of the infant's life followed by step by step introduction of other sustenance alongside breastfeeding for two, three or more years. Even in years of epidemics the IMR in these minimum IMR regions did not reach the average level for *herreder* where the infants were given supplementary feeding to the breast right from the birth. Only the war year 1849 brought the IMR up to the 22 percent, which was quite normal in places where extra substance was given from the birth.[36]

33. Løkke, "Liv og død på dåse. Markedet for industrielt fremstillet modermælkserstatning og amning i verdens fattige lande, Skandinavien og USA i det tyvende århundrede".
34. Brändström, *De kärlekslösa mödrarna*: 167-171.
35. Gage, "Variation and classification of human age patterns of mortality: analysis using competing hazards models".
36. Løkke, *Døden i barndommen*: 175-176.

Conclusion

The IMR has not been homogeneously high in historical populations and the changes over time have not been linear. Is it possible, then, that the IMR in some prehistoric and medieval populations can have been as low as the mid-nineteenth-century minimum level? A level which was 7-10 deaths in the first year of life per 100 live births.

On the resistance side, it should not have posed more problems for prehistoric and medieval mothers to breastfeed than it did for nineteenth-century mothers, given that their ideas of proper infant feeding were exclusive breastfeeding for five to six months followed by breastfeeding with complementary food for two or more years.

On the exposure side it is more complicated: In the sparsely populated areas in prehistoric times the chances are that exposure to epidemic diseases and other infections could be even smaller than in healthy rural areas in nineteenth-century Denmark. In the middle ages, however, there must have been as great a variation in exposure levels as in the nineteenth century, so the IMR there must have differed as much from place to place and over time as in later times. And most likely even more so, as the plague was intermittent in Denmark until 1711 and smallpox vaccination was not performed until the early nineteenth century. Even so, it is not unreasonable to think that there were rural localities which could have escaped severe epidemics for a generation or two.

What was missing in prehistoric and medieval times compared with nineteenth-century Denmark was the presence of midwives who were effectively trained to keep normal births normal and who attended to births in all parts of the population. Therefore, a higher perinatal mortality must be expected in prehistoric and medieval populations on an average. This does not, however, exclude that some gifted midwives at some places may have been able to keep the perinatal mortality low.

Thus, the overall result is that given that a prehistoric, rural population was fairly well nourished, had a breastfeeding-friendly culture, lived in a healthy place without severe endemic infections such as malaria, tetanus and smallpox or easy access for epidemics, and had an unusually gifted midwife, the minimal IMR should not need to be more than the 7 to 10 percent experienced in some rural parts of Denmark and Norway in the nineteenth century.

It is, of course, most likely that other ideas on infant feeding were dominant in other prehistoric populations as they were in nineteenth-century populations, which caused higher levels of IMR. The same goes for all kinds of variables enlarging the exposure. Therefore, it must be expected that the variation of the IMR between places and over time in prehistoric and medieval times must have been as large as in the nineteenth century. This means that some populations could have had an IMR as low as 7 to 10 percent for a generation or more, while populations nearby due to negative ideas about breastfeeding combined with high exposure could have had levels up to 70-80 percent. So no easy model can be applied as to how many infants' skeletons there need to be at a burial place to suggest that no dead infants are missing. On the other hand, few infant skeletons at a burial place could be a sign of a demographical pattern with low infant mortality due to a resistance-building breastfeeding pattern. It is possible to work with this hypothesis using stable isotope analysis on teeth from skeletons of adults, as the teeth provide the isotopic signal of the dietary protein consumed as infants and young children and thereby indicate whether they have been breastfed and if so for how long.[37]

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Persisting structures? Infant mortality decline and changes in infant feeding practices in Iceland 1850-1920

Ólöf Garðarsdóttir

Abstract

Prior to the beginning of the twentieth century feeding practices had important bearing upon survival chances of young children in Iceland. Areas with early introduction of solid food and low frequency of breast-feeding had extremely high rates of infant mortality, especially neonatal mortality. After the turn of the century feeding practices had less impact on the survival chances of young children. It is shown that, even though artificial feeding prevailed in many areas, there was a notable decline in infant mortality levels. Knowledge about the transmission of disease, hygienic measures and changes in the preparation of food for young infants influenced infant health and infant survival. In this shift towards better health in infancy midwives played a central role.

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Introduction

When I was working on my doctoral thesis during the late 1990s[1], I had the pleasure of discussing traditional child rearing methods and feeding practices with an elderly Icelandic woman, Róshildur Sveinsdóttir.[2] Róshildur was then almost ninety years old, a dazzling person and extremely active for her age. She remembered vividly details from her own childhood. She was born in 1911 in Ásahreppur in southern Iceland, a parish that even by Icelandic standards was both poor and extremely sparsely populated. The family was relatively well-off and occupied one of the largest landholdings in the parish.[3] Her parents had married in 1902, and their marriage was an unusually fertile one. During the period 1904 to 1925 her mother gave birth to 15 children, the main birth interval being slightly more than 18 months. Twelve of Róshildur's siblings survived childhood.

Róshildur's grandmother, Gyðríður Ólafsdóttir, lived close to the family and served as a midwife in the local community. She was born in 1844 and like many of the midwives of her generation, she had not received any formal education as a midwife but was one of the wise women who were entrusted to carry out the important task of helping women in childbirth. She married in 1865 and gave birth to fourteen children, eight of whom died before the age of one. Despite frequent childbirths, she worked as a midwife in the community until old age. Midwifery was by no

1. My thesis was published in 2002 under the name *Saving the Child. Regional, cultural and social aspects of the infant mortality decline in Iceland, 1770-1920*, Umeå: The Demographic Database, Umeå University 2002. This article is largely based on findings presented in the thesis.
2. Interview with Róshildur Sveinsdóttir, Hofteigur 44, Reykjavík. Interview 7 August 1999.
3. *Ný Jarðabók fyrir Ísland samin eptir tilskipun 27. maí mánaðar 1848 og allramildilegast staðfest með tilskipun 1. aprílmánaðar 1861.* Copenhagen, 1861.

Teat of wood. Source: National Museum of Iceland.

means easy at that time. Like many other agrarian regions in Iceland, the area where the parish of Ásar is located was remote and sparsely populated, and frequently midwives had to travel long distances on horseback across turbulent rivers to attend to childbirths.

Qualitative source material collected by the Ethnographic Department (Þjóðháttadeild) at the National Museum of Iceland indicates that it was fairly common during the nineteenth century for midwives to take newborns home with them and care for them for a few weeks while the mother recovered from the delivery.[4] According to Róshildur, her grandmother frequently stayed with the mother for a number of days and helped out in the household. On other occasions, she took the newborn infant home with her and kept it there for a period of two or three weeks. This was, according to Róshildur, especially true in case of poor families with many young children. The newborns were then given cow's milk diluted with water. The midwife used to take the children back home to their mothers dressed in new clothes. Gyðríður helped deliver my informant Róshildur and all her siblings except for the two youngest ones. None of them were ever breast-fed, and Róshildur maintained that breast-feeding was non-existent in the area when she grew up.[5]

Róshildur remembered vividly how as a little girl she used to clean the feeding bottles, a task that was by no means pleasant "…as the milk easily turned sour and used to stick to the bottle". Rubber teats were not available at the time and wooden spools (used for cotton thread) were carved and used as teats.[6] These wooden teats were covered with a piece of cloth so that they would not hurt the baby's mouth. "My mom used to sew a lot and therefore there were always lots of empty spools that could be used to make the teats", Róshildur claimed. When I asked her if she remembered if infants were given pre-chewed solid food, she answered with disgust: "No, thank God, that is an old custom and was no longer practiced when I grew up! I somehow got the idea that my grandmother worked hard to uproot this disgusting custom during her first years as a midwife in the community."

Through my encounter with Róshildur I caught a glimpse into customs and values of past times. Two elements in particular caught my attention: first, her statement about the total absence of breast-feeding in her home community, and, secondly, the fact that the midwife used to take infants home with her after delivery. When I started to work on my doctoral thesis, it was widely acknowledged among Icelandic historians that breast-feeding was unusual in Iceland during the eighteenth and early nineteenth centuries.[7] But it

4. The ethnographic soucre material on Birth, infancy and the first year consists of questionnaire collected during the early 1960s. For further information on the source material see Garðarsdóttir: *Saving the Child*, pp. 204-207.

5. This view is also expressed in an autobiography by Róshildur's daughter and her son-in-law. See Brynja Benediktsdóttir, Erlingur Gíslason and Ingunn Þóra Magnúsdóttir: *Brynja og Erlingur fyrir opnum tjöldum*, Reykjavík: Mál og menning 1984, p. 43.

6. Wooden teats are also described by Árni Björnsson: *Merkisdagar á mannsævinni*, Reykjavík: Mál og menning 1996, p. 95.

7. Loftur Guttormsson: "Barnaeldi, ungbarnadauði og viðkoma á Íslandi 1750-1860", in Sigurjón Björnsson (ed.): *Athöfn og orð: afmælisrit helgað Matthíasi Jónassyni áttræðum*;

was also a common assumption that breast-feeding increased during the second half of the nineteenth century and that most infants in early twentieth century were breast-fed. The rapid decline in infant mortality towards the end of the nineteenth century was seen as evidence to support this. The example referred to above proved to me that reality might have been more complex than indicated in earlier research.

In this article I will discuss regional differences in feeding patterns and show how feeding patterns from earlier periods prevailed into the twentieth century. Four areas are included in the study:

(1) The capital Reykjavík in the county of Gullbringusýsla. Even though Reykjavík did not count more than a few thousand inhabitants, it was by far the largest town in Iceland. It was characterized by an early provision of medical services, and it was well documented that breast-feeding was relatively common in Reykjavík as early as the first part of the nineteenth century.
(2) The fishing districts in the county of Gullbringusýsla outside of Reykjavík. Gullbringusýsla was by Icelandic standards densely populated. Most inhabitants were landless cottars who derived their livelihood from fishery. During the fishing season these fishing districts attracted people from different parts of the country. Mortality was traditionally high in these districts, and breast-feeding traditions were weak. Accounts from the eighteenth and the nineteenth centuries suggest that cottars' wives in the fishing districts who had no access to cow's milk tended to breast-feed their babies for a brief period of time, but that the babies were weaned at a relatively young age.
(3) The rural area of Þingeyjarsýslur in the north where mortality was traditionally low and where breast-feeding started early. This area was known for early provision of midwives.
(4) The county of Rangárvallasýsla in southern Iceland which adjoins the county of Skaftafellssýlsa where my informant was from and where infant mortality was extremely high and artificial feeding practices predominated.[8]

Feeding practices and infant mortality levels – earlier research

It is a well-known fact that in present day developing countries artificial feeding at early ages is generally associated with increased infant mortality risks. It has been revealed that infants who receive additional food in early infancy are up to two or three times more likely to die than those who are exclusively breast-fed.[9] The risks, however, are very much connected with household and poverty related factors. Infants from wealthy households with modern facilities, clean drinking water and a sewage system are not usually more at risk of dying young than their counterparts in wealthy western societies, even if they are not breast-fed. The beneficial influence of breast-feeding is greatest where water and sanitation are poor.[10]

Historical sources do not normally provide us with the same detailed knowledge on feeding methods as modern medical and ethnographic studies. However, there are a few studies that offer a relatively good picture of feeding practices in the past. It is well-known that in many societies where breast-feeding practices were prevalent, supplementary food was often given at very young ages. Furthermore, demographic and social conditions often resulted in many infants being deprived of the breast at very young

Reykjavík: Mál og menning 1983, pp. 137-170; Gísli Gunnarsson: *The Sex Ratio, the Infant Mortality and Ajoining Societal Response in Pretransitional Iceland*, Lund: Lunds universitet., Meddelande från Ekonomisk-historiska institutionen 32: 1983; Helgi Þorláksson: "Óvelkomin börn" *Saga* 24:1986, pp.79-120.

8. Garðarsdóttir, *Saving the Child*, pp. 138-39.
9. See for example: Lars Smedman: "Promoting breast-feeding in Guinea-Bissau", *Acta Pædītrica* 88: 1999; V. J. Hull: Breast-feeding and fertility in Yogyakarta. The infant feeding study. Semarang site report 1984.
10. See for example: Julie DaVanzo: "A Household Survey of Child Mortality Determinants on Malaysia", *Population and Development. Supplement to vol 10* (1984), p. 703.

ages. Many women in the lower social strata were forced to start working immediately after delivery.

The early introduction of different types of food to the diet of infants that were otherwise breast-fed is likely to have produced differences in mortality rates in historic Europe. Valerie Fildes has, for instance, argued that the drop in neonatal mortality in late seventeenth and early eighteenth century England can mainly be ascribed to the changes in traditional beliefs about the colostrum.[11] Towards the end of the seventeenth century it became increasingly common to put the infant to the breast shortly after birth, and the practice of giving infants purifying liquids instead of the colostrum was widely abandoned. As a consequence neonatal mortality fell.

There are a number of areas in pre-industrial Europe where breast-feeding was either very uncommon or totally absent. This was especially the case in southern Germany (in particular Bayern and the Würtemberg area)[12], Austria and districts around the Baltic Sea (northern Finland and northern Sweden).[13] Large areas in Iceland (especially in rural areas in the southern and western part of the country) were characterized by the almost total absence of breast-feeding, at least in the eighteenth and early nineteenth centuries.[14] In all these societies infant mortality rates were extremely high, between 300 and 400 per 1000 live births. Neonatal mortality rates was generally high, especially in the areas where breast-feeding was totally absent. In areas of Sweden and Iceland where infants were exclusively artificially fed the mortality rates cumulated during the second and third week post-partum.[15]

Regional differences in infant mortality

Figure 2 shows the development of infant mortality levels in the research areas. Unfortunately, no regional data in infant mortality is available for the first decade of the twentieth century. Between 1911 and 1920 there is only information on Reykjavík and for the period 1921-1930 there is information available for Reykjavík, other towns and villages lumped together and for rural areas.

Huge differences are seen during the mid-nineteenth century, differences that have chiefly been explained by variations in infant feeding traditions. The rural area of Þingeyjarsýslur and the most urbanized place in Iceland (Reykjavík) displayed comparatively low levels of infant mortality. In the rural area of Rangárvallasýsla, infant mortality levels were by far the highest, almost one out of three babies died before its first birthday in the 1850s. In the fishing districts of Gullbringusýsla this was true for one out of four babies.

As regards development of mortality during individual months of the first year there were different trends in the two high mortality areas. Medical reports from the rural county of Rangárvallasýsla stated that breast-feeding was uncommon in Rangárvallasýsla. Few mothers nursed their newborns, a tradition that produced elevated mortality, especially during the second, third and fourth week of life.[16] On the

11. Valerie Fildes: *Wet Nursing. A History from Antiquity to the Present*. Oxford / New York: Basil Blackwell 1980, pp.317-319.

12. John Knodel: *Demographic behavior in the past. A study of fourteen German village populations in the eighteenth and nineteenth centuries*. Cambridge 1988; John Knodel and Etienne van de Walle: "Breast Feeding, Fertility and Infant Mortality: An Analysis of some Early German Data", *Population studies* 21(2): 1967, pp.109-131. Georg Mayr: "Die Sterblichkeit der Kinder während des ersten Lebensjahres in Süddeutschland, insbesondere in Bayern", *Zeitschrift des königlich bayerischen statistischen Bureau* 2(4): 1870, pp. 201-247.

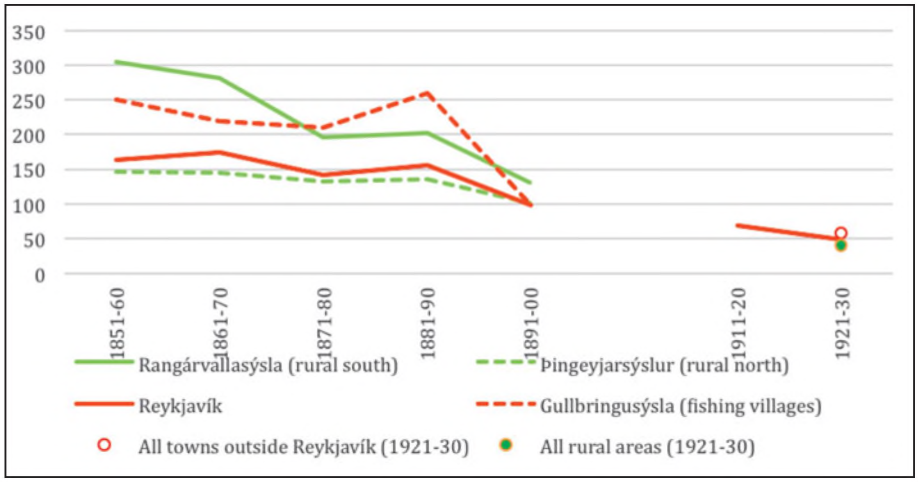
13. Anders Brändström: *"De kärlekslösa mödrarna." Spädbarnsdödlighet i Sverige under 1800-talet med särskild hänsyn till Nedertorneå*. Umeå: Demographic Database 1984; Ulla-Britt Lithell: "Childcare - A Mirror of Women's Living Conditions. A Community Study Representing the 18th and the 19th Century Ostrobothnia in Finland", in Anders Brändström and Lars-Göran Tedebrand (eds.), *Society, Health and Population During the Demographic Transition*. Umeå: Demographic Database 1988.

14. Guttormsson: "Barnaeldi, ungbarnadauði og viðkoma á Íslandi 1750-1860"; Garðarsdóttir: *Saving the Child*.

15. Brändström: *"De kärklekslösa mödrarna"*, pp. 104-106; Garðarsdóttir, *Saving the Child*, pp. 138-39.

16. Garðarsdóttir: *Saving the Child*, pp. 131-142.

Figure 1. Infant mortality (per 1,000 live births) in the research areas 1851-1900 (in Reykjavík 1851-1900 and 1911-1930) and in towns and rural areas 1921-1930



other hand, mortality levels after the second month of life were not particularly high, which may be explained by the fact that most households in the county were farming households. Milk production was thus household-based, and the milk was less likely to be contaminated than in more densely populated areas (e.g., Gullbringusýsla) where few households had access to fresh milk.

Analysis of the infant mortality pattern in Gullbringusýsla indicates that babies were breast-fed for at least the first few weeks. This is also supported by contemporary evidence (see above) that indicates that cottar's wives in the fishing districts tended to breast-feed their newborns for a brief period. At an early age, however, babies in this area were given various solid foods, often pre-chewed by adults. This practice led to elevated mortality after the second month of life.

Figure 1 shows that all four areas in the study experienced decline in infant mortality during the second part of the nineteenth century. The decline was most prominent in the high mortality areas, and towards the end of the nineteenth century there were little regional differences in infant mortality levels. Data from the second and third decade of the twentieth century indicates that there were little differences in mortality levels and development of mortality levels between areas.

The most prominent decline towards the end of the nineteenth century was in Gullbringusýsla where infant mortality fell from a level of 250 deaths per 1000 live births to 100 per 1000 in just one decade. How were such dramatic changes possible in such a brief time period? It is hardly plausible that such a decline could be explained by modified feeding practices. Human beings are generally rather conservative, and changes in longstanding traditions are prone to take more time than just one decade. In the following section infant feeding traditions in the early twentieth century will be presented.

Persisting traditions

Contrary to earlier periods, source material on feeding practices dating from the first part of the twentieth century is abundant in Iceland. As in most other European societies,[17] interest in infant health problems was profound in the early twentieth century, and several national studies were carried out to assess the extent of breast-feeding contra artificial feeding in different parts of the country. Most of these sources display types of feeding in a more detailed manner than

17. Alice Reid: "Infant and child health and mortality in Derrbyshire from te Great War to the mid 1920s", Unpublished ph.D.-thesis. University of Cambridge 1999; Dorothy Porter: *Health, Civilization and the State. A history of public health from ancient to modern times.* London, Routledge 1999.

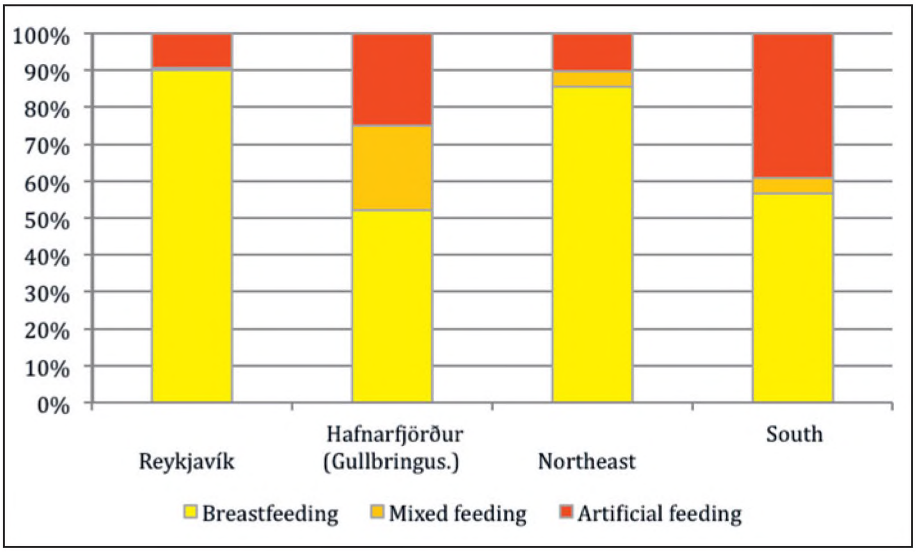


Figure 2. Feeding practices by region at the age of two weeks based on midwives' reports 1913-25.

before, dividing feeding methods into three groups: exclusively breast-fed, mixed feeding and exclusively artificially fed. After 1912 individual midwives were required to write detailed reports on every woman they helped in delivery.[18] Those reports were based on forms that midwives filled out for all births. The forms included detailed information on the child and the mother, together with data on feeding practices in the first two weeks from birth. Each midwife was supposed to send a report to the district physicians based on information from the forms. There is thus relatively detailed information on breast-feeding in individual districts from the early twentieth century.

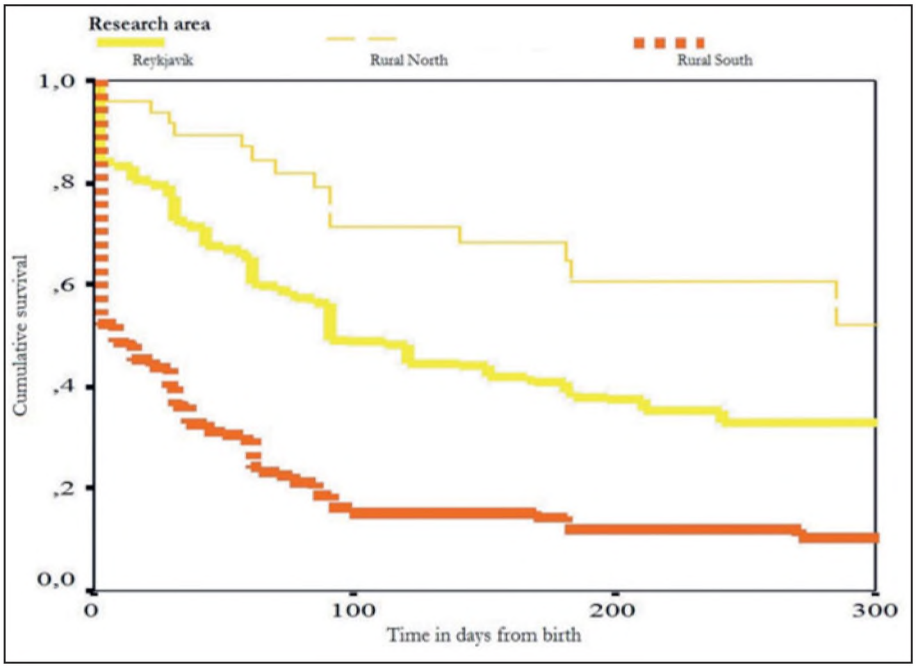
Another source material with information on breast-feeding is the Icelandic census of 1920. This census in unique in the sense that all households with children under the age of one were asked about feeding practices, that is, whether or not the child was being breast-fed or had been breast-fed and, if so, for how long.

The data in Figure 2 are based on information from the midwives' reports. Generally, midwives attended to childbearing women for about two weeks, and the information is thus likely to reflect feeding practices among babies in their second or third week of life. It is evident that there were considerable regional differences in feeding traditions, and that those differences reflect infant feeding traditions in earlier periods. In Reykjavík and in the rural areas in the Northeast (where Þingeyjarsýslur is situated) most babies were breast-fed. On the other hand, in the town of Hafnarfjörður (in Gullbringusýsla) it was common that young infants were either not breast-fed at all or received both the breast and the bottle. In the southern part of the country almost half of all babies were bottle-fed. It can thus be concluded that feeding patterns reported for the nineteenth century prevailed into the twentieth century.

Similar patterns are reflected in the information from the 1920 census (See Figure 3.) It is revealed that in areas with strong breast-feeding traditions babies were breast-fed for a longer period than in areas with weak breast-feeding traditions. In the case of Þingeyjarsýslur almost all newborns were put to the breast, and after nine months more than 50 per cent of all babies were still being breast-fed. In the case of the southern areas (where Rangárvallasýsla and Skaftafellssýsla (Ásahreppur) are located) only 50 per cent of all newborns were breast-fed. Most of them had already been weaned at the age of three months when less than 20 per cent were still being breast-fed.

18. *Alþingistíðindi*. Reykjavík 1912.

Figure 3. Duration of breast-feeding in days in three regions according to the Iceland census 1920.



Considering the fact that there was a strong convergence in infant mortality levels towards the end of the nineteenth century the notable differences in feeding practices appear contradictory. How can we explain the relatively low infant mortality levels in Rangárvallsýsla where only half of all newborns were breast-fed? Health reports offer some answers to this puzzle.

The health reports from different areas strongly suggest that there were important differences in the disease panorama between the areas with strong breast-feeding traditions and those where a majority, or at least a large minority, of babies were artificially fed. Gastro-intestinal diseases were thus reported to be the most common diseases among young infants in the areas where breast-feeding traditions were weak. These diseases were uncommon among young infants in areas where babies were breast-fed.[19]

The decrease in infant mortality in areas where artificial feeding dominated is without a doubt related to the changes in the preparation of food for infants. This included better knowledge about hygiene and the custom to dilute milk with boiling drinking water. In agricultural areas milk production was household based, and milk thus presumably fresher than, for example, in large urban centers in Europe where it was difficult to store the milk adequately. Obviously, the late nineteenth and early twentieth centuries were characterized by an improvement in the treatment of animal milk in Iceland. In addition, glass bottles were introduced towards the end of the nineteenth century, and rubber teats became common somewhat later. It goes without saying that the likelihood to be infected with e-coli or other intestinal bacteria decreased when unhygienic wooden vessels were replaced with clean glass bottles. As a consequence, infants who were not at all breast-fed or breast-fed for only a short period after birth had better possibilities of surviving infancy than their counterparts in previous periods. Midwives played a central role in this process. They instructed mothers about the importance of hygiene and they brought about new knowledge about the treatment of food given to infants.

Promoting breast-feeding was of central concern among the medical professions during the late nineteenth and the early twentieth century. However, in

19. Garðarsdóttir, *Saving the Child*, pp. 191-92.

areas with longstanding traditions of artificial feeding of newborns changes in feeding traditions did not happen overnight. Midwives were often recruited in the local community and many of them had thus little personal experience of breast-feeding. Midwives who started their career in an area where most infants were artificially fed, and where this mode of feeding was considered to be in the child's best interest, were not likely to be successful in persuading all women to putting their babies to the breast. Earlier research suggests that the age of both midwives and of childbearing women played a role when it came to promoting breastfeeding. Old midwives who had started their career when artificial feeding was considered natural are likely to have developed routines in their relationship with childbearing women and kept those routines through their career. Midwives who were trained during a period when breast-feeding was seen of central importance for infant health were more likely to attempt to promote breast-feeding. They were not always successful and here the age of the mother was of central importance. A young primpara was more likely to listen to the midwife's advice whereas an experienced mother who had given birth to many children was not likely to take such advice from a young woman.[20]

Conclusions

This article has shown that prior to the beginning of the twentieth century feeding practices had an important bearing upon survival chances of young children in Iceland. Areas with early introduction of solid food and low frequency of breast-feeding revealed extremely high rates of infant mortality, especially neonatal mortality rates. After the turn of the century feeding methods had less impact on survival chances of young children. The study also indicates that, even though survival chances among young infants increased, morbidity rates were higher in areas with traditions of artificial feeding.

Prevailing traditions do not generally change overnight. During the second part of the nineteenth century, Icelandic midwives and physicians strongly advocated breast-feeding.[21] Without a doubt, this effort eventually left its imprint on feeding traditions. In the short run, however, other changes had greater impact upon survival chances of young infants. Knowledge about the transmission of disease, hygienic measures and changes in the preparation of food for young infants were important factors affecting infant health and shifts in infant survival. In this move towards better health midwives like Gyðríður, who was introduced in the beginning of this article, played a central role.

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20. Garðarsdóttir, *Saving the Child*, pp. 200-204.

21. Garðarsdóttir, *Saving the Child*, pp. 151-66

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12

Long term health effects of the Dutch famine of 1944-45: A summary of research findings

L.H. Lumey

Abstract

Studies of the Dutch famine of 1944-1945 (also known as the Dutch 'Hunger winter') provide an opportunity to look at the long-term impact of early life nutrition changes on later health and disease. This contribution gives a summary of research findings from study cohorts in the famine followed from birth to adolescence and later age with medical examinations and DNA methylation analysis. The studies show a relation between prenatal famine and body size, type 2 diabetes, lipid metabolism, and DNA methylation at age ~60 years and to current mortality through age 63 years. Long-lasting epigenetic changes in DNA methylation could provide a biological pathway to explain some of these epidemiologic observations. Our study findings point towards the early gestation period as being especially sensitive to environmental changes for later health effects.

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Introduction

One aim of our studies of the Dutch famine of 1944-45 is to address unresolved questions about the nature of 'fetal programming' (Barker and Martyn 1992, Lucas and Cole 1999, Kermack, McKendrick and McKinlay 1934, Forsdahl 1977). This is the idea that there are critical time periods in gestation that are important for life-long health.

According to the fetal programming hypothesis, undernutrition in pregnancy can have permanent effects because the developing fetus is highly responsive to its environment. Possible future growth and development trajectories are adjusted based on the prevailing conditions in the womb. In an adverse environment, the fetus can make adjustments to its nutrition requirements that may be beneficial in the short run. If however the adjustments cannot be reversed over time, they may be harmful in the long run should the circumstances improve after birth. As an example, changes in fetal nutrition may have an effect on the regulating mechanism of one or more genes. Animal studies show that this may lead to differences in gene expression and in the synthesis of important enzymes (Waterland and Michels 2007).

From a life course perspective, the changes in the prenatal environment could be the first among a series of cumulative insults; they may initiate a chain of events which over time increase the risk of disease; they may also create an increased susceptibility to other exposures later in the life course (Ben-Shlomo and Kuh 2002, Lynch and Smith 2005).

In the setting of the Dutch famine of 1944-45, individuals who were exposed to extreme undernutrition in the womb can be followed over time. This provides an opportunity to evaluate long-term health effects of prenatal undernutrition in general (Lumey, Stein and Susser 2011) and to address important questions related to the fetal programming hypothesis.

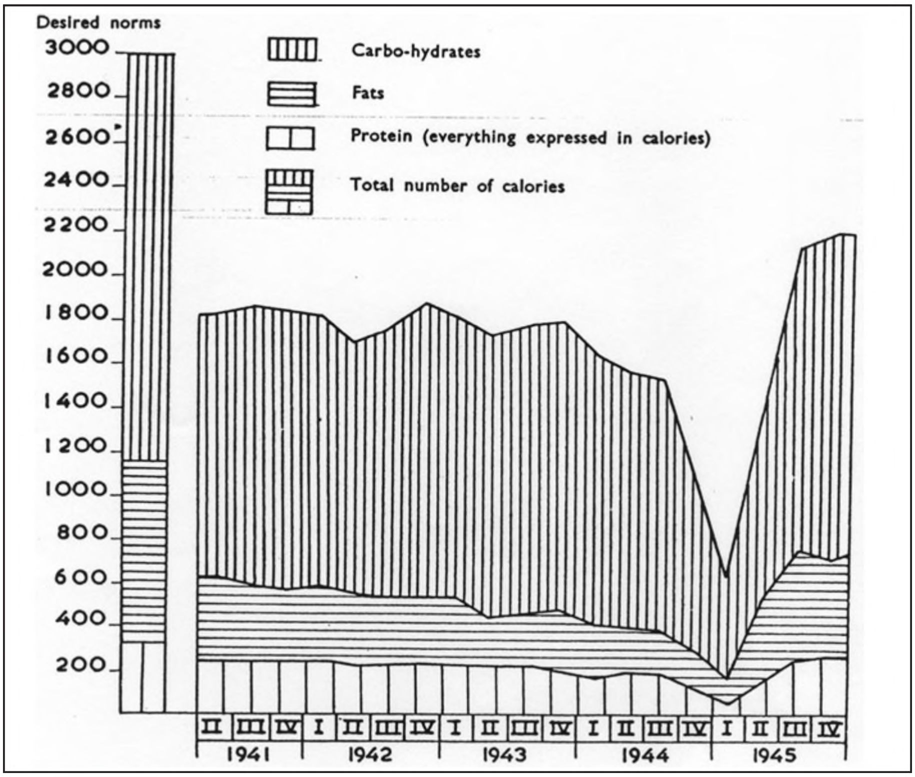


Figure 1. Distributed food rations (calories/day/person) for the Western Netherlands, 1941-1945 (Burger, Drummond and Sandstead 1948).

We here provide a summary of research findings based on the natural experiment that the Dutch famine provided.

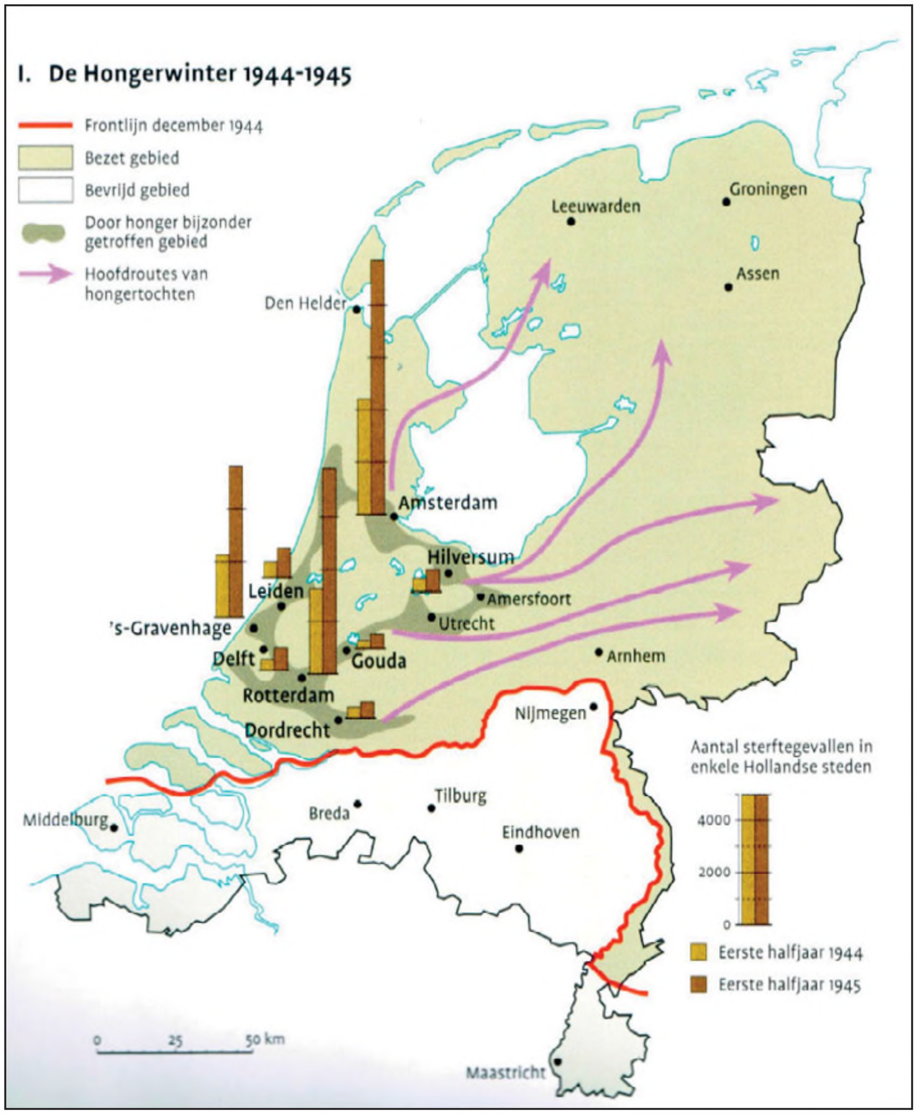
Historical setting

The Dutch famine of 1944-45 is known as the "Hunger Winter". During WWII, the country was invaded by the German army in 1940 and remained occupied until 1945. Following the Invasion of Normandy in June 1944, the Allied troops had liberated most of the South of the country by September 1944. The advance came to a halt when supplies became overstretched and the Allies faced newly regrouped German lines at the Waal and Rhine rivers. Crossing these rivers at Arnhem and Nijmegen proved to be 'One bridge too far'. In support of the Allied advance, the Dutch government in exile in London called for a national railway strike to hinder German military transports. In retaliation, the German authorities blocked shipments of all food supplies to the occupied West of the country in October 1944. The population of this area was approximately 4.3 million people, of whom 2.3 million lived in the cities of Amsterdam, Rotterdam, the Hague, Delft, Leiden, Haarlem, and Utrecht.

Despite the war, the general nutrition of the population in the occupied Netherlands had been adequate until October 1944 (Trienekens 2000). Thereafter, food supplies became increasingly scarce in the West although supplementary rations were distributed by the Government. These rations provided the only food source for many people living in the cities in the West. They had fallen to below 1,000 kcal per day by November 26, 1944 however and to 500 kcal per day by April 1945 (Burger, Drummond and Sandstead 1948).

While some people obtained additional food from black markets and from bartering, these supplements were not generally available to most. Widespread starvation followed in the Western Netherlands, with an immediate death toll of over 20,000 (De Jong 1981, Lumey and Van Poppel 1994). The excess deaths were

Figure 2. The Hunger Winter of 1944-1945. Map of the Netherlands with estimated number of deaths in selected cities in the Western Netherlands in the first half year of 1944 (pre-famine period; light brown columns) relative to the first half year of 1945 (famine period; dark brown columns) (Bosatlas 2011).



Top left legend translation: Frontlijn december 1944=German-Allied front as per December 1944; Bezet gebied=German occupied area; Bevrijd gebied=Area liberated by Allied forces; Door honger bijzonder getroffen gebied=demarcation of Western Netherlands area that was especially affected by famine; Hoofdroutes van hongertochten=Main food foraging routes from the Western famine area to non-famine areas in the East and North of the country.

Bottom right legend translation: Aantal sterftegevallen in enkele Hollandse steden=death counts in selected cities in Western Netherlands (Amsterdam, Rotterdam,'s-Gravenhage and others), comparing the number of deaths in the first half year of 1944 to the number in first half year of 1945.

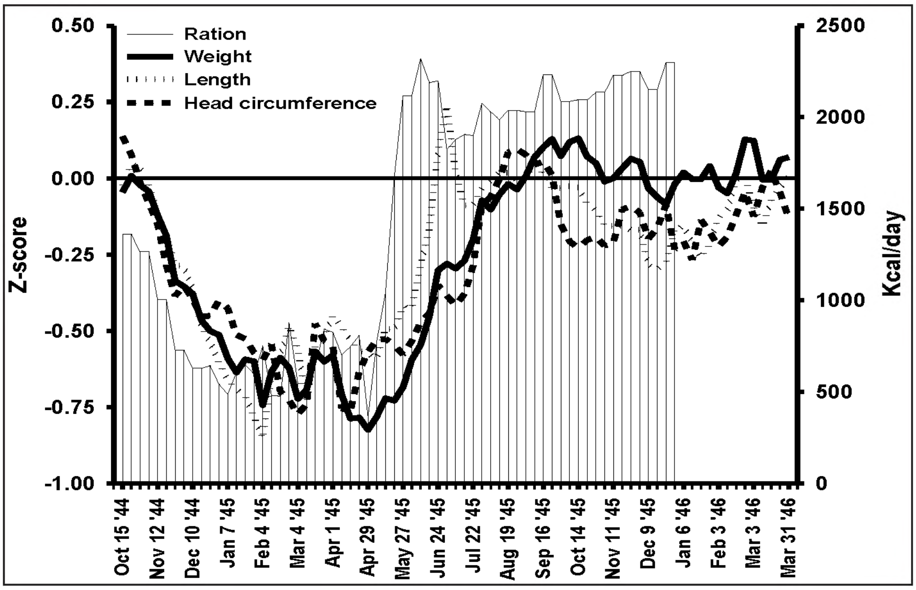


Figure 3. Weekly caloric rations (kcal/day) and averages of z-scored linear measures of weight, length, and head circumference at birth, for births in two clinics in the Western Netherlands, 1944–1946. The reference population (births in 1943) has a mean Z-score of 0 (Stein et al. 2004).

mostly seen in the large cities in the Western Netherlands that could no longer be supplied with food. Supplies were restored very soon after liberation on May 5, 1945.

The famine had a strong impact on size at birth. Infants born at the end of the famine showed a birth weight decrease of about 300 gm (Sindram 1953, Stein and Susser 1975). Together with the birth weight changes there was a decline in length at birth and in head circumference. The decline was only seen in infants exposed to famine during the last trimester of pregnancy. Birth weights recovered immediately after Liberation and infants conceived during the famine and born after the war had normal birth weights again (Stein et al. 2004).

The famine as a natural experiment

The Dutch famine can be investigated as a 'natural experiment'. A large number of individuals in the Western Netherlands were exposed by circumstances beyond their control to increasing levels of starvation. Pregnant women were exposed during different stages of pregnancy. The dates of birth of their infants provide information on the timing of exposure in relation to the stage of gestation. These stages represent potential 'critical periods' for development and long-term health. Possible long-term effects can be evaluated by comparing health outcomes in individuals exposed to prenatal famine with health outcomes in unexposed controls. These controls can comprise individuals born before or after the famine (time controls) or individuals born at the time of the famine but in non-famine areas (place controls). In addition, outcomes can be compared in siblings without famine exposure (sibling controls).

In this setting, there are several ways to define critical exposure periods. Most studies of the Dutch famine define prenatal famine exposure by place and date of birth (Stein et al. 1975). This assumes a gestation of 40 weeks for each pregnancy. Sometimes mothers' reported Last Menstrual Period (LMP) rather than birth weight can be used to estimate the time of conception (Lumey et al. 2007). If LMP is available this can be more helpful for studies of famine exposures during the periconceptional period or very early pregnancy.

In famine studies of individuals with hospital birth records (Lumey et al. 2007) we characterized prenatal famine exposure by determining the gestational ages (in weeks after LMP) during which the mother was exposed to distributed food rations of less than 900 kcal/day. Accordingly, we considered the

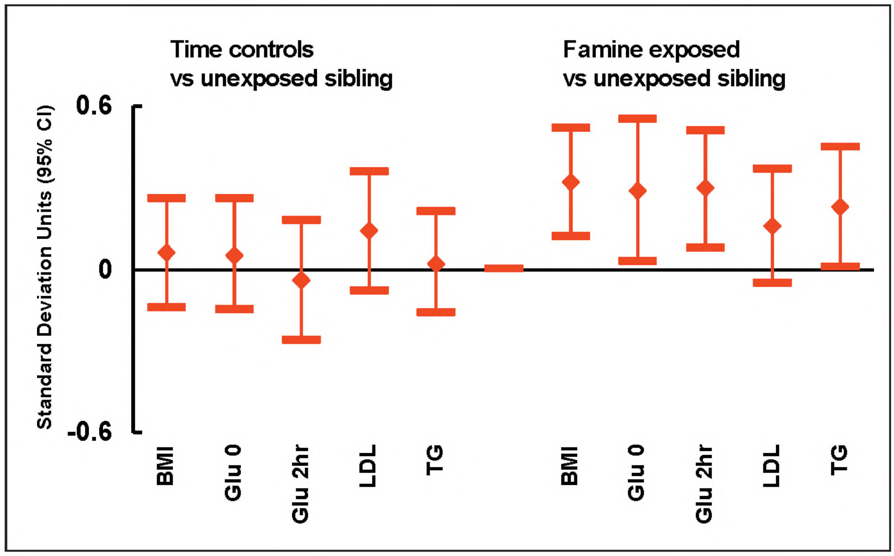


Figure 4. Between sibling outcome differences in Body Mass Index (BMI), fasting Glucose (Glu 0), 2hr Glucose from Glucose Tolerance Test (Glu2 hr), fasting LDL cholesterol (LDL) and Triglycerides (TG), all measured at age ~58 years. Point estimates in Standard Deviation (SD) Units with 95% Confidence Intervals. Left panel: Unexposed time controls vs siblings; Right panel: Famine exposed individuals vs siblings. Data from several studies combined (Stein et al. 2007, Lumey, Stein and Kahn 2009, Lumey 2009).

mother exposed in gestational weeks 1-10, 11-20, 21-30, or 31 to delivery if these gestational time windows were entirely contained within this period. Pregnancies with LMP between 26 November 1944 and 4 March 1945 were thus considered exposed in weeks 1-10; between 18 September 1944 and 24 December 1944 in weeks 11-20; between 10 July 1944 and 15 October 1944 in weeks 21-30; and between 2 May 1944 and 24 August 1944 in weeks 31 to delivery. No individuals were exposed during the entire gestation period.

In famine studies of individuals without birth records, including military conscripts (Ekamper et al. 2014, Ravelli, Stein and Susser 1976, Stein et al. 1972), prenatal famine exposure can only be classified by the date of birth in relation to distributed food rations.

Follow-up studies of clinic populations

As described elsewhere (Lumey et al. 2007), we identified for one study all live-born infants in three clinics in the famine cities Amsterdam, Rotterdam, and Leiden who were born between February 1945 and March 1946. In addition, we sampled births in 1943 and in 1947 in these clinics as unexposed time controls. A current address was obtained by population register tracking and traced individuals were invited to participate in a telephone interview and in a clinical examination, together with a same-sex sibling not exposed to the famine serving as a family-control. We conducted about 1,000 interviews and clinical examinations between 2003 and 2005.

Body size and glucose and lipid metabolism

The study showed an increase in body weight, BMI, and waist circumference after prenatal famine exposure, especially in women (Stein et al. 2007). These findings are in agreement with other studies (Ravelli et al. 1999).

In addition, we found elevated serum levels of fasting and 2hr glucose in a glucose challenge test (Oral Glucose Tolerance Test, OGTT) among famine-exposed subjects compared to unexposed controls and associations with type 2 diabetes (Lumey, Stein and Kahn 2009) and LDL-cholesterol and triglycerides (Lumey 2009). With earlier diabetes findings (Ravelli et al. 1998), several studies in the Netherlands point towards a link between prenatal famine and glucose metabolism. More work is needed however in aggregated data with larger numbers to refine critical exposure windows in pregnancy and to evaluate sex-specific effects.

The impact of prenatal famine on Body Mass Index (BMI), blood glucose levels, LDL-cholesterol

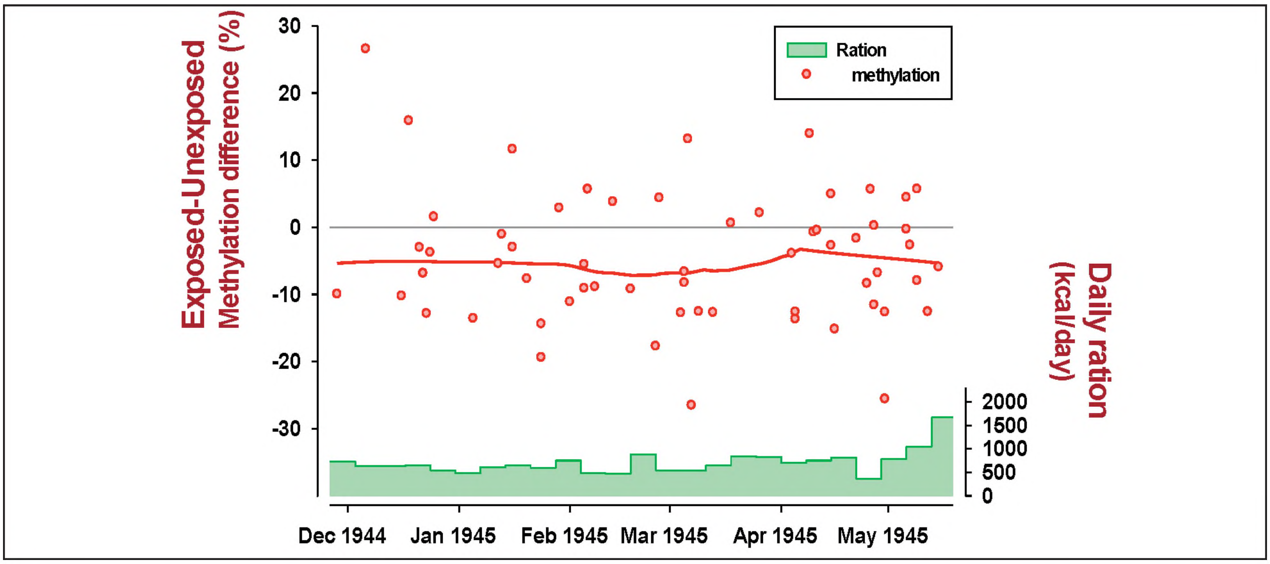


Figure 5. Differences in IGF2 DMR methylation at age ~58 years between individuals prenatally exposed to famine and their same sex siblings. X axis: date of mother's last menstrual period of the famine exposed pregnancy. Each red dot depicts the methylation difference of a same-sex sibling pair comprising a famine exposed individual and its unexposed sibling. To describe the difference in methylation according to estimated conception dates, a smoothed lowess curve (red) is drawn. The average distributed rations (kcal/day) (scaled on Right y-axis) between December 1944 and June 1945 are depicted in green (Heijmans et al. 2008).

and triglycerides is especially clear when the outcomes are contrasted with unexposed sibling controls who took part in the same examination. This comparison shows an adverse famine effect at age ~58 years controlling for maternal genes and early family environment. In the time-controls, born in the famine cities but before or after the war, we see no differences with their unexposed siblings. This is reassuring as neither the time-controls nor the sibling controls were exposed to prenatal famine.

DNA methylation

Gene expression is sensitive to environmental signals. Regulating mechanisms can increase or decrease gene expression depending on environmental conditions at critical phases over the lifecourse. It appears that the pre-natal period may be one of these phases.

We studied the Insulin-like growth factor II (*IGF2*) gene in men and women who had been exposed to famine in early pregnancy or in late pregnancy. The *IGF 2* gene is under epigenetic control and has been used in many studies of growth dysregulation and cancers, some of which show hypo-methylation of this locus.

We selected unexposed same-sex siblings as study controls. For each study pair, comprising an exposed individual with an unexposed sibling control, the outcome of interest was the difference in methylation between the siblings (Heijmans et al. 2008).

In Figure 5, each within pair difference in methylation % is represented by a dot, and the average difference over time is represented by a solid line. Pairs are arranged by mother's last menstrual period in relation to the famine. In individuals exposed to famine early in pregnancy, the average methylation of the gene was 5% lower compared to an unexposed same-sex sibling (Heijmans et al. 2008).

These findings suggest that nutrition very early in life can cause permanent epigenetic changes in humans. Additional studies show that persistent chan-

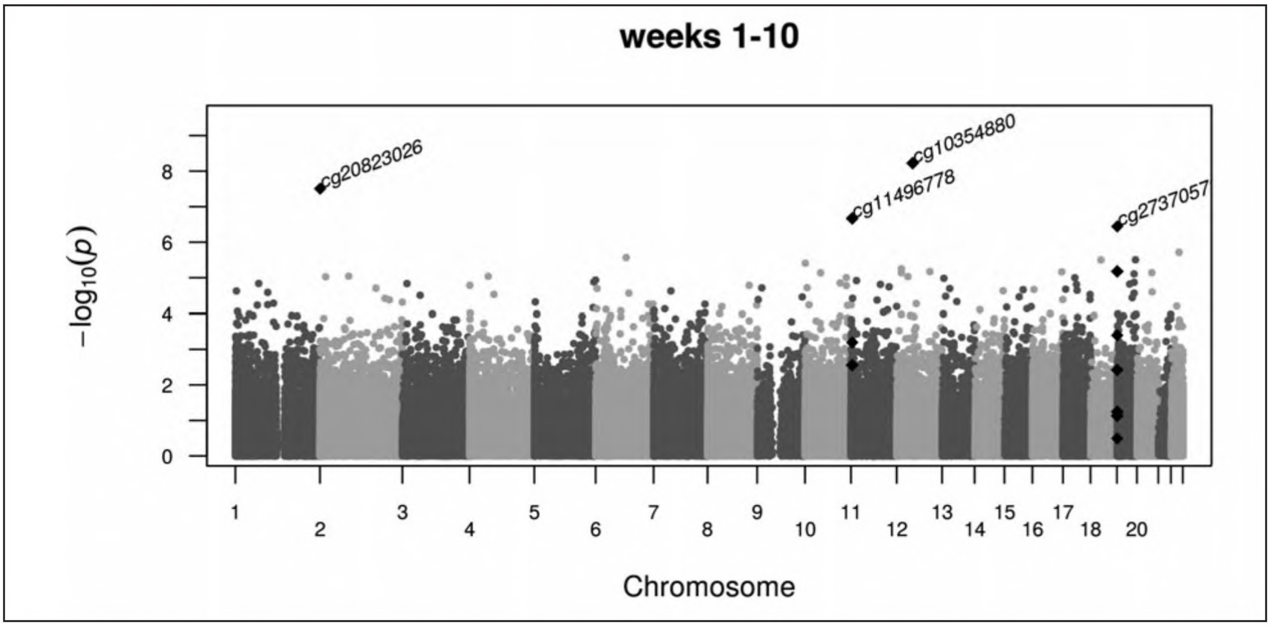


Figure 6. Manhattan plot of specific CpG associations at age ~58 years with prenatal famine exposure during weeks 1-10 of gestation. Shown are the -log10 P-values (y-axis) of the association between DNA methylation at single CpG dinucleotides and famine exposure along the autosomal chromosomes (x-axis). Marked by the CpG dinucleotide identifier are the CpG dinucleotides significant after multiple testing. These and adjacent nominally significant CpG dinucleotides are depicted as black diamonds (Tobi et al. 2015).

ges in DNA methylation elsewhere in the genome may be common, depending on sex and the timing of the exposure (Heijmans et al. 2009, Tobi et al. 2009).

In further studies, with a focus on genomic regions with differential methylation after prenatal famine, we identified specific changes at regions with regulatory potential in the subgroup of individuals with very early famine exposure around the time of conception in relation to their sibling controls (Tobi et al. 2014). Expanding this study to all exposure trimesters, and evaluating genome-wide DNA methylation data generated by the Illumina 450K BeadChip, we established that prenatal famine can affect DNA methylation at specific CpG dinucleotides linked to genes involved in growth, development, and metabolism (Tobi et al. 2015). Interestingly, and of great importance, the changes at the loci were only seen after famine exposure in weeks 1-10 of gestation, and not after exposure in any of the other gestation weeks.

Mortality among military conscripts

30 years ago, investigators had explored the relation between prenatal famine and health measures in young adults, using the health examinations from over 400,000 Dutch men tested for military service at age 18 years. It turned out that prenatal famine was not associated with intelligence scores (Stein et al. 1972), but the men exposed to famine in early and mid-gestation did show a weight increase at the upper end of the scale compared to unexposed controls (Ravelli, Stein and Susser 1976).

Because all men in the Netherlands of the birth cohorts 1944-1946 were examined for military service, these records provide information on the entire surviving male population and the large numbers needed for reliable effect estimates.

There was also an increased risk of schizophrenia in this study population among births conceived at the height of the famine (Susser et al. 1996). The schizophrenia findings were later replicated in studies based on the Chinese famine of 1959-1961 (St Clair et al. 2005, Xu et al. 2009).

As the conscripts grew older, there was increasing interest in evaluating the impact of prenatal famine on mortality. From the conscript records, we selected for further study the subgroup of approximately 25,000 men who had been born at the time of the famine in six affected cities in the Western Netherlands together with 10,000 unexposed time controls born before or after the famine in the same cities and 10,000 place controls born outside the famine region. These men were followed from age 18 through the national population and death records to study time and cause of death in relation to the timing of prenatal famine exposure.

We found a 10% increase in mortality after famine exposure in early gestation but not in middle or late gestation, even after adjustment for social class, education at age 18, or other risk factors at that age for later mortality (Ekamper et al. 2014).

These findings again suggest that the timing of famine exposure in relation to the stage of pregnancy is critical for later health.

Looking at the causes of death, we documented close to 2,000 deaths from cancers, 1,000 from heart diseases, 1,400 from other natural causes and 500 from external causes after more than 1,8 million person-years of follow-up. We found no increase in the mortality from cancers or cardiovascular disease after prenatal famine exposure during any stage of gestation. There was a 20-40% increase however in mortality from the combined other natural causes or from external causes such as reported suicides and accidents after famine exposure in the first trimester of gestation (Ekamper et al. 2015). The number of deaths in these subgroups is still too small however for analysis by stage of gestation. Further follow-up of these cohorts is therefore needed, as most men are still alive and a longer observation period will provide more accurate estimates for deaths from specific causes with larger numbers.

Conclusions

1. The setting of the Dutch famine offers special opportunities to study the relation between prenatal nutrition and adult disease and to address specific questions about fetal programming.

2. Even under extreme famine conditions, birth size and body proportions vary only with exposure to famine at the end of gestation and not with exposure at the beginning of gestation. In general, birth size or body proportions should therefore not be used as a marker of pregnancy nutrition in the study of adult disease.

3. Clinical examinations conducted ~60 years after the famine show unhealthy changes in weight, BMI, and glucose, LDL-cholesterol and triglyceride serum levels after prenatal famine exposure. These differences hold when the health examinations of famine exposed individuals are compared with their unexposed siblings, controlling for maternal genes and early family environment. The number of individuals with clinic examinations in separate studies is still too small to examine the impact of early, mid. and late gestation exposure with confidence.

4. Epigenetic studies indicate that the early gestation period and not middle or late gestation is the critical time-window during which the fetal environment may affect the human blood methylome in adults. The functional implications of these findings need further exploration.

5. Mortality studies of conscripts with prenatal famine show an increased mortality from 18-63 years in men exposed in early gestation but not in men exposed in mid or late gestation. This again points to a specific sensitive period of early gestation for later health effects.

Acknowledgements

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Diet, disease, and health in prehistory and history: The foraging to farming transition

Clark Spencer Larsen

Abstract

The transition from a lifeway based on production and consumption of wild plants and animals to domesticated plants and animals began some 10 to 12 thousand years ago, originating in a dozen or more independent centers and spreading around the globe. Today, nearly all humans are dependent on domesticated plants and animals for meeting all dietary and nutritional needs. A rapidly expanding bioarchaeological record based on analysis of stable isotope data for carbon and nitrogen and paleopathology from around the globe is providing new understanding of the impact of this transition on human health. Consumption of cereal grains meets energy requirements, but provides insufficient nutrition, resulting in decline in health and well-being. Specifically, bioarchaeological study from a range of settings around the world reveals a decline in oral health (dental caries, periodontal disease) and skeletal health (nonspecific and specific infectious disease). The former reflects the increased consumption of carbohydrates, associated changes in oral flora, and conditions conducive to poor oral health. The latter reflects increasing population size, aggregation, and sedentism, and circumstances that promote the maintenance and spread of pathogens. This period of time is important to study because it provides the context for who we are as a species today and looking for answers to questions about our future status, viability, and sustainability moving forward.

Introduction

The success of humans today, numbering more than 7 billion at last count, is linked to sustainable food production, largely derived from production of domesticated plants and animals. These food sources provide the nutrition necessary for reproduction, growth and development, and health through the years of adulthood. Today, our species is completely dependent upon these plants and animals for its survival. This dependency has been so for only a tiny part of the history of humans. Humans and human-like ancestors have been around for some 6 to 7 million years, but humans first started consuming domesticated plants and animal just 10 to 12 thousand years ago. And, even then, the first record of domestication shows that the amount of domesticated vs. wild resources in daily diet was quite small and involved just a few places on the globe. But, domestication must have been of value for humans, if for no other reason that it fueled a remarkable economic and population growth such that virtually all humans living today are completely dependent on domesticated food sources, especially cereal crops. It is clear that without farming, the globe and the record of humanity that occupies it would be a very different place, at least certainly with a much lower world population size.

As it has been in the last several millennia, the growth of population and its sustainability in the 21st century is highly linked to food production, and especially to the so-called superfoods–maize, wheat, and rice. Anthropologists and other social and behavioral scientists are very curious about the foraging-to-farming transition, and issues relating generally to the transition from living on exclusively wild to exclusively domesticated plants and animals, the intensification of this major economic change once it was set into motion, and its outcomes. They ask the following fundamental questions: Why and when did the shift occur? How did it spread? What were the benefits and costs for those societies that adopted domesticated plants and animals? The first two questions are not easy ones to answer, but in general we know that plant domestication arose independently in at least a dozen primary centers throughout the world (and likely more), including in North America, South America, Asia, and Africa. Europe was not a primary center, but it rapidly adopted domesticated plants and animals as a central food source. The western Asian source of key domesticates – wheat, barley, and rye–first got to southern Europe and spread northward, reaching Scandinavia by six thousand years ago (various in Whittle and Bickle, 2014).

There has long been a debate about the vector for the spread of agriculture into Europe, earliest in southern Europe and latest in northern Europe reaching Denmark and Sweden relatively late. Did it arrive via immigrants from western Asia bringing with them the seeds of the idea, so to speak, or was it via cultural diffusion not involving actual people moving, just the ideas? The archaeological record based on the study of plants, material culture, and ancient DNA is beginning to show that the process involved migration by farmers and their replacement of local hunter-gatherers is highly unlikely. Rather, Europe in the Holocene during the transition from foraging to farming involved considerable movement of both ideas and people. In reality, then, the spread of agriculture throughout the continent was complex (Linderholm, 2011; Robb, 2014). And, that is similarly the case in other localities around the world.

This paper addresses the outcomes of the agricultural transition, and especially as these outcomes are based on the study of ancient human skeletal remains recovered from archaeological sites. The following discussion focuses primarily on the general patterns of diet, disease, and health for assessing quality of life generally. The discussion here employs the science of bioarchaeology–the study of human remains from archaeological settings–in order to identify answers to questions about costs and benefits of a lifeway based in part or in whole on production and consumption of domesticated food sources, especially plants. Human remains provide a fund of information about health, especially with respect to the impact of consumption of domesticated plants and a range of issues pertaining to diet, lifestyle, and changing living circumstances (Larsen, 2015). Domesticated plants are carbohydrates, and thus, they provide a central source of energy, but have nutritional deficiencies that serve to lessen the body's ability to be in a state of homeostasis and health. In addition, in comparison of forager and farmer lifestyle, there are general differences in social organization and settlement pattern whereby the living conditions associated with plant production are characterized as generally larger, more concentrated groups of people living in semipermanent to permanent settlements.

Thus, combining what we know about the biology of bones and teeth and how environmental factors affect these tissues in growth and development through the life course gives the study of bioarchaeology a central position in the ongoing dialog regarding the recent history of health, especially over the course of the last 10,000 or so years when farming is first introduced, spread globally, and intensified. If for no other reason, this period of time is important to study because it provides the context for who we are as a species today and looking for answers to questions about our future status, viability, and sustainability moving forward (Brooke and Larsen, 2014; Larsen, 2006; Steckel and Rose, 2002).

Documenting diet from the dead: The bioarchaeological record

The foods we eat have a considerable role to play in our health and wellbeing, largely because the foods we consume provide key nutrients necessary for maintenance of bodily functions, growth, development, and replacement of body tissues (including bone), and well-being overall. The application of geochemistry and stable isotope analysis, especially of stable isotope ratios of carbon (^{12}C, ^{13}C) and nitrogen (^{14}N, ^{15}N) have provided an explosive increase in our understanding of dietary and associated adaptive shifts since the method was first introduced by the collaboration of an archaeologist and a geochemist in the late 1970s (van der Merwe and Vogel, 1978; Vogel and van der Merwe, 1977). This event commenced a revolution in dietary reconstruction, opening up an understanding for the timing and spread of plant domestication throughout much of the world (Larsen, 2015). Unlike dietary reconstruction from plant and animal remains, stable isotope analysis provides documentation of the relative importance of specific foods and proportions consumed, thereby facilitating an understanding of nutrition (Katzenberg, 2008; Larsen, 2015; Schoeninger, 2010). Thus, in addition to providing a record of the timing and spread of plant domestication, stable isotope analysis also gives us a window onto the quality of the foods consumed.

Documentation of isotope signatures passed from the foods consumed to the tissues of the consumer via metabolism of foods consumed provides a remarkably robust record of food pathways. Among the best documented examples of the importance of stable isotope analysis are from those settings involving transitions to and/or intensification of consumption of domesticated plants having C_4 photosynthetic pathways from the earlier wild plants consumed that had C_3 photosynthetic pathways. For example, in the Americas the shift from C_3 (wild varieties of plants) to C_4 (domesticated varieties of plants) occurred with the shift to and intensification of maize agriculture (e.g., Ambrose, 1987; Harrison and Katzenberg, 2003; Larsen et al., 1992, 2007; Schoeninger, 2009; Tykot et al., 2006; Wright, 2006), in Europe and Asia the shift involving consumption of millet (Bonsall et al., 2004; Le Huray and Schutkowski, 2005; Murray and Schoeninger, 1988; Pechenkina et al., 2005, 2013; Svyatko et al., 2013; Tafuri et al., 2009; Yang et al., 2012), and in Africa the adoption of sorghum and millet (White & Schwarcz, 1994). The documentation is provided via determination of the ratios of the $^{13}C/^{12}C$ (expressed as $\delta^{13}C$) in the consumer's skeletal and/or dental tissues. These ratios vary according to the amount of C_3 vs. C_4 plants in diet. In this regard, C_4 plants have less negative $\delta^{13}C$ ratios than C_3 plants, which are reflected in the tissues of the consumers.

The documentation of stable nitrogen isotope ratios provides an essential picture of the kinds of plants and animals consumed in regard to their trophic level in local food webs. Organisms that are higher in the food chain are more enriched in ^{15}N than ^{14}N, thus producing relatively higher $\delta^{15}N$ values for herbivores than plants and for carnivores than herbivores. This opens up the possibility of documenting the amount of meat in diet (higher $\delta^{15}N$ values indicated more meat consumption than lower $\delta^{15}N$ values). Owing to the highly varied diets of many human populations where they are consuming plants, herbivores, and carnivores, their stable isotope signatures tend to track somewhere between those of herbivores and carnivores. This record is complex and is influenced by consumption of seafood and a myriad of other local circumstances, but has successfully documented patterns of dietary variation in a wide range of settings (e.g., Choy et al., 2010; Pearson, 2013; Prowse et al., 2005; Katzenberg and Weber, 2009; Larsen et al., 2001).

In addition to documenting the shift from foraging to farming, the stable isotope record has been invaluable in demonstrating the pattern of change in coastal settings where prior to agriculture, foods were often dominated by marine resources, but with the adoption of agriculture, foods quickly became largely terrestrial-based to include an emphasis on less marine or meat and more plant cultigens in diets. This has been especially well documented in the Pacific region a millennium after original settlement of some islands (e.g., Field et al., 2009), in Denmark (Jørkov et al., 2010; Richards et al., 2003; Tauber, 1981, 1986) and elsewhere (Lidén, 1995). The record shows that in at least some settings of Europe the foraging-to-farming (Mesolithic to Neolithic) was generally not a gradual process, but rather, occurred rapidly, perhaps within a century.

Wear on the chewing surfaces of teeth, ranging from microscopically-visible scratches, pits, and surficial textural changes (e.g., Krueger, in press; Teaford, 1991; Ungar et al., 2008) to highly-visible alterations in form and angle of macroscopically-visible wear can yield information about diet (e.g., Burnett, in press; Smith, 1984; Walker, 1978). In general, there is more severe tooth wear in forager populations than in farming populations. For a number of Old World settings, in addition to plants, animal products such as milk have been a food of major importance in Europe, providing an energy and nutritional resource for at least eight thousand years. Recovery and analysis of the whey protein ß-lactoglobulin preserves in calculus of teeth gives an accurate representation of this food source (Warriner et al., 2014).

Health implications of diet and dietary change in the foraging-to-farming transition

The implications of the shift from foraging to farming globally and locally, be it in Denmark, Egypt, eastern North America, or virtually anywhere else where the transition took place, are well-documented in human skeletal remains. But, before addressing that record, let's look at the issue from the point of view of *expectations* of what one would expect to see in people having diets dominated by cereal crops–for example, maize, millet, wheat, and rice. Fundamentally, poor health in the consumers of these plants is predicted by a suite of observations of living people from clinical, ethnographic, and other observational research. These cereal grains:

- are deficient in or missing one or more essential amino acids, such as lysine, isoleucine, or tryptophan;
- have inadequate iron, caused by either deficiency of iron and especially presence of phytate, which prohibits full availability of iron to body tissues for growth, development, and replacement (such as in bone tissue);
- are deficient in one or more vitamins (A, the group of organic compounds that include retinol, retinal, retinoic acid; B_1, thiamine; B_2, riboflavin; B_3, niacin; B_{12}, cobalamin; C, ascorbic acid; and others);
- have clear links with malnutrition, immunosuppression and reduced ability to resist local and general infection, and increased susceptibility to a variety of pathogens (viruses, bacteria);
- are carbohydrates, creating a cariogenic oral environment and increase oral infections, dental caries, and antemortem tooth loss;
- are characteristically associated with populations living in dense, crowded, and sedentary communities, resulting in water contamination by parasites (e.g., hookworm) and/or pathogenic bacteria (such as *Vibrio cholera*, the bacteria that causes cholera).

The impact of farming on health in past populations

The above short list of attributes of the grains cultivated and consumed by the people provides the record for the testing the hypothesis that agricultural dependence will result in poorer health. The record for testing the hypothesis has been building for the better part of the last four decades, beginning with a series of regionally-based bioarchaeological studies, especially in North America (e.g., Cook, 1984; Goodman et al., 1984; Larsen, 1982, 1984), and in other settings in Europe, Africa, Asia, and South America (various in Cohen and Armelagos, 1984). This record has subsequently expanded to include numerous other investigations (Klaus and Tam, 2010; Pechenkina et al., 2013; Roberts and Cox, 2003; Temple and Larsen, 2013; various in Steckel and Rose, 2002; Cohen and Crane-Kramer, 2007; Pinhasi and Stock, 2011). The study of thousands of human remains around the world reveals some highly consistent results, but certainly with variation (Larsen, 1995, 2006). Here, I

Figure 1. Dental caries in adult mandibular dentition from Ochsenfurt, Germany, dating to ca. AD 1300-1700 (individual 41). Note the loss of most of the tooth crowns of the right second premolar and right first molar. The right second molar was lost antemortem. Image courtesy of Leslie L. Williams.

present a brief summary of what bioarchaeologists have learned about health changes in the last 10 thousand years with respect to the foraging to farming transition and its later intensification. Bioarchaeologists employ a variety of measures of health and living conditions. For purposes of this paper, I focus on dental caries, periodontal disease, and periostitis to illustrate trends in these conditions as representing key aspects of health. (For discussion of other indicators, see Larsen, 2015.)

Some of the most consistent evidence showing clear evidence of health declines is revealed in study of dental caries, a disease process characterized by focal demineralization of dental tissues by acids produced by bacterial fermentation of dietary carbohydrates. The process usually commences in grooves and fissures of the chewing surfaces of unworn teeth, followed by engagement of the tooth crown generally, and in most extreme circumstances, loss of the crown, extending into or involving the entire tooth root (Figure 1). The basic gradient from low to high prevalence based on level of commitment to agriculture is straightforward, but the degree of rise varies considerably, in part owing to differences in age composition of comparative samples. That is, the longer someone is alive, the greater the chances of having caries. The

Figure 2. Antemortem tooth loss in adult mandibular dentition (individual 14) from Ochsenfurt, Germany, dating to ca. AD 1300-1700 (individual 14). Missing teeth–those lost prior to death–include the right first, second, and third molars. Image courtesy of Leslie L. Williams.

condition is also highly influenced by food preparation technology. Grains prepared into soft gruels will provide a relatively more cariogenic environment for the bacteria (e.g., *Streptococcus mutans*) that produce the acids that dissolve the tooth enamel and other dental tissues. Moreover, there is some evidence to suggest that some cultigens are relatively more cariogenic than other cultigens. For example, while certainly having cariogenic properties, rice may be less so than maize, millet, or wheat (see Domett and Tayles, 2007; Oxenham et al., 2006; Pechenkina et al., 2013; Pietrusewsky and Ikehara-Quebral, 2006). In the American Midwest, an earlier farming regime involving production and consumption of five domesticated native starchy plants 2000-4000 years ago–bottle gourd (*Lagenaria siceraria*), marshelder (*Iva annua* var. *macrocarpa*), sunflower (*Helianthus annuus* var. *macrocarpus*, and two varieties of chenopod (*Chenopodium berlandieri*) (Smith and Yarnell, 2009). These plants are cariogenic, but less so than maize (*Zea mays*), the domesticate that was introduced to societies in Eastern North American beginning by A.D. 800 or so (Smith, 1989).

Dental caries is a harbinger of other oral problems, including especially the general suite of outcomes of pathogenic oral bacteria that cause dental caries but are also implicated periodontal disease

Figure 3. Periostitis in adult tibia from Ochsenfurt, Germany, dating to ca. AD 1300-1700 (individual 76). Note the irregular surface and buildup of bone owing to processes relating to infection. Image courtesy of Leslie L. Williams.

(periodontitis), a condition that involves the accumulation of bacteria (plaque) on teeth and subsequent inflammation of the gums, loss of tissues connecting teeth to jaws, eventually resulting in the exfoliation and loss of teeth (Figure 2). Periodontitis is common in industrialized countries today, including the United States and most countries in Europe. It is becoming increasingly common in the developing world with the wider availability of low-quality carbohydrates. Like dental caries, the bioarchaeological record for periodontitis and antemortem tooth loss reveals a higher prevalence in prehistoric farmers than foragers (Bennike and Alexandersen, 2007; Clarke et al., 1986; Klaus and Tam, 2010; Nelson et al., 1999; and many others).

Dental caries and periodontitis have profound implications for general health, both for the individual and for the population as a whole. That is, a wide range of clinical and epidemiological investigations document the association between poor oral environment in earlier life and the association with increased mortality, and susceptibility to chronic, systemic health conditions such as cardiovascular disease and respiratory infections in later life (Buhlin et al., 2003; DeStefano et al., 1993). For past populations, there is a growing record for an increased risk of death for those having poor oral health. For example, individuals with dental caries and periodontal disease have an increased risk of death in Medieval populations (De-Witte and Bekvalac, 2010).

Another consistent pattern documented by bioarchaeologists in comparison of foragers and farmers or earlier and later farmers is an increase in periosteal reactions or periostitis in a wide variety of settings (Cunha et al., 2007; Danforth et al., 2007; Douglas and Pietrusewsky, 2007; Garner, 1991; Gold, 2004; Hoyme and Bass, 1962; Klaus and Tam, 2009; Larsen et al., 2007; Márquez Morfín and Storey, 2007; Martin et al., 1991; Pechenkina et al., 2007; Stodder et al., 2002). In the Dickson Mounds series from Illinois, the prevalence doubled from 31% to 67% of individuals affected in comparison of later farmers with earlier farmers (Goodman et al., 1984). Periosteal reactions are represented as bone plaques with irregular elevations of bone surfaces. The underlying production of new bone is caused by compression and stretching of blood vessels by pus, blood, and/or a variety of other factors and is the follow-up response of the bone as a healing mechanism (Weston, 2008) (Figure 3). The tibia is the most commonly affected bone, perhaps owing the minimal soft tissue separating the skin from bone and increased susceptibility to local infection from bacteria (e.g., *Staphylococcus*) entering wounds in this area of the body.

Other factors may be involved, but most periosteal reactions are likely caused by local infection. Thus, in settings where populations are sedentary and closely aggregated, this creates the circumstances for accumulation of debris, poor living conditions, and decreased sanitation, all the ideal circumstances for the increased chances of infection in circumstances involving traumatic injury and wounding. Moreover, under circumstances where nutritional quality is reduced in farming populations, the synergy between infection and poor nutrition likely exacerbates the ability of immune system to resist the infection. That is, there is a synergy between infection and malnutrition (Keusch and Farthing, 1986; Scrimshaw et al., 1968)–malnourished individuals are less resistant to infectious pathogens and are rendered more susceptible to infectious disease; conversely, infection worsens nutritional status. Overall, the bioarchaeological record provides strong support for the epidemiological model that an increase in population size and density contributes to a decline in community health at least as it is represented by periosteal reactions in comparison of foragers and farmers and less intensive with more intensive farmers. Similarly, a number of Old World and New World settings display clear evidence in the skeletal remains for specific infectious diseases, such as nonveneral (endemic) syphilis and tuberculosis (e.g., Bruwelheide et al., 2010; Cole and Waldron, 2011; Lambert, 2006; Marden and Ortner, 2011; Mays et al., 2003; Powell and Cook, 2005; Roberts and Manchester, 2005; Sandford et al., 2002), with an especially prominent record in Eastern North America (e.g., Danforth et al., 2007; Hutchinson, 2004; Hutchinson and Norr, 2006; Lambert, 2000; Smith, 2008; Powell, 1990, 1994; Powell and Cook, 2005; Wilson, 2005).

Much of the record discussed in this paper pertains to the Neolithic and other prehistoric settings involving early farmers. The *European History of Health Project*, a collaboration of a group of 75 European, Canadian, and American biological anthropologists, has documented oral and skeletal pathology from a data set of some 75,000+ skeletons, both on data previously and newly collected for dental caries, antemortem tooth loss, and periostitis (Wittwer-Backofen et al., 2009; Marques et al., 2009). Preliminary analysis reveals increases that continue during the Medieval period when populations are highly dependent on cereal grains and live in crowded community settings. The elevation in caries and antemortem tooth loss become especially elevated in the pre-industrial and industrial periods, likely in part fueled by access to refined sugar (Larsen et al., 2012; Wittwer-Backofen et al., 2009).

So, if farming and focus on agricultural products–especially cereal crops–are so bad, then how is it that human population size has so dramatically increased? In other words, there would appear to be a contradiction between the quality of diet and the explosion in human population size. In fact, analysis of the skeletal record indicates that birthrates and population growth were fueled by increasing fertility that accompanied the foraging-to-farming transition (Bocquet-Appel, 2002, 2011; Buikstra et al., 1986; Larsen et al., 2007; Milner et al., 1989), likely made possible by the availability of foods promoting earlier weaning and hence, reduced birth spacing (Buikstra et al., 1986; Lambert, 2009). Like current populations in developing nations where there is a coupling of high birthrates and poor nutrition, the study of past populations underscores the point that survival to reproductive years may not necessarily be healthy. Nonetheless, survival and reproduction can support a growing population as long as enough resources—good or bad—are available.

Conclusion

The key findings in assessing the impacts and outcomes on human health in the transition from foraging to farming and later intensification of farming include the following:

1. Diet and nutrition are key elements of quality of life and living conditions generally;
2. In comparison with prehistoric foragers, early farmers show a general pattern of declining health, but with regional variation;
3. While early farming may have been generally deleterious to health, rice farming may have been less so than maize or wheat farming owing to the lesser amount of phytate in the former than the latter.
4. Post-Neolithic farming involves intensification of earlier patterns and origins of evolving superfoods—wheat, maize, and rice—in the 21st century; our foods and health outcomes today have their roots deep in the human past. The development of poor oral health beginning 10,000 years ago laid the foundation for continuing oral health issues, and may represent the conditions necessary for the origins of a range of chronic health conditions, including cardiovascular disease and other circumstances resulting in earlier death. That is, in currently living populations those with poor oral health are predisposed to the development of chronic health issues in later life. It is likely that the same holds true for past populations.
5. The tide of poor health has turned in some of the modern world, made possible by improved health care, appropriate hygiene, and better nutrition, especially for upper echelons of society. Unfortunately, today as in the past, better conditions are available primarily for the minority of the population having access to these developments.

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14

Food supply, health and economic development in England and Wales during the eighteenth and nineteenth centuries

Bernard Harris

Abstract

This paper examines food availability in England and Wales during the eighteenth and nineteenth centuries and its implications for the history of height, health and economic development.

SCI.DAN.H. 4 · 7 · FOOD, POPULATION AND HEALTH – GLOBAL PATTERNS AND CHALLENGES
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During the last thirty years, anthropometric historians have devoted increasing attention to the study of human height and, to a lesser extent, weight. As Phyllis Eveleth and James Tanner (1976: 1; 1990: 1) explained, 'the average values of children's height and weights reflect accurately the state of a nation's public health and the average nutritional status of its citizens, when appropriate allowance is made for differences, if any, in genetic potential'. Anthropometric historians have used this insight to develop new ways of measuring changes in the health and physical well-being of populations in many different parts of the world in both the short and long terms (Floud, Harris and Hong 2014: xiii-xiv).

In 2011, Floud, Fogel, Harris and Hong (2011) published a major synthesis of the research which had been undertaken into changes in the average height and weight of populations in Europe and North America since *circa* 1700. They also linked this work to the theory of 'technophysio evolution' which Fogel and Costa had advanced some years earlier (Fogel and Costa 1997). This theory rested 'on the proposition that, during the last three hundred years, humans have gained an unprecedented degree of control over their environment – a degree of control so great that it sets them apart not only from all other species, but also from all previous generations of *homo sapiens*' (Fogel and Costa 1997: 49). Floud and his coauthors incorporated this theory into a five-stage model of human development, linking the investments in health made by each generation to the health and productivity of its successors.

Floud *et al.* also examined the relationship between different measures of health and improvements in diet, sanitation, environmental conditions and medical care. They devoted particular attention to the estimation of the number of calories which might have been consumed by people living in England and Wales during the eighteenth and nineteenth centuries and explored the extent to which variations in the food supply may have underpinned improvements in health and mortality. They argued that increases in food availability may have contributed to economic growth by increasing the proportion of the population which was able to engage in remunerative labour and the number of hours for which they could work. They also explored the extent to which these changes were associated with a more equitable distribution of food within the household and suggested that this may have had particular implications for the health of children and adult women.

The changing body was only one of a series of publications which included more- or less-detailed estimates of the amount of food available for human consumption in England and Wales at different points in time since the late-thirteenth century. Overton and Campbell published their initial estimates in 1996 (Overton and Campbell 1996; 2006) and Robert Allen published his series in 2005. Other figures have been published by Muldrew (2011), Kelly and Ó Gráda (2013a; 2013b), Meredith and Oxley (2014), and Broadberry *et al.* (2011; 2015). Many of these publications reached quite different conclusions about trends and levels of food availability during this period. Both in their original publications, and in the work they subsequently co-authored with Broadberry, Klein and van Leeuwen, Overton and Campbell argued that average per capita consumption remained at a low and relatively constant level from the end of the thirteenth century to the middle of the nineteenth century (Overton and Campbell 1996; 2006; Broadberry *et al.* 2011; 2015). Allen (2005) argued that consumption levels began at a lower level than Overton and Campbell but doubled between 1270 and 1500, before rising again between 1700 and 1750 and then falling back. Muldrew (2011) argued that food availability increased sharply from the end of the sixteenth century, reaching a peak of over 5000 calories per head in 1770. Kelly and Ó Gráda (2013) compared Allen's estimates for 1750 and 1800 with Broadberry *et al.*'s estimates for 1770 and 1800 and concluded that the truth lay somewhere between them. Meredith and Oxley (2013) applied some of Floud *et al.*'s conversion factors to Muldrew's data, but still concluded that consumption levels fell substantially from the late-eighteenth century.

Since the publication of their original estimates, Floud and his coauthors have corrected an error in their calculations and made a series of additional revisions in response to these other publications. These changes are described in the first three sections of this paper. Section 4 discusses the impact of the changes on Floud *et al.*'s assessment of changes in the composition of the average diet between *circa* 1700 and 1913. Sections 5 and 6 examine changes in the composition of British diets and attempt to estimate the proportions of the population consuming different amounts of food under conditions of 'low, 'moderate' and 'high' egalitarianism. The concluding sections compare Floud *et al.*'s revised and corrected estimates with those published by other authors and assess the impact of the changes on our understanding of the relationship between food availability, health and economic development in Britain before the First World War.

Corrections to Floud *et al.*'s original estimates

When Floud *et al.* published their initial figures, they provided two different sets of estimates. These were based on the use of different sources to estimate the average yields of different cereal crops in the years 1750, 1800 and 1850. Based on these estimates, they concluded that the average number of calories consumed per person per day in 1750 was either 2100 calories (Estimate A) or 2237 calories (Estimate B) (Floud *et al.* 2011: 154-7, 205-9). When these figures were combined with their other figures, they implied that average consumption either fell between 1700 and 1750, or rose almost imperceptibly. However, both of the calculations for 1750 included a spreadsheet error which was subsequently identified by Deborah Oxley. Once this error had been corrected, the revised estimates for 1750 increased to 2327 calories (Estimate A) or 2515 calories (Estimate B) (see Table 1). Nevertheless, Floud *et al.*'s estimates still fell well below those published by Allen (2005) and Muldrew (2011), and they remained very similar to those published by Broadberry *et al.* (2011).

Extraction rates

When estimating the number of calories obtained from cereal production, it is also necessary to make allowances for seeding, the consumption of grain by animals, processing, distribution and wastage. Floud

Table 1. Calories derived from domestically-produced wheat and other sources in England and Wales, 1700-1850: Published and revised estimates.

	Published figures: Estimate A					Corrected figures: Estimate A				
	Domestically-produced wheat	Other domestically-produced cereals and pulses	Total calories from domestically-produced cereals and pulses	Calories from all other sources (including imports)	Total calories	Domestically-produced wheat	Other domestically-produced cereals and pulses	Total calories from domestically-produced cereals and pulses	Calories from all other sources (including imports)	Total calories
1700	502.43	1,063.94	1,566.37	662.26	2,228.63	502.43	1,063.94	1,566.37	662.26	2,228.63
1750	430.09	845.03	1,275.12	824.84	2,099.96	657.28	845.03	1,502.32	824.84	2,327.16
1800	732.04	634.08	1,366.12	1,106.00	2,472.12	732.04	634.08	1,366.12	1,106.00	2,472.12
1850	706.28	375.22	1,081.50	1,422.58	2,504.08	706.28	375.22	1,081.50	1,422.58	2,504.08
	Published figures: Estimate B					Corrected figures: Estimate B				
	Domestically-produced wheat	Other domestically-produced cereals and pulses	Total calories from domestically-produced cereals and pulses	Calories from all other sources (including imports)	Total calories	Domestically-produced wheat	Other domestically-produced cereals and pulses	Total calories from domestically-produced cereals and pulses	Calories from all other sources (including imports)	Total calories
1700	502.43	1,063.94	1,566.37	662.26	2,228.63	502.43	1,063.94	1,566.37	662.26	2,228.63
1750	526.28	886.19	1,412.46	824.85	2,237.31	804.29	886.19	1,690.48	824.84	2,515.32
1800	717.77	615.12	1,332.89	1,106.00	2,438.89	717.77	615.12	1,332.89	1,106.00	2,438.89
1850	729.03	392.74	1,121.77	1,422.60	2,544.37	729.03	392.74	1,121.77	1,422.60	2,544.37

Source: Floud, Fogel, Harris and Hong 2011: 160, 205-9

Table 2. Differences between estimates, using Broadberry et al.'s extraction rates

	Crop	Floud *et al.* A (Calories per person per day)				Floud *et al.* B (Calories per person per day)			
		1700	1750	1800	1850	1700	1750	1800	1850
(1) Original extraction rates	Wheat	502.43	657.28	732.04	706.28	502.43	804.29	717.77	729.03
(2) Original extraction rates	Rye	250.76	131.15	76.31	14.09	250.76	131.15	68.75	14.01
(3) Original extraction rates	Barley	598.22	421.05	314.98	227.49	598.22	417.67	306.75	226.80
(4) Original extraction rates	Oats	122.19	204.98	172.02	101.14	122.19	269.00	183.94	119.88
(5) Original extraction rates	Total	1473.60	1414.46	1295.35	1049.00	1473.60	1622.11	1277.21	1089.72
(6) Broadberry *et al.*'s extraction rates	Wheat	548.19	735.53	839.66	820.81	548.19	900.04	823.29	847.25
(7) Broadberry *et al.*'s extraction rate)	Rye	359.69	197.28	120.11	22.18	359.69	197.28	108.22	22.05
(8) Broadberry *et al.*'s extraction rates	Barley	467.31	320.68	233.73	126.43	467.31	318.10	227.63	126.05
(9) Broadberry *et al.*'s extraction rates	Oats	154.69	233.13	173.52	52.35	154.69	305.95	185.54	62.05
(10) Broadberry *et al.*'s extraction rates	Total	1529.88	1486.62	1367.02	1021.77	1529.88	1721.37	1344.68	1057.40
(11) Difference between (5) and (10)		56.28	72.16	71.67	(27.23)	56.28	99.26	67.47	(32.32)

Sources: Harris, Floud and Hong 2015: Table 12.

et al. (2011: 205-9) used data from the United States to estimate the proportion of cereals and pulses 'lost' as a result of seeding, animal consumption and processing, and allowed an extra ten per cent for wastage. They assumed that the gross extraction rate (the amount of food available for human consumption as a proportion of the gross yield of each crop) remained constant over the whole of the period from 1700 to 1850.

Kelly and Ó Gráda (2013b: 2) argued that 'Floud *et al.*'s assumed proportions of wheat, barley and rye entering gross product … seem to be on the low side' and that 'the assumed losses from processing and distribution may be too high except, perhaps, in the case of barley'. Meredith and Oxley (2014: 180) also thought that Floud *et al.*'s 'assumptions regarding loss … are arguably very high' although, as we shall see, this did not prevent them from accepting the same rates when performing their final calculations.

As we have already seen, Floud *et al.* assumed that the overall proportions of each crop which were 'lost' in the form of seeding, animal consumption, processing and waste remained constant over the whole of their period. However, it is probably more reasonable to assume that seed ratios fell as yields rose; and that the losses associated with crops such as oats and barley would have increased as a result of changes in the proportion of food fed to animals and in the conversion of barley to beer. Harris *et al.* (2015) have therefore recalculated their data using the extraction rates proposed by Overton and Campbell (1996; 2006). These rates also underpin the data published by Broadberry *et al.* (2011). The results are not radically different from Floud *et al.*'s original calculations but they do make a difference to the overall figures. These differences are shown in more detail in Table 2.

The problem of internal trade

One of the main differences between the different contributions to these debates has been the amount of attention devoted to the number of calories associated with imports and exports. Both Allen (2005) and Muldrew (2011) focused exclusively on domestic production and assumed that all of the calories produced in England (or England and Wales) were consumed within the same territory. Broadberry *et al.* (2011) and Floud *et al.* (2011) did make allowances for imports and exports but reached different conclusions regarding their magnitude. However, as both Kelly and Ó Gráda (2013a) and Meredith and Oxley (2014) have noted, neither Broadberry *et al.* nor Floud *et al.* took any account of the flow of items between the constituent parts of the United Kingdom. Meredith and Oxley (2014: 172) claimed that 'Scotland, Wales and especially Ireland were key suppliers [of English food]: as early as the 1750s and 1760s, beef imports from Ireland trebled, and there were big increases in butter and pork'. Kelly and Ó Gráda (2013a: 1154) argued that 'allowing for imports of Irish meat and butter and … Scottish cattle would increase Broadberry *et al.*'s total by a further 60/75 kcals in 1800 and by perhaps 20/25 kcals in 1750'. They also suggested that the inclusion of Irish grain imports would have 'accounted for about 100 kilocalories daily per head in 1850 and perhaps double that before the Great Famine' (*ibid.*: 1155).

Harris *et al.* (2015) have now attempted to fill the gap in their original analysis by including new estimates of the number of calories derived from a range of Irish imports, including processed meat and dairy products, livestock, cereals and potatoes. They concluded that these sources added an extra 89 calories to the average daily diet at the end of the eighteenth century and 155 calories fifty years later. However, they also acknowledged that the data were subject to limitations and that these were compounded by the choice of base years (see Table 3).

Floud *et al.*: Revised estimates

Harris *et al.* (2015) have now incorporated the results of these additional calculations into their previous findings. The effects are shown in the following two graphs. Figure 1 compares the corrected version of Floud *et al.*'s original findings with new figures which reflect the introduction of Overton and Campbell's extraction rates and the new data on calories derived

Table 3. Calories derived from Irish dairy, meat and grain imports

	1700	1750	1800	1850
Grain imports*	0.00	0.00	31.70	64.49
Meat imports**	0.00	0.00	10.52	5.83
Butter imports†	0.00	0.00	21.77	50.71
Livestock	0.00	0.00	5.30	33.84
Potatoes‡	0.00	0.00	19.77	0.00
Total	0.00	0.00	89.06	154.87

Notes
* The average number of calories derived from grain imports during the period 1841-5 was 140.86 calories.
** In estimating the calorific value of meat imports, we have assumed that 50% of the imported beef and pork was consumed elsewhere.
† We have also assumed that the number of calories derived from butter in 1850 was the same as the average figure for the years 1823-5.
‡ If we had used the recorded data for 1800, the calorific value of imported potatoes would have been worth 0.01 calories per person per day. If we had used Bourke's figures to calculate the number of calories derived from potatoes in a 'normal' year and applied this figure to 1850 (i.e. ignored the effects of the Famine), the calorific value of potato imports in this year might have been equivalent to approximately 30 calories per person per day.
Sources: See Harris *et al.* 2015: Tables 2, 13, 16, 22-24 and text.

from Irish imports. Both of the revised sets of estimates suggest that food availability rose during the first half of the eighteenth century. The revised version of Estimate A suggests that the rate of increase accelerated during the second half of the eighteenth century before levelling off. The revised version of Estimate B suggests that there was a small decline in food availability during the second half of the eighteenth century, followed by a slightly larger increase. Both estimates suggest that food availability was significantly higher even than the corrected version of Floud *et al.*'s original estimates. However, the revised estimates are still much closer to Broadberry *et al.*'s estimates than to the much higher figures proposed by Allen (2005) and Muldrew (2011) (see Figure 2). They are also well below the 'compromise' figures proposed by Kelly and Ó Gráda (2013a; 2013b) and by Meredith and Oxley (2014) for the years before 1800.

The distribution of calories

The preceding sections have concentrated on various attempts to estimate the average number of calories available per head but it is also important to consider how food was distributed within the population and its relationship to nutritional needs.

Floud *et al.* sought to address this question in two ways. In the first instance, they transformed the number of calories per head into the number of calories per consuming unit, or adult male equivalent. This takes account of the fact that men and women, and adults and children, have different energy needs. They then attempted to estimate the distribution of calories between different deciles of the population by making different assumptions about levels of inequality. They estimated that between eighty and ninety per cent of the French population consumed fewer than 3000 calories per consuming unit on the eve of the French Revolution (Floud *et al.* 2011: 53). The bottom forty per cent of the Anglo-Welsh population in 1800 also fell below this figure (Floud *et al.* 2011: 56).

Table 4 presents new figures based on the revised estimates of average calorie consumption presented in this paper. Although the new estimates suggest that the average number of calories was greater than previously supposed, a significant proportion of the popu-

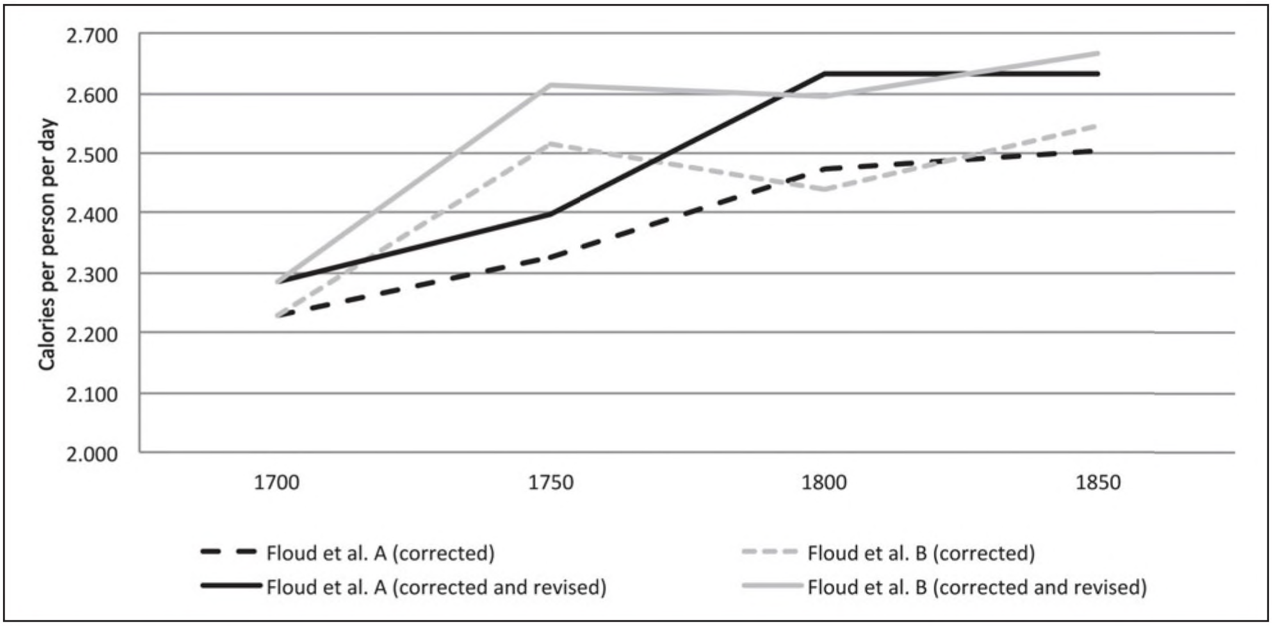

Figure 1. Calorie availability in England and Wales, circa 1700-1909/13: Corrected and revised estimates.

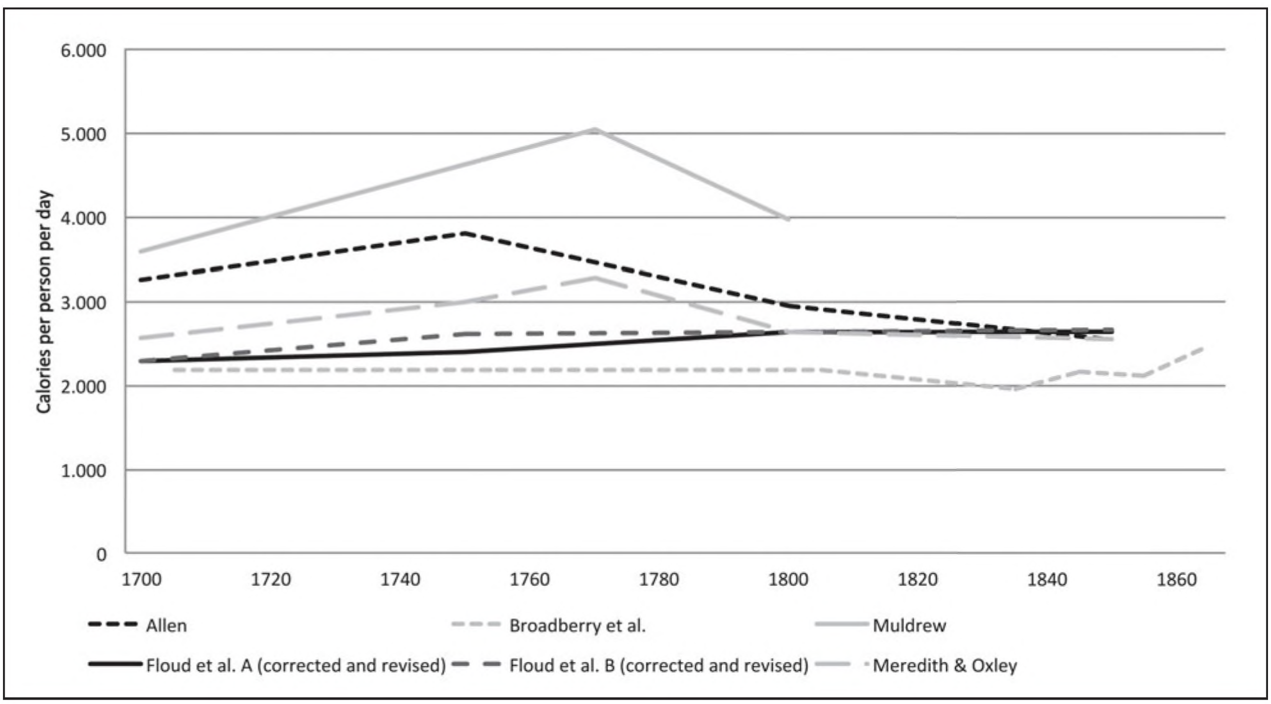

Figure 2. Calorie availabilty in England and Wales, circa 1700-1871.

Table 4. Calories per consuming unit, by decile of the population, under conditions of 'low', 'medium' and 'high' egalitarianism

	% calories consumed	1700	1750A	1750B	1800A	1800B	1850A	1850B	1909/13
					High egalitarianism (s/x=0.2)				
Highest	13.90	4,203	4,407	4,802	4,873	4,804	4,833	4,898	5,409
9th	12.06	3,648	3,825	4,168	4,230	4,169	4,195	4,251	4,694
8th	11.22	3,392	3,556	3,875	3,933	3,877	3,901	3,953	4,365
7th	10.59	3,202	3,357	3,659	3,713	3,660	3,683	3,732	4,121
6th	10.06	3,041	3,189	3,475	3,526	3,476	3,497	3,544	3,913
5th	9.57	2,893	3,033	3,305	3,354	3,307	3,327	3,372	3,723
4th	9.09	2,747	2,881	3,139	3,186	3,140	3,160	3,202	3,536
3rd	8.58	2,594	2,720	2,964	3,007	2,965	2,983	3,023	3,338
2nd	7.98	2,412	2,529	2,756	2,796	2,757	2,774	2,811	3,104
Lowest	6.96	2,104	2,207	2,405	2,440	2,405	2,420	2,453	2,708
					Medium egalitarianism (s/x=0.3)				
Highest	16.11	4,867	5,104	5,562	5,644	5,563	5,598	5,673	6,264
9th	13.03	3,938	4,129	4,499	4,566	4,501	4,529	4,589	5,067
8th	11.70	3,535	3,706	4,039	4,098	4,040	4,065	4,120	4,549
7th	10.74	3,245	3,403	3,708	3,763	3,709	3,732	3,782	4,176
6th	9.95	3,006	3,152	3,435	3,486	3,436	3,458	3,504	3,869
5th	9.24	2,792	2,928	3,190	3,237	3,191	3,211	3,254	3,593
4th	8.56	2,586	2,712	2,955	2,999	2,956	2,975	3,014	3,329
3rd	7.86	2,375	2,490	2,714	2,754	2,714	2,731	2,768	3,056
2nd	7.06	2,132	2,236	2,437	2,473	2,437	2,452	2,485	2,744
Lowest	5.77	1,745	1,830	1,994	2,024	1,995	2,007	2,034	2,246
					Low egalitarianism (s/x=0.4)				
Highest	18.42	5,565	5,835	6,358	6,452	6,360	6,400	6,486	7,161
9th	13.91	4,202	4,406	4,801	4,872	4,803	4,833	4,897	5,408
8th	12.07	3,646	3,823	4,166	4,228	4,168	4,194	4,250	4,692
7th	10.79	3,260	3,418	3,724	3,779	3,726	3,749	3,799	4,195
6th	9.76	2,948	3,091	3,369	3,418	3,370	3,391	3,436	3,794
5th	8.86	2,675	2,805	3,057	3,102	3,058	3,077	3,118	3,443
4th	8.01	2,420	2,538	2,765	2,806	2,766	2,783	2,821	3,114
3rd	7.16	2,164	2,269	2,472	2,509	2,473	2,489	2,522	2,785
2nd	6.22	1,879	1,970	2,147	2,178	2,147	2,161	2,190	2,418
Lowest	4.79	1,448	1,518	1,654	1,679	1,655	1,665	1,687	1,863

Notes. For further discussion of the definitions of 'low', 'medium' and 'high' egalitarianism and the methods used to estimate consumption levels in different population deciles, see Floud *et al.* 2011: 49-57. In the current table, values below 3000 calories per consuming unit have been shaded. The light shading indicates estimates based on the revised versions of Floud *et al.*'s Estimate A and the dark shading indicates estimates based on the revised versions of Estimate B.

Table 5. Calories per adult male equivalent and requirements for heavy work.

	1700	1750	1800	1850	1909/13
Estimate A (Revised)	2,284.91	2,399.32	2,632.85	2,631.72	2,976.72
Estimate B (Revised)	2,284.91	2,614.58	2,595.42	2,666.92	2,976.72
Conversion ratios	0.7553	0.7564	0.7506	0.7564	0.7646
Estimate A (Revised)	3,025.17	3,172.03	3,507.66	3,479.26	3,893.17
Estimate B (Revised)	3,025.17	3,456.61	3,457.79	3,525.80	3,893.17
Requirement for heavy work			3,376.89	3,470.28	3,433.05

Sources: Calories per head: see Figure 2 and text; Conversion ratios: Floud *et al.*, 2011, p. 167; Requirements for heavy work: Floud *et al.*, 2011, p. 169.

lation consumed fewer than 3000 calories per consuming unit under conditions of what Floud *et al.* (2011:53) called 'medium egalitarianism'. The table also illustrates the extent to which these calculations are sensitive to changes in the degree of egalitarianism which can be assumed. Changes in the distribution of calories may therefore have been just as important as changes in the overall supply of calories in determining the relationship between consumption and health during this period (see also Allen 2009).

Floud *et al.* (2011: 167-9) also sought to compare the distribution of calories with the number of calories required to perform different kinds of labour. They suggested that the number of calories needed to enable an adult male of average height and weight to perform eight hours of 'heavy work' was between 3377 and 3470 calories per day. The new estimates suggest that the average number of calories per consuming unit may have reached this figure either by 1750 (Estimate B) or 1800 (Estimate A), but the proportion of the population whose consumption fell below this level remained substantial (see Table 5). This shortfall was likely to have continued to exert an effect on the health of working-class men and their families throughout the nineteenth century (Gazeley and Newell 2015).

The composition of average diets

When Floud *et al.* published their original estimates, they also estimated the number of calories derived from different food sources. The results suggested that the proportion of calories derived from cereals fell substantially between 1700 and 1750 but then rose between 1750 and 1800 (Floud *et al.* 2011: 161). The revised estimates suggest that the proportion of calories derived from cereals fell during the first half of the eighteenth century but to a much smaller extent, and that there was relatively little changes in this figure over the next century. However, the percentage of calories derived from cereals fell dramatically between 1850 and 1909/13, and there were corresponding increases in the proportions derived from meat and dairy products and other food sources, including sugar (Table 6).

Lean and plenty

It is difficult to analyse Allen's data in great detail because of a lack of information in the original paper, but Harris *et al.* (2015) have compared their data with Muldrew's. They argued that Muldrew's figures exaggerated the amount of land under cultivation; underestimated the proportions of different crops which were used for human consumption; and overestimated the number of animals providing meat and, espe-

Table 6. Sources of calories, by food group, in England and Wales, 1700-1909/13.

Estimate A: Crop yields from Chartres, Holderness and Allen										
	Calories					Percentage				
Source of calories	1700	1750	1800	1850	1909-13	1700	1750	1800	1850	1909-13
Cereals	1,517	1,318	1,485	1,433	999	66.37	54.94	56.41	54.44	33.55
Fish	24	24	24	24	32	1.04	0.99	0.90	0.90	1.08
Fruit and vegetables (inc. potatoes)	167	189	266	338	349	7.31	7.86	10.12	12.84	11.72
Meat and dairy products	538	786	745	689	1,067	23.52	32.75	28.31	26.19	35.85
Other	40	83	112	148	530	1.75	3.46	4.25	5.62	17.80
Grand total	2,285	2,399	2,632	2,632	2,977	100.00	100.00	100.00	100.00	100.00
Estimate B: Crop yields from Turner, Beckett and Afton										
	Calories					Percentage				
Source of calories	1700	1750	1800	1850	1909-13	1700	1750	1800	1850	1909-13
Cereals	1,517	1,553	1,463	1,469	999	66.37	59.40	56.37	55.06	33.55
Fish	24	24	24	24	32	1.04	0.91	0.92	0.89	1.08
Fruit and vegetables (inc. potatoes)	167	169	251	338	349	7.31	6.46	9.68	12.65	11.72
Meat and dairy products	538	786	745	689	1,067	23.52	30.06	28.72	25.84	35.85
Other	40	83	112	148	530	1.75	3.17	4.32	5.55	17.80
Grand total	2,285	2,614	2,595	2,667	2,977	100.00	100.00	100.00	100.00	100.00

Sources: See text.

cially, dairy products. They also rejected Meredith and Oxley's (2014) attempts to construct a new series by combining Muldrew's figures for land use and crop yields with Floud *et al.*'s data on imports and exports and extraction rates during the eighteenth century, and then merging these data with Floud *et al.*'s original data for 1850 and 1909/13. They argued that this approach introduced inconsistencies in the use of different figures to estimate calorie values and made implausible assumptions about changes in land use between 1800 and 1850. They also rejected Meredith and Oxley's attempts to reconcile their new series with other data on the cost of living and adult male heights.

Food, wages, population and health

Meredith and Oxley (2014) argued that prices in agricultural areas rose significantly during the second half of the eighteenth century and that this was consistent with growing food shortages. However, Figure 3 suggests that increases in price levels were matched by improvements in farm workers' wages from the 1750s onwards. Moreover, recent attempts to examine changes in both wages and prices suggest that the average value of real wages across the country as a whole was also increasing, albeit very slowly, over much of this period (Figure 4).

Floud *et al.* (2011: 262-3) also argued that their original figures were 'broadly consistent' with the

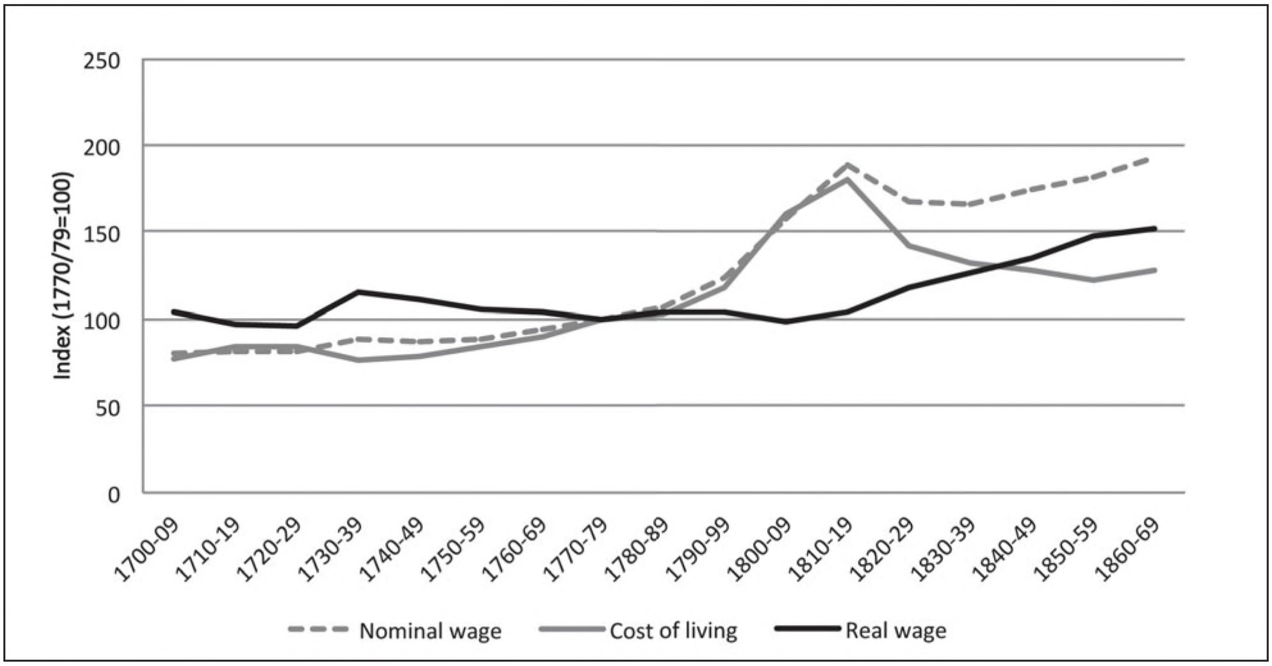

Figure 3. Farm worker's wages, 1700/09-1860/69.
Source: Clark, 2007, pp. 130-4.

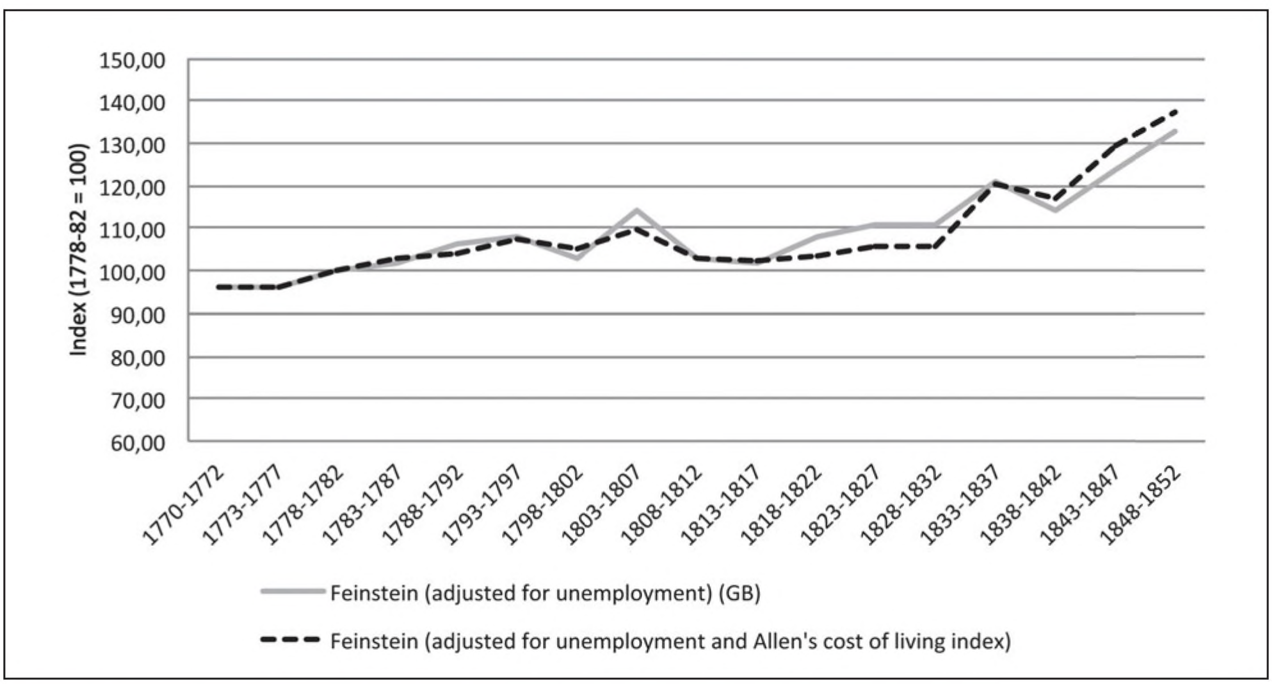

Figure 4. Real wages 1770/2-1848/52.
Sources: Feinstein, 1998, p. 648; Allen, 2007, p. 36.

height trends published by Floud, Wachter and Gregory (1990) 20 years earlier. Harris *et al.*'s (2015) revised and corrected figures suggest that this is still true of Estimate A, though not necessarily of the revised and corrected version of Estimate B. However, Meredith and Oxley (2014) have also recalculated Floud, Wachter and Gregory's height data. They argue that their recalculated data are much more closely aligned with their revised food data.

One of the main issues in this debate concerns the interpretation of trends in heights of men who were recruited by different branches of the armed forces. Floud, Wachter and Gregory (1990: 111-5) argued that it was appropriate to pool the results obtained from the analysis of the heights of the Army and the Marines because each branch drew its recruits from the same population. They also argued that it was appropriate to use unweighted samples of soldiers and marines for the same reason. Meredith and Oxley (2014: 186-7) agreed that the results ought to be pooled. However they argued that they should be weighted according to the shares of soldiers and marines in the armed forces because the two branches operated different height standards and that a failure to weight the results would be analogous to estimating the height of the underlying population from disproportionate numbers of males and females. Harris *et al.* (2015: 179) rejected this analogy, and argued that the results should be pooled without weighting, providing one used the correct procedures to move from the heights of the recruits to those of the population from which they were drawn.

In a series of papers, Bodenhorn, Guinnane and Mroz (2013; 2014; 2015) have criticised anthropometric historians for failing to take account of the impact of sample selection factors. In their earliest paper, they claimed to 'show strong evidence of selection using micro-data on the heights of British soldiers of the late-eighteen[th] and nineteenth centuries' and concluded that the results reported by previous authors may owe less to 'variations in living standards during a soldier's formative years' than to 'the process determining selection into the sample' around the time of recruitment (Bodenhorn *et al.* 2013: 2). However, it is arguable that they have failed to take account of all the work which has been undertaken on this topic. Contemporary commentators identified a series of factors which might have undermined the capacity of military recruiting statistics to shed light on changes in the health of the underlying population during the second half of the nineteenth century and many of these issues were discussed at length by Floud, Wachter and Gregory before they published *Height, health and history*. They concluded that 'the source is not seriously biased and that, after some statistical correction, the data suggest a gradual improvement in the … average height of the British working class' between 1870 and 1914 (Floud, Wachter and Gregory 1985).

Conclusion

Although Harris *et al.*'s corrected estimates are still well below the levels suggested by Allen (2005) and Muldrew (2011), as well as those suggested by Meredith and Oxley (2014), they are significantly greater than the figures published by Floud *et al.* in 2011, and the new data on extraction rates and Irish imports raise them further. What are the implications of these changes for our understanding of the relationship between changes in food supply and the path of economic and demographic development?

In their original study, Floud *et al.* (2011, pp. 162-3) argued that changes in food availability were 'broadly consistent' with changes in height and life expectancy during the late-eighteenth and early-nineteenth centuries and this supported the view that improvements in food availability were one cause of improvements in height and mortality during this period. Although this statement is still true of the revised version of Estimate A, it is less true of the revised version of Estimate B. The difference between the two estimates therefore helps to reinforce Joyce Burnette's (2014, p. 115) recent call for new research into the changing level of agricultural productivity before 1870.

The revised figures also suggest that the amount of food which was available for human consumption may have approached conventional levels of adequacy for a much larger section of the population at a somewhat earlier date that Floud *et al.* originally supposed. However, this conclusion should be treated cautiously. It is important to remember that eighteenth- and nineteenth-century consumers were exposed to much poorer environmental conditions, with a much higher incidence of diarrhoea and other enteric diseases. This problem would have been compounded by the high percentage of cereals in their diets. When Dasgupta and Ray (1990: 215-6) examined the nutritional status of individuals living under pre-industrial conditions in the modern world, they concluded that such individuals needed to increase their consumption by more than 35 per cent in order to derive the same nutritional benefit from the food they consumed as individuals living under more favourable circumstances (see also Floud *et al.* 2011: 130, 162; Schneider 2013).

It is also important to recognise the importance of inequalities in the distribution of calories. As this paper has shown, even under conditions of 'high' egalitarianism, it is likely that more than half the population consumed fewer than 3000 calories per adult male equivalent at the start of the eighteenth century and this may still have been true of consumers in the bottom decile of the population on the eve of the First World War. Many contemporary writers also pointed out that, when times were hard, it was women and children who often bore the greatest cost and the effects of this may have been felt, not only by themselves, but also by future generations (Harris 1998; 2008; Floud *et al.* 2011: 160-2; Osmani and Sen 2003).

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A survey of Danish cookbooks 1616-1970

Caroline Nyvang

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Abstract

This article presents a survey of Danish first edition cookbooks printed between the years 1616 and 1970. The purpose is to offer a broad periodization which can be used as a backbone for further research into the cultural significance of food. In the article I conclude that the coming of different author groups constitute the most significant changes in the Danish cookbook genre and argue that these reflect larger societal transformations. These conclusions are founded on a quantitative survey combined with a qualitative study of the 753 available Danish cookbooks published 1616-1970.

During the cultural turn in the 1970s and '80s, food culture emerged as an area of study within the humanities and social sciences.[1] As part of their field studies, anthropologists had long documented cultural norms of eating, but food was given unprecedented attention with the advent of structuralism in the 1960s. In a number of influential texts, Claude Lévi-Strauss (1908-2009), Roland Barthes (1915-80) and Mary Douglas (1921-2007) emphasized the dinner table as a fruitful site for studying the inner workings of communities. Barthes, for instance, notoriously proposed that "[o]ne could say that an entire 'world' (social environment) is present in and signified by food."[2] In this way, food served as a microcosmos in which the social structures of any community could be uncovered and studied.

Whereas the anthropologists studied the dinner table as a site for social integration, the works of sociologists have often highlighted the segregating forces inherent in food consumption. Although neither Thorstein Veblen (1857-1929) nor Pierre Bourdieu (1930-2002) has treated food as an object of study in itself, both "conspicuous consumption" and the theory of distinction have become central to researchers who have turned their attention towards food as a means for constructing social boundaries.[3]

Thus, despite their differences, both the anthropological and sociological traditions embrace the idea that food is a way of communicating a sense of belonging. Sharing a meal can thus be likened to the sharing of ideals and serves as a central element in identity formations. This assumption also holds a potential for the study of history. Focusing on how people have ascribed meaning through (and to) food is

1. Peter Scholliers, "Twenty-five years of studying un Phènoméne social total: Food history writing on Europe in the nineteenth and twentieth centuries", *Food, Culture and Society: An International Journal of Multidisciplinary Research* 10 (2007): 449-71.
2. Roland Barthes, "Toward a Psychosociology of Contemporary Food Consumption", i *Food and Culture: A Reader*, red. Carole Counihan og Penny Van Esterik (Routledge, 1997), 23. The piece originally appeared in *Annales: Économies, Sociétiés, Civilisations* 5, 1961.
3. Pierre Bourdieu, *Distinction: A Social Critique of the Judgement of Taste*, transl. Richard Nice (Cambridge Mass.: Routledge, 1984); Thorstein Veblen, *The Theory of the Leisure Class* (New York: Dover Publications, 1994).

not only an entry into the bellies, but also, possibly, into the hearts and minds of people in the past.

Although promising in theory, approaching food as an all-encompassing social phenomenon also poses a practical problem to the historian. In writing cultural histories of food, we are first and foremost challenged by the fact that we – contrary to other scholars in the field – are not able to observe past meals. We might be able to savor potsherds and analyze the stomach content of bog bodies, but the bygone meal, along with the associated norms and ideals, is per definition elusive. This has lead historians to employ new types of primary source material such as advertisements, menus, women's magazines and cookbooks in order to gain insights into the meaning making involved in deciding what's for dinner.

What is a cookbook?

Cookbooks belong to the realm of prescriptive literature and do not necessarily reflect common practices, now or in the past. But even if the cookbook is merely considered prescriptive, it holds important clues to the community that is assumed to use it. With its formulaic and didactic format, printed cookbooks enable the proliferation of standardized recipes across both geographical and social boundaries. For this reason, in recent decades, cookbooks have been recognized as a valuable source for the study of gendered, ethnic and national identity formations.[4] Following this line of research, my case for the inclusion of cookbooks into the history of food is also founded on a basic assumption that changes in discourse reflect broader cultural transformations. By tracing the macroscopic changes in the Danish Cookbook genre, I offer a broad periodization of first edition Danish cookbooks published 1616–1970.[5]

As far as we know, 1616 marks the year of the first Danish printed cookbook. The cut-off in 1970 has been selected for two reasons: first, the number of cookbooks increased significantly during the 1970s and '80s, rendering it virtually impossible to revise all publications within a reasonable timeframe; second, as Denmark became subject to the common food and agricultural policies of the EEC in the early 1970s, the conditions for discussing food radically changed. Thus, in many ways, the year 1970 marks the beginning of a new era to the cookbook and in Danish food history alike.

In determining which books to include, I have set up a number of guidelines. By means of the Danish National Bibliography[6], I have reviewed all listed first edition publications of 16 pages or more that has been published in Danish within the changing national borders.[7] This approach includes translations, but excludes the publications from former colonial possessions whenever these were written in languages other than Danish. In keeping with the guidelines of international bibliographers, measured by the number of pages, a book must consist of 2/3 recipes in order to be included in my bibliography.[8] For the years 1616–

4. Arjun Appadurai, "How to Make a National Cuisine: Cookbooks in Contemporary India", *Comparative Studies in Society and History* 30, 1 (January 1988): 3–24; Anne Bower, *Recipes for reading: community cookbooks, stories, histories* (Amherst: University of Massachusetts Press, 1997); Janet Theophano, *Eat my words: reading women's lives through the cookbooks they wrote* (New York N.Y.: Palgrave, 2002); Liora Gvion, "What's Cooking in America?: Cookbooks Narrate Ethnicity: 1850-1990", *Food, Culture and Society: An International Journal of Multidisciplinary Research* 12 (March 2009): 53–76.

5. This article combines insights from two different research projects, focusing respectively on printed cookbooks from the 19th and 20th century. Partial results have previously been presented in Caroline Nyvang, "Medie og måltid: danske trykte kogebøger i 1800-tallet", i *Synet på mad og drikke i det 19. århundrede*, ed. Ole Hyldtoft (København: Museum Tusculanum, 2010), 145–231; Caroline Nyvang, "Danske trykte kogebøger 1900-70. Fire kostmologier" (PhD thesis, University of Copenhagen, 2013).

6. *Dansk Bogfortegnelse*, the Danish National Bibliography, was not started until 1841. But the Royal Library of Copenhagen has records of all legal deposit publications since 1697.

7. Publications with less than 17 pages are considered pamphlets, not books, according to the Danish National Bibliography.

8. See, for instance, Elizabeth Driver, *A bibliography of cookery books published in Britain, 1875-1914* (London: Prospect Books, 1989); Henry Notaker, *Printed Cookbooks in Europe, 1470-1700. A*

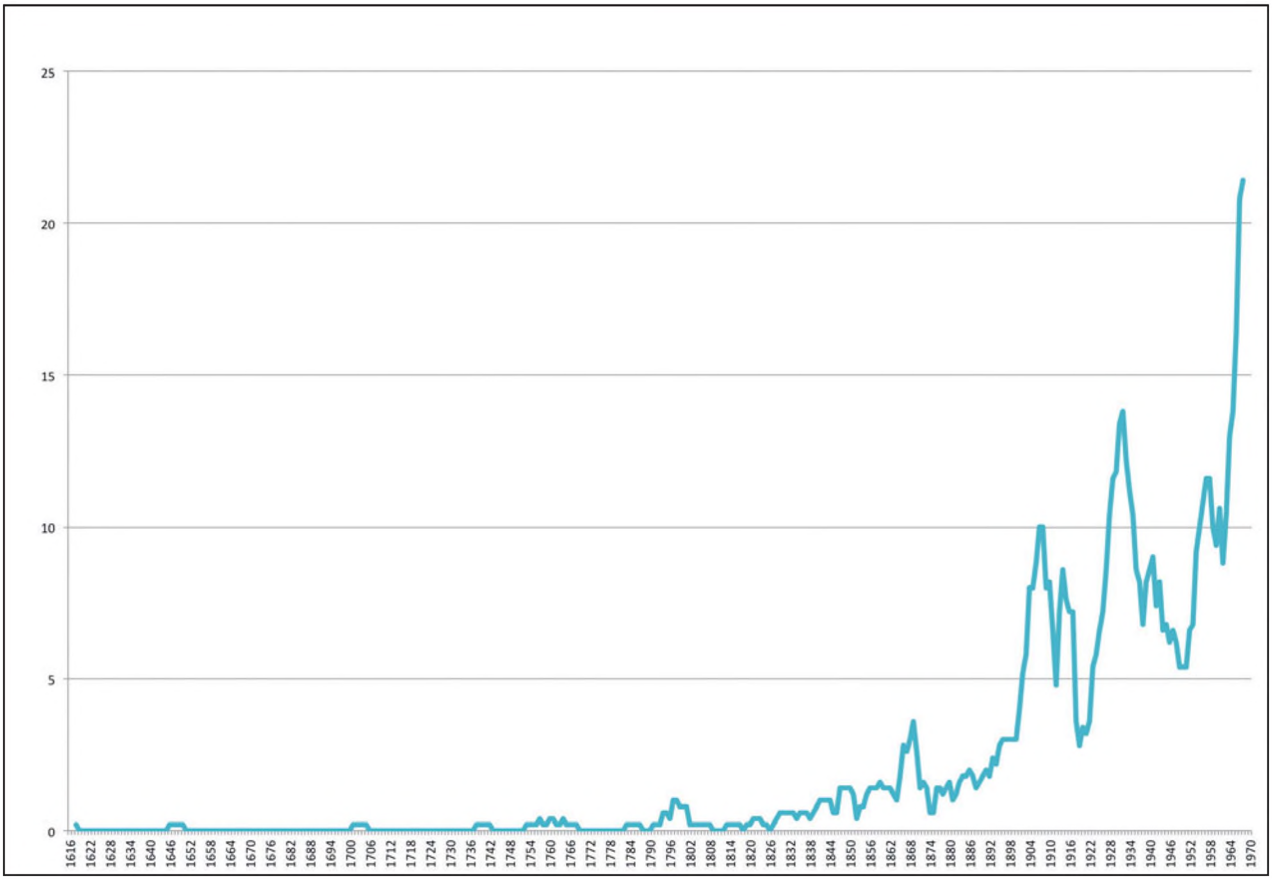

Fig. 1. Danish printed cookbooks 1616-1970. Sources: Nyvang, Caroline. "Medie og måltid: danske trykte kogebøger i 1800-tallet". In *Synet på mad og drikke i det 19. århundrede*, ed. by Ole Hyldtoft, 145–231. København: Museum Tusculanum, 2010. Nyvang, Caroline. *Danske trykte kogebøger 1900-70. Fire kostmologier*. PhD thesis, University of Copenhagen, 2013.

1970, a total of 756 publications match these very criteria. Their distribution across time is shown in figure 1.

The graph shows a steady increase in the number of first editions published throughout the centuries. In economic terms, books can be considered a luxury good.[9] Thus, with increasing incomes, the demand for books is expected to rise, in percentage terms even beyond the actual income gain. It is only fair to assume that this tendency would be augmented for cookbooks as a subgenre. As has been pointed out by several researchers, when caloric needs are met, food increasingly seems to fulfill other wants. Nutritionist Eileen Satter, for one, has proposed a hierarchy of food needs in the form of a Maslowian pyramid. With this she argues that a sufficient, acceptable and reliable supply of foodstuffs are prerequisites to the interest in food as "good-tasting, novel and instrumental".[10]

Scholars within the field of cultural studies have proposed similar theories. In his famed *La Distinction* (1979), Bourdieu operates with an opposition between the taste for "necessity" and that for "luxury"

Bibliography of Early Modern Culinary Literature (HOUTEN: HES & De Graaf Publishers BV, 2010).

9. C. Hjorth-Andersen, "A model of the Danish book market", *Journal of Cultural Economics* 24, 1 (2000): 27–43 estimates that the income elasticity of books is close to 1.97.

10. Ellyn Satter, "Hierarchy of Food Needs", *Journal of Nutrition Education and Behavior* 39, 5 (September 2007): 187–88.

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Kongelige Danske
og i Henseende til alle Slags Maader
fuldstændige
Koge-, Bage-
og
Sylte-Bog,
eller
syv hundrede og ti Anviisnings-Regler,
indrettet for
Herskaber og fornemme Familier,
saavelsom for
alle og enhver især,
hvorefter der kan tillaves saavel kostbare, som ordinaire
Retter, saaog hvorledes endeel Have-Frugter skal
tørres og indsyltes,
samt
52 Regler om Confiturer.
Alt efter mange Aars egen Erfaring oprigtig og uden
al Interesse lagt for Dagen af
Marcus Looft,
Mester-Kok i Itzehoe.
Tredie og forbedrede Oplag.
Kiøbenhavn, 1781.
Findes tilkiøbs hos Johann Gottlob Rothe, i hans
Boglade i No. 8. paa Børsen.

Fig. 2. Frontispiece from *Den Kongelige Danske og i Henseende til alle Slags Maader fuldstændige Koge Bage og Sylte-Bog* [*The Royal Danish and in Respect of all Manner Complete Cooking, Baking and Preserving Book*], published by in 1766 by Marcus Looft, masterchef in Itzehoe.

(or "freedom"). Whereas the French working class of the 1960s – in Bourdieu's study exponents of the taste for necessity – gives priority to food that induce a sense of fullness, the bourgeoisie, associated with the taste for freedom, emphasizes the visual appearance of food.[11] Barthes, too, noted the dualism of food serving as both nutrition and protocol, and assumed that "its value as protocol becomes increasingly more important as soon as basic needs are satisfied".[12]

Consequently, a certain level of economic surplus seems to be a precondition for both the demand for books and the interest in food beyond mere physiological needs. Viewed in this light, is it perhaps not surprising that the number of publications generally rose during times when the overall welfare increased and expenditures on food, measured as part of income, decreased for all income brackets.[13]

The graph does indeed show prominent peaks in the 1860s, at the beginning of the 20th century and in the late 1950s. These were all times of increasing prosperity, which is consistent with an idea that this would offset an increased demand for cookbooks. More notably, however, there are also peaks in times of dearth, e.g. during the First World War and the crisis ridden 1930s. Furthermore, years with a high publication rate include the war years 1915 and 1941, both of which saw a rate eight times higher than the mean for all the years examined. This indicates that the trend is not alone attributable to economic factors, and that something *else* or *more* is in play.

Despite the crude increase from 1616 to 1970, figure 1 also shows that Danish cookbooks were issued in surges separated by long periods of stagnating or falling publication frequency. A closer look at the books reveals that this pattern was first and foremost propelled by changes in author groups. These different author groups will be expounded in the following six sections, each representing a wave of publications:

11. Bourdieu, *Distinction*, 173.
12. Barthes, "Toward a Psychosociology of Contemporary Food Consumption", 25–26.
13. Nyvang, "Danske trykte kogebøger 1900-70. Fire kostmologier", 9–10.

The Early Decades – Cooks and Copycats

As figure 1 shows, from the first cookbook was issued and until the last decades of the 18th century, printed cookbooks were still a rarity. In the 17th and 18th centuries, a mere 15 new cookbooks were published. In general, these were either composed by male chefs or compiled by printers.

The early cookbooks almost exclusively addressed male chefs and were mainly written by other male chefs, working at large estates or even in royal households, cf. Marcus Looft above (Fig. 2). Their recipes were short, without precise measurements and mostly resembled *aides-mémoire* for the well versed in the art of cooking and dishing out big banquet dinners.

The oldest preserved Danish cookbook was issued in 1616. The 80-page octavo, originally published in German as *Ein Köstlich new Kochbuch* in 1598, is symptomatic to the Danish cookbook genre during its first decades. The translation was allegedly published in Danish by Salomon Sartor (d. 1642), a Copenhagen based printer primarily known for his biblical works.[14] The printer represents a second subset of "authors", who at the time worked to disperse printed recipes to a Danish readership via translations. This was possible as the Danish book market was not yet subject to international copyright laws until the signing of the Berne Convention in 1903. Therefore, in part or whole, publishers could freely translate foreign books in order to sell them under their own name. Hence, the earliest Danish cookbooks were often adaptions of English or German recipes.[15]

1837-1880s: The Housewife Writer

In many ways, the printed cookbook had a literary breakthrough in the middle of the 19th century. Although it wasn't until 1900 that new cookbooks were issued each year, the publication rate rose steeply and geographically, too, publications were now widely dispersed. Until 1831, all but one cookbook had been published in Copenhagen, but by the end of the 1860s, almost all provincial towns were publishing cookbooks.[16]

The breakthrough of the cookbook can be ascribed to several factors. The 1840s is generally recognized as a transformative phase in the history of the Danish book. This period saw an increasing interest in the educative potential of the book, and a number of technological advances enabled a larger and cheaper production of books, which paved the way to both new authors and readers.[17]

As for the cookbook, the publication rate took off after Ane Marie Mangor (1781–1965) published her successful *Kogebog for Smaa Huusholdninger* [*Cookbook for Small Households*] in 1837. Targeting an audience amongst the middle classes, Mangor's recipes gave instructions for everyday dinners serving a small family of four to six people. Selling more than 260.000 copies in the 19th century alone, the recently widowed cookbook author was the first who was really able to make a living writing cookbooks.[18] For a long time, Danish women had had a tradition for compiling and sharing handwritten recipes, but in Mrs Mangor and her cookbook they now had an impetus to present their personal collection to a publisher. Thus, with the opening of the book market, writing cookbooks became a feasible sideline business to housewives across the country, and the increasing number of

14. Harald Ilsøe, *Bogtrykkerne i København og deres virksomhed ca. 1600-1810. En bio-bibliografisk håndbog med bidrag til bogproduktionens historie*, Danish Humanist Texts and Studies 5 (Museum Tusculanum, 1992), 43–47.
15. Caroline Nyvang, "Originaler og kopister: danske trykte kogebøger 1616-1900", *Magasin fra Det kongelige Bibliotek*, 4 (2007): 15–21.
16. Caroline Nyvang, "Medie og måltid: danske trykte kogebøger i 1800-tallet", i *Synet på mad og drikke i det 19. århundrede*, ed. Ole Hyldtoft (København: Museum Tusculanum, 2010), 150–52. The place of publication is an important indication of the actual dissemination of cookbooks of the time as most were sold directly out of the printer's shop.
17. Henrik Horstbøll, *Menigmands medie. Det folkelige bogtryk i Danmark 1500-1840: en kulturhistorisk undersøgelse*, Danish Humanist Texts and Studies 19 (Det Kongelige Bibliotek: Museum Tusculanum, 1999).
18. Else-Marie Boyhus, *I lære som kokkepige: det danske borgerlige køkken 1880-1910* (Frederikshavn: Dafolo, 2000), 159.

cookbooks published in the course of the 19th century can be attributed to this new group of authors. Out of the all first editions published between 1837 and 1880, females wrote at least 92 %.[19]

1880s–1920s: The professionalization of Cooking

In the late 19th century, women who had a professional affiliation with cooking replaced the autodidact housewife as the prime author of cookbooks in Denmark. The home economics movement, which swept the country from the 1880s forward, employed a large number of women.[20] Besides offering young girls a formal education in domestic work, teachers also made a significant contribution to the cookbook genre, allowing the publication rate to increase steeply at the end of the 19th and the early 20th century.

During the second half of the 19th century, many Danes moved from the countryside to the cities. With this urbanization family units generally became smaller while the distance to the older generations increased.

Young women were often left to their own devices, as they could no longer rely on the help and guidance from parents or grandparents. The authors of a new line of cookbooks books sought to remedy this situation by giving readers a science based approach to housekeeping and organizing family life.

Moreover, these cookbooks were published in the wake of the transmission from a rural subsistence economy to a monetary household economy, which sparked a growing awareness of food's share of the household budget. Relying on caloric values relative to the price, a new measure at the time, authors would often list the content of their cookbooks according to the price of each dish, and in the recipes expenses would appear directly from the list of ingredients. Thus, in the face of a new economic reality, authors associated with the domestic science movement would accentuate food as a powerful tool in budget management.[21]

1920s-40: The Doctor's Cookbook

The 1920s and '30s saw another surge in cookbooks, yet again driven by a change in authors. With an increased focus on dietary research and following the malnutrition scare of World War I, medical doctors increasingly looked to cookbooks as a means of propagating state-of-the-art information to a broad audience.

In the public and private health resorts, established in Europe during the interwar years, many doctors were given an opportunity to observe close-hand the role of food in obtaining and maintaining good health. Especially from 1925 and onwards, as the ability to identify vitamins improved, nutritional values were added to the recipes, and cookbook authors called for a reconfiguration of traditional Danish dinner ideals towards a plant based, uncooked fare. The pot and the pan was to be put aside in favor of graters and chopping boards, and doctors often favoured recipes for raw food and vegetarian dishes. In fact, in the 15 years between 1925 and the beginning of the Second World War, more than every fourth cookbook had meatless recipes alone.[22]

The attention to micro- and macronutrient needs meant that meals were individualized in a previously unseen manner. Women, children and men with physically demanding as well as sedentary jobs had to eat according to distinct guidelines, and the social benefits of dining together was downplayed. In the doctor's cookbook, the meal thus took on a new ideal form in contrast to that of the domestic science move-

19. 65 new cookbooks were published in the years 1837–1880. Judging from the name on the front cover and/or the wording of the introduction, at least 60 of these had been written by women.

20. The first Danish home economics school was established in 1877 by Justine Saugman (1833-1920), who also authored the cookbook *Elevernes Optegnelser fra Thoreby Husholdningsskole* [*Students' Notes from Thoreby Home Economics School*] (1895).

21. Nyvang, "Danske trykte kogebøger 1900-70. Fire kostmologier", 61–84.

22. Caroline Nyvang, "Back to the Roots? Vegetarian Cookbooks as Countercuisine". Unpubl. conference paper, *ESSCS* (The London Consortium, 2010).

ment.[23] The coming of the Second World War provided a very effective hindrance to the doctors' endeavors, as vegetables and especially fruits became scarce due to import restrictions. Furthermore, the limitations on gas revoked slow cooking methods that were out of tune with the doctors' attempt to minimize vitamin loss.

1945-60s: Domestic Consultants

In the decades following the war, the domestic consultant became a seminal figure in Danish cookbooks. These consultants, many with a formal home economics education from the beginning of the 19th century, can be considered a second wave of the domestic science movement. However, unlike their predecessors, these women did not pursue teaching positions, but were mainly employed by the Danish food industry. Recipes provided an entrance into the pockets of the middleclass, and during the years of 1945-60, these domestic consultants accounted for a third of all Danish cookbooks, allowing the publication rate to once again soar.[24]

In particular, the domestic consultants targeted women who worked outside of their home. During the economic boom of the 1960s, Danish women's labour market participation increased significantly. In compliance with the busy schedule of the working mother, domestic consultants embraced the convenience of prepackaged foodstuffs and new kitchen technologies, in turn introducing dinner manners and rituals that required less effort than previously.[25]

23. Nyvang, "Danske trykte kogebøger 1900-70. Fire kostmologier", 103–14.
24. Caroline Nyvang, "Good Fare and Welfare. Perceptions of American and French Food in Postwar Danish Cookbooks", *Media food and identity*, ed. J. Leer & K.K. Povlsen, Critical Food Studies (Routledge, forthcoming).
25. Nyvang, "Danske trykte kogebøger 1900-70. Fire kostmologier", 117–34.

1955-70: The bon vivant

During the late 1950s, a number of trendsetting male intellectuals – e.g. actors, artists and journalists – began writing cookbooks, pushing the publication rate towards its ultimate peak in the late 1960s (figure 1). In lieu of any formal kitchen training, these authors rallied around the foundation of L'Académie de la Gastronomie au Danemarkin 1964.[26]

Contrary to previous publications, authors now invited guys into the kitchen. For the first time in Danish cookbooks, men were pictured in front of the stove and shopping for groceries. This shift in authority was, at least in part, driven by the fact that cooking was increasingly associated with art. Thus, the kitchen became a site for leisure and artistic production, and cooking could be deemed a creative outlet.[27]

This reconceptualization of cooking also affected the recipes. The repertoire mainly included recipes for foreign dishes with a strong fervor for Mediterranean dishes. Furthermore, the recipes were short and rarely included precise quantities, but instead relied on tactile instructions such as "tender" and "a dollop". In keeping with the artistic spirit, users of cookbooks were thus encouraged to evoke their senses while cooking. Perhaps inadvertently, these cookbooks thus came to resemble the earliest Danish cookbooks published by male chefs.

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26. Due to its homage to French cooking, the organization has no formal English title.
27. Caroline Nyvang, "I den gode smags tjeneste. Den gastronomiske bevægelse i danske trykte kogebøger 1950-70", *Tidsskrift for Kulturforskning*, 2014, 3-4, 64-81.

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16

Global food security: A grand challenge of the present times

Kirsten Hastrup

Abstract

Food security has been on the global agenda since the 1940s, when the modern UN-system was established. The immediate target was to secure sufficient food for impoverished or starving populations, mainly in the Global South. The chapter discusses the development towards present concerns with *food safety*, embracing also the Global North. A case from Greenland is presented to illustrate the complexities inherent in the notion, and not least in dealing with it.

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In this brief presentation, I shall take us through the grand and truly global challenge of food security. With shifting resource bases and environmental changes that do not respect national or even regional boundaries, with major land-grabs by powerful states that introduce mono-crops into diverse agricultural regimes and reduce independent farmers to paid labour, and with the depletion of phosporus from existing large scale agricultural lands, we have to find new solutions to feed the population of the earth, soon numbering nine billion. Many of the chapters in this volume exude optimism – in the sense that they remind us of the immense inventive powers of humankind. Let us keep that in mind, while I address, first, the global discourse on food security, and, next, give you an example from my own work in Greenland, illustrating some of the local complexities – and not leading to any immediate solutions.

Food security – a changing concept

Food security is no longer an exclusive issue for an impoverished Global South, but a truly global challenge potentially affecting the entire population of the earth. In relation to the well known issue of there not being *enough* to eat, food security has increasingly become a pervasive issue also of *unsafe* food – resulting in a virulent spread of 'northern' diseases related to obesity, Type II diabetes, and cardio-vascular malfunction. In addition to the globalization of over-eating – or just unhealthy eating – the world also faces a boundless risk of contamination of even the most local and purportedly 'purest' of food.

Let us look back just a couple of generations, to trace the emergence of food security on the international agenda. The United Nations was created in the 1940s to secure an international balance between nation-states, some of which had been at war with each other, while others were emerging in the process of decolonization. Under the new UN umbrella several organizations were designed at looking into particular areas of concern; among them were the World Health Organization (WHO) and the Food and Agriculture Organization (FAO). The concerns of these organizations were, and still are, global health and food security. In the early days of these organizations, it was largely a concern with there not being *enough* food for people in certain regions, mainly in what is now known as the Global South.

While food is a biological necessity, we must realize that hunger is also a hard *social* fact (Hastrup 1993). It deeply affects family life, reproduction, and sociopolitical relations. While, at first, it may be seen as the outcome of a simple crop failure, owing to drought or something else, at closer inspection it emerges as a comprehensive issue, deeply affecting community life and leaving long-lasting traces in whole societies. A case in point is the Irish famine, allegedly caused by potato blight, starting in 1845 and costing about one million lives and making another million flee the country. Clearly, the issue of causation is not easily narrowed down to the potato, but must also be seen in relation to the state of the Irish people within a larger scheme of history, politics, demographic development, and an increasing dependence on a single crop.

More recently, in the post-colonial era, we have seen how natural disasters, protracted drought, or warfare all of them have contributed to upsetting the balance between land and population. This gradually gave rise to a new awareness of the social and political dimensions of hunger that was eventually to transform the issue of food security from being simply a matter of local food shortages – sometimes simply seen as a means to keeping population numbers in check in a natural way, as Malthus had suggested in 1798 (1970: 242). Yet, in the 1940s when the WHO and FAO were first set up, the priority was still mostly (and importantly) to increase food supply in impoverished regions. People were entitled to life and hence to sufficient nutrition, in line with the Universal Declaration of Human Rights.

The sufficiency perspective still dominated the 1970s, exemplified by the 1974 World Food Conference in Rome. The conference took place in the wake of a devastating famine in Bangladesh, and the government attendees to the conference made the proclamation that "every man, woman and child has the inalienable right to be free from hunger and malnutrition in order to develop their physical and mental capacities," as stated in the first clause of the resulting *Declaration on the Eradication of Hunger and Malnutrition* (UN Resolution 3348, 1974). The goal was to eliminate hunger, food insecurity, and malnutrition within a decade, and the matter pertained predominantly to the impoverished Global South. This was not to happen, as we know.

An important step towards a more comprehensive understanding of famine and entitlement was taken by Amartya Sen, later a Nobel Laureate in economics, who challenged the proposition that famine was a simple outcome of food shortage. Some famines, he argued, occurred during periods of peak food availability for the economy as a whole, as was actually the case for the 1974 famine in Bangladesh (Sen 1987:7). As he succinctly suggested, "starvation is the characteristic of some people not *having* enough food to eat. It is not the characteristic of there *being* not enough food to eat" (Sen 1981:1).

Food sufficiency remained at the core of the concern with food-security, but politics and distribution were henceforth seen as an integral part of the problem. This recognition precipitated a process during which the hard fact of hunger gradually moved beyond measuring individual intakes of calories to the social experience of wellbeing and belonging as related to food and nourishment in a wider sense. In addition to the matter of basic sufficiency of food, an explicit acceptance of entitlement to *safe* and nutritional food emerged.

While hunger and poverty have still not been obliterated from the world, the connotations of food-security (and its opposite: food-insecurity) have multiplied and now reflect a global situation that radically departs from the post World War II scenario. On a truly global note, it is increasingly clear that climate change has serious implications for food safety, and always has been (FAO 2008a,b; Hassan 2002; Ringler et al 2010). Part of the problem is related to demographic changes and environmental migration, part of it to shifting resource bases in large areas and also the depletion of nutrients in the soil (Hastrup and Olwig 2012; Lobell and Burke 2010).

All of this has entailed an expansion of the definition of food security; it is now seen as "the reassurance that all people at all times have both the physical and economic access to the food they need for an active, healthy life. This means that food itself is safe, nutritionally adequate and culturally appropriate and that this food can be obtained in a way that upholds basic human dignity" (WHO 2006). This is a very comprehensive definition, indeed, and one that certainly transcends any idea of a simple minimum intake of calories. The shift from food security to food safety is significant, and is in line with the definition provided by FAO (2001: 58), stressing people's "access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life".

This shift reflects the increasing challenge to food-safety from environmental contaminants, as well as changing micro-biological regimes, including genetically modified organisms, chemical additives to processed food, and new microbiological health hazards presented by quite ordinary (processed) food-items. Along with manifest global health problems of obesity and Type II diabetes, all of these developments move the problem of food security from being mainly a problem in the Global South to also embracing the Global North. We are in it together, and it is not simply a matter of being able to extract enough and safe food from the land, but also from the sea, being another important source of nutrition across the globe, yet increasingly contaminated.

I shall examine a case that illustrates how the spectrum of uncertainty about food safety expands. In turn, this may contribute to the charting of new areas of concern, and hence of new avenues for action. The case is that of a hunting community in Northwest Greenland facing a series of worrying developments with respect to their traditional dietary habits, as well as the access to resources. The case emphasizes health and food preferences as comprehensive social, cultural and historical facts, now under siege by environmental changes and contamination whose effects are barely known as yet.

Local challenges: An arctic case

On the fringe of the Nordic welfare states, some of their Arctic populations already face some of the direr consequences of the global development. One could say that the bill for industrial development, mainly but no longer exclusively in the Global North, has been distributed for all to pay, not least in terms of environmental degradation even in the most isolated regions. The *Arctic Monitoring and Assessment Programme* (AMAP), for example, regularly publishes rather disturbing findings about diet and contaminants. In 2009, AMAP documented that sweet and fatty store-bought food had become the main source of energy for children in the region (especially in North America, but also in the Arctic more generally), and that "the decreasing proportion of traditional foods in the diet has had negative impact on the intakes of most nutrients," while still contributing positively to the intake of vitamin C, folate, and possibly calcium (AMAP 2009: 21).

Meanwhile, the persistent organic pollution of the Arctic seas is not diminishing (AMAP 2002). What is also apparent is that "dietary exposure to persistent contaminants and metals in Arctic indigenous communities is higher than in neighbouring non-indigenous communities. The main explanation is that indigenous populations consume tissue from marine top-predators that are not normally eaten in other parts of the world" (AMAP 2009: 21-22). With the rather dramatic environmental changes in the Arctic, living conditions are further deteriorating with new problems of storage, now the natural deep-freezer switches off, of more obviously sick and polluted animals, and of intensified zoonotic disease frequencies (see e.g. Hovelsrud et al. 2012). This, again, is related to the general environmental changes in the region, including the thinning of sea-ice, the reduction of snow cover, the thawing of permafrost and the related changes in floral and faunal distribution.

This takes us to a community in Northwest Greenland (Avanersuaq), where we find the last truly High Arctic hunting community, numbering some 700 people in a vast territory, until recently ice-covered for most of the year, but now melting down rather rapidly and complicating access to the living resources. While in some – maybe not too distant – future, the warming may open up entirely new economic possibilities, at present the economy is still totally dependent on the living resources and hunting, which is becoming increasingly precarious.

For the past nine years I have followed the development closely, visiting the community every year, going out with the hunters on their dog sledges, or following them when narwhal hunting, and spending a lot of time conversing with men and women concerned about their future – but also imaginative and demonstrating that the basic ingredient in social resilience is human agency and social flexibility (Hastrup 2009). The hunters and their families are all too aware of their shrinking opportunities and of the need to monitor the sea-ice very closely, whenever they go out; a proper reading of the ice is a matter of life or death, and they must use all the acquired skills at reading and reasoning about the passable routes towards the known, if shifty hunting grounds (Hastrup 2013). The shrinking sea-ice and the decline in food accessibility has contributed to more general concerns about remaining self-sufficient, and about the implications for health in general.

Greenland now has self-rule but is still part of the Danish kingdom, and is closely monitored in terms of health and well-being; generally, the country finds itself between a traditional subsistence economy based on hunting (mostly in the north) and fishing. This has been supplemented by some sheep rearing (in the far south), and not least by a more widespread modern economy based mainly on large-scale fishing and fish processing for export, having been supplemented by uneven booms in shrimp- and crab-harvesting and processing.

Social life and expectations in Greenland are very much shaped by Nordic values and the horizons of a welfare state. It is estimated (by the Greenlandic Board of Nutrition and Environment) that on average one quarter of the food intake in Greenland consists of traditional food, while the remaining three quarters are imported; in small towns and even smaller settlements, the proportion of traditional food is much higher, but everywhere there is a fragile balance between two health regimes to maintain – and not much choice where supplies are limited (Bjerregaard and Mulvad 2012).

Generally, local traditional food is deemed healthy – in spite of the problem of heavy metal contamination in both marine mammals and in polar bear – the latter now a less prominent part of the local food than before. The point is that among the food options available, local food is the most nutritional, if in important ways apparently less 'safe', and not compliant with the fibre recommendations (Jeppesen and Bjerregaard 2012). There is thus a tension between food preferences and food safety, and a potential loss of self-reliance if the hunters are advised against seeking to sustain their own subsistence as they have done since times immemorial – dwelling within a forbidding landscape.

The questionnaire-based *Survey of Living Conditions in the Arctic* (SLiCA) shows how a large proportion of people in the Arctic still perceive traditional food as an important part of their diet, not only in terms of nutrition as such but also as part of general well-being (Poppel et al. 2007). It will be recalled that this is now part of the FAO definition of food-safety. The SLiCA project actually offers some quantitative observations, based on questionnaires, by which we may underpin this. Avanersuaq is not singled out in the statistics, but we find it within the category of North Greenland along with a couple of other small towns and settlements. If anything, Qaanaaq and the North-Westernmost part of Greenland would be in the higher end of the traditional food-intake scale within this larger region.

Proportion of traditional food consumed in households (meat and fish):

	North Greenland	*Greenland in general*
None	<1%	< 1%
Less than half	38%	33%
About half	23%	27%
More than half	39%	40%

Proportion of traditional food harvested by households (meat and fish):

	North Greenland	*Greenland in general*
None	18%	25%
Less than half	36%	38%
About half	18%	15%
More than half	27%	21%

Households received traditional food from others:

	North Greenland	*Greenland in general*
Received traditional food from others . . .	81%	77%
Received traditional food in exchange for assisting others . . .	25%	39%
Received traditional food in exchange for other traditional food . .	11%	23%
Received gift of traditional food . . .	96%	90%
Paid for traditional food in last 12 months . . .	41%	71%

(Source: SLiCA, Poppel et al 2007: p 72-77).

What transpires from these numbers is, first, that within Greenland in general, the North does not depart significantly from the country as a whole when it comes to consumption; second, a similar pattern is found for actual harvesting of traditional food; third, in terms of receiving traditional food from others, the two columns show a similar pattern, yet one item stands out, namely the lesser propensity to *pay* for traditional food in the North. Comparing with the other named regions in Greenland, there is no doubt that the consuming, harvesting, and sharing traditional food is a strong feature of social life in Greenland, while the kinds of meat and fish may differ.

The quantitative data provided by the SLiCA survey supplement the qualitative material from fieldwork in Avanersuaq, where for all festive occasions traditional Greenlandic food is served and offered to anyone from the community who cares to come. Eating this food gives people a sense of continuity, by celebrating their traditional hunting life and also, significantly, by the deeply social act of *sharing*. Traditional food *makes* the community. It also contributes to wellbeing in another way; people would say to me that they needed to have *mattak* (narwhal skin and blubber) stored for the winter as a remedy against depression (Hastrup 2009); we know that the *mattak* is vitamin rich and understand the need – in spite of the contamination. The locals know about this, having been targeted by health campaigns over many years, warning about the accumulation of heavy metals in the marine mammals, and advising people to eat variedly and to avoid older seal and bear where the contaminants are more concentrated than in younger animals. This public health advice is most emphatically directed towards pregnant women.

However, even here the case is not as clear as one would think. While the accumulation of heavy metals etc. may have some harmful effects, it seems that the particular kind of fat in these animals goes a long way toward protecting people against cardio-vascular diseases (Hansen 2000). Also, in actual fact the alternatives are few. The further north one gets, the less choice of diet there is, because all provisions beyond the local resources have to be flown or sailed in from far away and are consequently priced beyond the economic capacity of most households. This effectively leaves large groups of people at a loss; if no longer able to hunt, they have to resort to industrialised food, with loads of sugar and low levels of protein and vitamin, at next to prohibitive prices.

The challenge, which is professionally addressed in Greenland, is to design health campaigns with an innovative approach to traditional foods in combination with a new 'cuisine' (Bjerregaard and Mulvad 2012). This is truly delicious, but anyone who has spent time in the far north will know that 'finesse' is maybe not a prime cooking skill, and that money is short. You may have your walrus steak or your boiled seal, if you are lucky or know someone who is, or indeed some guillemots, arctic char, or halibut. Sheer subsistence takes the driver's seat in this distant and isolated region, not innovative dishes.

If we zoom even closer in on the health of the population in Avanersuaq, one notes a significant development in local perceptions of health and risk. This development is heavily influenced by an event that took place in 1968, when an American B-52 plane crashed in the region and went through the sea ice with four plutonium bombs. This caused a degree of anxiety in the region, where hunters were called in to help removing the contaminated snow. People's subsequent fear of radiation negatively affected their sense of self-reliance and safety; this example testifies to the oft-noted point that singular dramatic events can contribute to long-term anxieties (e.g. Harries 2008). This was one of the reasons behind a recent (2010) study of health in the region, centring on the town of Qaanaaq with some 600 inhabitants (Bjerregaard and Dahl-Petersen 2010). The study was based both on qualitative and quantitative methods, and resulted in some highly interesting finds on the issues of safety we are discussing here.

The study documented that while people in Qaanaaq generally felt more exposed to contamination and subjectively considered themselves to be more afflicted by illness than people further south, there were no epidemiological indications that they were in fact more affected by either radiation or diseases related to earlier exposures than their compatriots. Yet there were significant differences in their perceptions of health; the northerners saw themselves as much more vulnerable, not only because of their own health-condition, which they evaluated negatively, but also because of a greater prevalence of infected and therefore inedible game that was added onto it. The environmental threat was conspicuous in the appearance of malformed fish and game, which suddenly emerged as a theme for concern, as did the continued presence of the US airbase, since 1953 a very sore point, indeed, in the history of the hunters. All of these anxieties merged into a general sense of insecurity, where the individual factors precipitated others.

The pervasive sense of fear links up with the new global realities of invisible contamination and long-distance effects of industrial (including military) developments. In a follow-up study in 2011, based on a new set of interviews with people in Qaanaaq, the findings of the previous study were confirmed and elaborated in terms of policy issues (*Den Individuelle Helbredsundersøgelse* 2011). One conclusion was that more reliable information from the authorities was needed to empower people and to downscale their, partially unfounded, worries about contamination; this information should range from actual dietary and life-style factors on the one hand to larger issues of wildlife management and environmental changes on the other. While the local food options are few, a measure of trust in food governance may still be established, alleviating individuals from making an impossible choice.

What I am getting at here is the fact that people across the globe are living with multiplying 'liquid fears' (Bauman 2006). They are *liquid* because they seep into the everyday and greatly affect the sense of self and safety; as *fears* they are distinct from risk as I, following Bauman, use these terms here. Risks are identifiable and something to be managed – at least theoretically – while fear derives from unknown sources and have unknown scopes. The concept of risk makes sense only in a routinized world, where one may calculate risks with reference to precedents (Bauman 2006: 10, 98ff). Beyond the presumably calculable risks are those dangers that are non-calculable, because they belong in a setting that is irregular in principle, and where non-repetition is the rule. This is part of the perceived framework of food safety, so very tenuous in many places.

Concluding remarks: food safety in changing environments

In this chapter I have wanted to discuss emergent challenges to food safety worldwide, through the lens of the Arctic case. These challenges are multiplying as well-known landscapes and resources are destabilized, resulting in emerging 'food wars' in the global community (Lang and Heasman 2004), and in increasing uncertainties about food safety in peoples' everyday lives.

While food security, in the sense of all people getting sufficient nutrition to lead active and healthy lives, has not even nearly been achieved in spite of long-term international efforts, an even more complex issue of safety is creeping in on the global community, North and South alike. New patterns of disease, including dramatic increase in Type II diabetes, in obesity, in certain forms of cancer, and in cardiovascular problems, testify to a global malaise that is not easily countered by simple advice because of its very complexity. Meanwhile, people's general fears of unknown dangers multiply, as scientific knowledge deepens and the hidden threats from microbiological realities surface, yet remain incomprehensible. Such is the case of the shattering sense of food-safety in Avanersuaq, despite the continued relish in traditional food in the community – even partly because of it. So far there are no real alternatives, anyway.

It is apt to return to FAO here and relate a recent call for a new management of food safety: "Emerging food safety risks may require a change to the 'old' way of doing things – both in terms of industry food safety management programmes and public sector food safety activities, including the development of guidance of industry on 'good practice'. A better understanding of changes that might arise is an essential first step to ensuring preparedness for those changes" (FAO 2008: 6).

In the larger scheme of global food security, it is expedient to rethink issues of safety with a view to new environmental challenges that affect the entire world and give rise to a liquid fear – of invisible and largely unknowable threats to human health. As I intimated in the introduction, we may take heart from the fact that the human powers of invention seem inexhaustible, even as lands and oceans now suffer conspicuously from exactly that.

Acknowledgements

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Food, economy and society: Multi-faceted lessons to learn from ancient plant remains

Mette Marie Hald, Peter Steen Henriksen and Morten Fischer Mortensen

Abstract

Plant remains and animal bones from archaeological excavations form the basis for interpretation in ancient food studies. This paper presents the methods and theory of archaeobotany, followed by a discussion of the Danish archaeobotanical record. The often very well-preserved archaeobotanical assemblages, of which some examples are presented below, hold great potential for providing new insights on ancient agriculture and food practices.

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Ancient food studies have become an increasingly popular aspect of archaeology, with a growing number of specialist disciplines providing us with a variety of information on the subject. The amount of systematically sampled bioarchaeological material retrieved from excavations within the last 70 years enable us to move from the spectacular single finds of charred seeds or bones to a much more representative dataset of food remains reflecting both large-scale feasting events (Dietler and Hayden 2001) as well as the everyday, mundane activities of having a meal.

These studies also provide us with information on the organization of food production – the tilling of fields, processing of crops, hunting of animals, and the cooking of meals. Apart from the purely economic and nutritional aspect, food has also long been recognized as an important factor in constructing society and culture (Douglas 1972, Gosden and Hather 1999). Food reflects both social strategy and cultural practice, enabling and upholding the division of gender and social classes, and it is used as a tool in the accumulation of power and wealth. We share meals with family, friends and allies, and by sharing meals with others, we not only invite them into this inner circle of social relations but also leave them in our debt (Halstead 2004). As such, food is extremely powerful. Finally, food, as the very fabric of our existence, brings us as close to the individual human being and the most mundane activities of the past as it is possible to come when studying the archaeological record. The last meal of Iron Age Grauballe Man (Harild *et al.* 2007) or the accidentally charred, dried apples (*Malus sylvestris*) found at Late Neolithic Nørre Sandegård (Helbæk 1952), pose fascinating glimpses into ancient subsistence strategies: the actual meal still sitting in the stomach of a human being, and the wild apples, carefully halved and dried, ready for winter storage sometime during the latter half of the third millennium B.C. (Fig. 1.).

In this paper, we focus on the potential of plant remains including pollen to inform us on food practices in Denmark in the past; on their own and in connection with other archaeological finds. In the case of one particular find, discussed below, the spectacularly non-culinary context adds information on other uses of plants in the past and reminds us of the importance of the social value adhered to food products. An introduction to archaeobotany is followed by some archaeological examples in order to show the variety and potential of the Danish archaeological record

Fig. 1. Wild apples (*Malus sylvestris*) from the Neolithic site of Nørre Sandegård, Bornholm. The apples had been carefully halved and dried in order to preserve them before they were accidentally charred. This find throws light on the ancient practice of preserving food other than grain crops. Photo: Peter Steen Henriksen 2016.

with regards to subsistence practices. We conclude with an outline of an interdisciplinary research project now underway at the National Museum of Denmark to take us even further by combining a range of finds, analyses and methodological approaches.

Archaeobotany and plant economy

Plant remains (grains, seeds, pollen etc.) are potentially very useful in the reconstruction of ancient subsistence practices. Given the right conditions, charred or waterlogged plant remains provide insights into the production and management of crops, including (1) methods of field cultivation and post-harvest processing of crops; (2) the storage, distribution and consumption of plants as food and fodder, and other economic uses such as roof thatching and textiles; and (3) the distribution of crops and other economic plants over shorter or longer distances as part of larger exchange networks (Hald 2008).

Plant remains are easy to extract from excavated soil and store for analysis, making their use a cost-efficient strategy for bioarchaeological problem solving. Charred plant remains are extracted from soil samples by means of flotation, a simple process in which soil is mixed with water, leaving the charred plant remains to float to the surface and thus be separated from the soil. Waterlogged plant remains are wet sieved by hosing down soil samples through a series of sieves. The identification of plant remains is done by assessing their morphology (size, shape, surface cell pattern, etc.) with a microscope and with the help of a modern reference collection for comparative analysis.

Plant remains are very good indicators on the state of agriculture, starting with the presence of wild and domesticated taxa – i.e. defining whether agriculture was at all undertaken at a given site. Whereas cereal crops like wheat, barley and rye are relatively tolerant to agricultural strategies such as varying intensity of manuring, watering and weeding, the weeds in the crop field are often comparatively more specific in their habitat requirements. These requirements include levels of humidity and nitrogen in the soil, and levels of disturbance from, for instance, trampling, hoeing or weeding. As a consequence, whereas the crops can tell us primarily which types of plant food were present at a given site, the accompanying crop weeds may be able to give us an indication of the conditions in the field, reflecting the character and intensity of crop management practices – as such, they potentially reflect the nature of agriculture at a given site. Recent developments in isotope studies have also made it possible to detect manuring and watering practices from the values of $\delta^{14}N$ and $\delta^{13}C$ isotopes, respectively, in the cereal grains (Bogaard and Outram 2013; Bogaard *et al.* 2013).

We have come a long way from simply assuming that every plant found at an archaeological site must reflect its use as a food resource. It has been recognized that plants, both crops and wild taxa, could have had multiple uses and entered the site along a variety of routes; for instance, crops may have been used for both food and fodder and it is quite obviously to our advantage to be able to distinguish between meals and manure. Hemp (*Cannabis sativa*) may have been used for both rope making and as a hallucinogenic or medicinal plant, while flax (*Linum usitatissimum*) may have been used for its edible seeds, for oil production, and for its fibres in textile production. The distinction is not always quite fixed, either. Ethnographic studies in Greece have shown how cereal crops are used for both food for humans and fodder for animals, depending on, for instance, the success of one season's harvest; what is regarded as an inferior crop used only for fodder in times of plenty may be "upgraded" to a perfectly acceptable food crop during lean years (Jones and Halstead 1995). What is necessary, therefore, before making any culinary assumptions based on the plant material in front of us, is to ascertain that this is indeed *food*. This can be undertaken by an identification of the plant composition of each sample coupled with an assessment of the associated context and finds. Wild taxa with a growing cycle different to that of wheat or barley, for instance, are unlikely to have produced seeds by the time a cereal crop was harvested; therefore, if seeds from these particular wild taxa are found within a sample of cereal grains, we must assume that those cereal grains have been mixed with other plant material along its post-harvest "lifetime" – i.e., we are not looking at a pure food sample, and should be careful with an interpretation in terms of food practices.

As with all other archaeological artefacts, plant remains are silent without a definite and thoroughly recorded finds context. Associated tools and ceramics as well as the presence of features such as grindstones, hearths or ovens may assist in the interpretation of a particular assemblage of plant remains. Given the right conditions, it will be possible to interpret the archaeobotanical assemblage with respect to practices such as the processing and consumption of crops, cooking and serving traditions, and strategies concerning the preservation and storage of food.

It should also go without saying that questions on ancient food practices are best solved when excavating archaeologists and specialists work towards a strategy of problem solving and sampling from the time of the very definition and design of the archaeological project. Defining what we are looking for not only defines the number and types of samples needed to be taken during excavation, but also limits time and funding being spent on types of analysis that may end up being irrelevant. In the words of one specialist our research "will need to be driven by archaeological questions, not analytical opportunism" (O'Connor 2014).

Making the most of the Danish archaeological record

Denmark holds a rich, varied, and often very well-preserved archaeological heritage. Archaeological finds have been collected and registered in Denmark systematically for the past 150 years, providing us with a very large collection of not only traditional archaeological finds, but also of bioarchaeological material. In some cases, such as the wealth of bog bodies and oak coffin burials, the archaeological assemblages provide collections unique in their size, state of preservation and long-term sampling strategy.

Plant remains and pollen have been sampled systematically from archaeological excavations in Den-

Fig. 2. Barley (*Hordeum vulgare*) grains from the storage cellar at Overbygård, Northern Jutland. Analysis showed how individual deposits of crops were stored in different stages of crop cleaning. The crop cleaning waste was also stored, indicating that this had some economic purpose, and the weed flora from the samples was useful in reconstructing the conditions of the crop fields at Overbygård. Photo: Peter Steen Henriksen 2015.

mark for more than 70 years. Most of these samples are housed at the National Museum in Copenhagen, with the collection of plant remains comprising more than 60.000 samples, reflecting the plant economy through prehistory to the Renaissance. Along with these, some 75.000 pollen samples, covering primarily the prehistoric periods, present us with a reflection of the surrounding landscape and its use. The archaeobotanical assemblages derive from a mixture of long-term research projects and shorter-term rescue archaeology. Accompanying these major datasets from both collections are the extensively detailed archives containing excavation data, early reports and related correspondence with staff at the National Museum – an invaluable mine of information regarding contexts and general background knowledge of the samples.

Stories from a burnt-down granary

Concentrations of charred or waterlogged plant remains are found in excavations across the country. The apples from Neolithic Nørre Sandegård are a particularly fine example of preserved food remains, but the Danish archaeobotanical material spans everything from a few grains in a posthole to very large concentrations of grains in definite storage contexts. One such example is the find of 100+ litres of grains in various stages of crop processing from a burned-down storage room at Early Iron Age Overbygård in Northern Jutland (Henriksen and Robinson 1996). At Overbygård, analysis of the charred plant remains showed that barley (*Hordeum vulgare*) and bread/club wheat (*Triticum aestivum/*var. *compactum*) were the most common crops, with smaller concentrations of oat (*Avena sativa*) and flax (*Linum usitatissimum*), which may have been present as crop weeds. The arable weed flora accompanying the crops showed that they were most likely spring sown and derived from fields with variable soil conditions in terms of moisture and nutrient levels. It was noted by the archaeologists digging the assemblage that the charred plant remains had been stored in clearly definable individual deposits, and samples were taken from each of these deposits. This enabled the archaeobotanists to identify crop samples in several different stages of processing and cleaning. This particular assemblage of plant remains, therefore, has provided us with detailed information not only on the crops grown around Overbygård, but also the means of storing and processing the crops, as well as the growing conditions of these crops (Fig. 2).

The last meals of our ancestors – the Iron Age bog bodies and the Bronze Age Egtved Girl

In many cases, the archaeological record provides us with insights into the subsistence practices of the past. The bog bodies provide us with a close-up view of last meals, from the preserved stomach contents of some of them, including Tollund Man (Helbæk 1950), Huldremose Woman (Holden 1997), and Grauballe Man (Harild *et al.* 2007). Studies of the stomach contents of Grauballe Man, for example, have shown that his last meal consisted primarily of seeds from a large range of wild taxa as well as cereal glume bases with a minor component of cereal grains – a relative composition of plant remains usually seen in by-products of cereal crop cleaning, and, in fact, almost identical to some of the deposits of crop processing waste analysed from Overbygård, mentioned above. It appears, therefore, that Grauballe Man was served a gruel or porridge made primarily from waste from crop cleaning. Included in this meal there may have been a small proportion of meat, judging from the tiny bone remains found in the stomach.

Overall, the content and composition of the meals reconstructed from Tollund Man and Huldremose Woman is similar to that of Grauballe Man. There are a number of caveats and questions to keep in mind regarding the bog bodies, including how to interpret these meals (typical everyday meals, floor sweepings as a final insult to the condemned, or the only type of food left during a time of famine?). Nevertheless, the stomach contents of the bog bodies give us a unique glimpse of what was eaten by a specific person on the last day of his or her life. The meals, although relatively nutritious, do not strike us today as very tasty, and the high proportion of weed seeds thrown in with the cereal grains in the meal does suggest that we are looking at a poor man's diet, or perhaps even famine food. From what we have seen at Overbygård, above, crop processing methods were advanced enough to provide a fully clean crop ready for consumption. What we have also learned from Overbygård, however, is that crop cleaning waste clearly had some economic value, as it was stored along with the cleaned crop. Perhaps what we see, in the stomachs of the bog bodies, is this crop cleaning waste coming to use to bulk up an otherwise meagre cereal gruel at a time of scarcity. And this, in turn, may aid in the interpretation of the practice of human sacrifice: If we consider the high proportion of weed seeds as an indicator of scarcity or even famine (also bear in mind the Greek ethnographic example, above), it is tempting to view the bog bodies as sacrifices made during times of scarcity in the hope of improving the next harvest. The archaeobotanical analysis can, in this way, throw some new perspective on the bog bodies, and, not least, why these people were sacrificed in the past.

The Bronze Age coffin burials are also informative with respect to ancient food practices. Probably the most famous of the burials, the Egtved oak coffin, dated to 1370 B.C., contained the remains of a young girl, 16-18 years of age along with some of her possessions. A flower of yarrow (*Achillea* sp.) found in the coffin with her shows that her funeral must have taken place in July or August. While her skeleton has dissolved, organic remains such as her hair, teeth and nails are still intact, along with her well-preserved woollen top and skirt. The burned bones of an infant were found in the coffin with her. A birch (*Betula*) bark box by her head contained tools, more burned bones, a tuft of wool and a hair net made of ox- or horse tail hair (Nielsen 2013: 97-99). From a food perspective, the most interesting find was a bucket made of birch bark, found at the girl's feet, containing a fermented drink made by using ingredients such as malted wheat, bog myrtle/sweet gale (*Myrica gale*), cow- or

Fig. 3. Birch bark bucket found in the oak coffin of the Egtved Girl. Analysis of the bucket showed that it had once contained a fermented drink made from malted wheat, sweet gale, cow- or cranberries, and honey. These ingredients were used to craft the "prehistoric" beer next to the bucket, now for sale in the shops. Photo: Morten Fischer Mortensen 2015.

cranberries (*Vaccinium oxycoccus*), and honey. The analysis of the contents of the bucket, represented by pollen grain deposited in the bottom of the container, has subsequently led to the commercial production of a light "prehistoric" beer, crafted by Peter Steen Henriksen in cooperation with a Danish brewery (Fig. 3).

The Nørre Sandegård Vest onion – lucky charm, identity marker or moth ball?

Finally, a find from the National Museum collections, made recently when revisiting the archival material on the Nørre Sandegård excavations, and with anything but a culinary context, was that of a clove of wild onion (*Allium scorodoprasum/oleraceum/vineale*) deposited in a woman's grave (Hald *et al.* 2015). The woman, buried at Nørre Sandegård Vest and dating to the Iron Age (ca. 700 A.D.), wore several brooches on her chest, from one of which a small copper-alloy box was suspended (Jørgensen and Jørgensen 1997). The box, made of thin sheet-metal and decorated on the outside with zoomorphic figures, contained a rolled-up ball of woollen string and a single clove of wild onion (Fig. 4). This is the earliest appearance of onion in the Danish archaeological record, and possibly the earliest archaeobotanical find of onion in Europe; onions have little chance of survival in the earth due to their high moisture content and very thin outer skins, and, if burned, will quickly burn to ashes. Consequently, they are usually only found preserved by desiccation in arid climates such as that in Egypt (van der Veen *et al.* 2009). In the case of the Nørre Sandegård Vest onion, preservation was aided by its placement in a copper alloy container, which has prevented it from decaying.

The presence of a single onion clove in a woman's

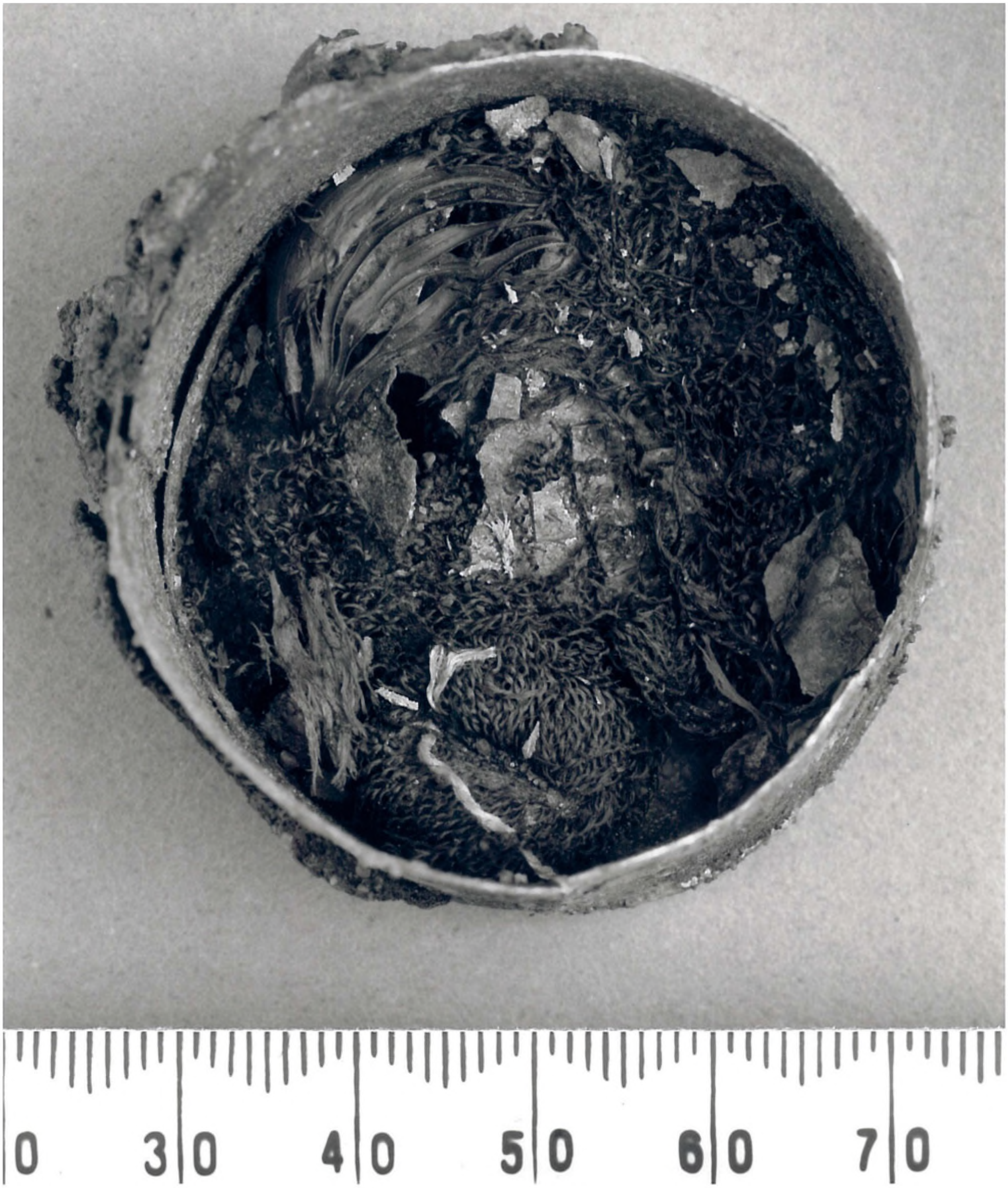

Fig. 4. The Nørre Sandegård onion, as it was found in the copper alloy box along with the ball of yarn. Food in a non-culinary context such as this indicates the social value often adhered to food products. Photo courtesy of Lars Jørgensen, from Jørgensen and Jørgensen 1997.

grave, worn as part of her jewellery set, strongly suggests that here we are not looking at food. The unusual finds conditions suggest that high value was attributed to onions, whether symbolic, medicinal or practical. The strong taste of onion, enhancing the flavour of a meal, is coupled with its equally strong smell, which may have given the onion a reputation as a powerful object. Onion is mentioned in several of the Norse sagas, probably most famously in the saga of Regnar Lodbrog, described below. It was also known for its abilities to neutralise poisoned mead (Alm and Furnes 1998). As a medical tool, onion is said to have been used to detect lesions in the stomach and bowel regions from its smell; a wounded warrior would be given an onion-based gruel to eat, and if his wounds smelled of onion, it would indicate that the stomach or bowels had been penetrated (*ibid.*).

There are numerous possible interpretations of this unusal find from Nørre Sandegård. The box itself has been interpreted as a sewing box (Mannering 1997) due to the presence of the ball of wool, but it is more likely to have served as an amulet or a marker of identity, either personal and/or with respect to profession. The combination of wool and onion can be interpreted as a symbol of the dyeing of textiles with plants, onion skins providing the wool with a rich golden colour. The wool is indeed of a particularly fine white colour, a result from selective breeding in sheep since the Bronze Age, as white wool is particularly well suited for plant dyeing. Another suggestion is that onions may have functioned as a moth repellant, which again ties in well with the presence of the ball of yarn, symbolizing not only the mundane chores of keeping your woolen garments moth-free, but also, perhaps, hints at thoughts of longevity or eternity in the company of the dead.

One association with the sagas is the aforementioned saga of Regnar Lodbrog, who set his future wife Kraka the challenge of arriving at his ship neither full nor hungry, neither naked nor dressed and neither alone nor in the company of people. Kraka solved the riddle by biting an onion, dressing in a fishing net and taking her dog along for company. It is tempting to see an association with the Kraka figure in this box from its content of the onion itself, the ball of yarn representing the fishing net and the zoomorphic figures on the outside of the box representing the dog. Kraka, a strong-willed and resourceful woman, could well have been a popular character to relate to.

Another saga association is that of the Völsa þáttr, featuring a dried horse's penis, named Völsa, used for ritual ceremonies and kept in a linen cloth with onions and herbs to keep it from rotting (Larsen 1943-6). The story has been rejected by some scholars as a real Norse saga describing ancient rituals; some argue that this story should be regarded as later Christian propaganda, highlighting the debauchery of the Norse savages subsequently saved and christened by Olaf the Holy, king of Norway, who plays a major role in the Völsa þáttr. The association with Völsa is very likely to have had a connection to fertility and the Nørre Sandegård Vest box, with its clove of onion and ball of yarn possibly representing the linen cloth, may thus have served as a lucky charm. If this is indeed the case, it would add authenticity to the Völsa þáttr, which may be describing a ritual that in fact did take place in the past.

Putting it all together

As part of the research strategy *People, Food and Society* currently underway at the National Museum of Denmark (Jørgensen *et al.* this issue), a major synthesis of the archaeobotanical data, on its own, and coupled with a range of other bioarchaeological and "traditional" archaeological finds, will be attempted in the coming years.

Integrating different strands of bioarchaeological data is, surprisingly, still novel. Research on, for instance, archaeobotanical and zooarchaeological data is often presented in separate appendices following the "main" site report, which is not always cross-referenced with the bioarchaeological information. Inevitably, this makes it very hard to come to a fuller understanding of the palaeoeconomic strategies undertaken at the particular site, or for that matter, an entire region.

The application of large-scale data sets to archaeological problem solving has been shown to have a number of advantages. The integration of smaller (often single-period and site-based) datasets into a larger supra-regional dataset has made it possible to detect large-scale patterns and trends otherwise unnoticed (Conolly *et al.* 2011, Coward *et al.* 2008). Comparison of site-based assemblages on a larger scale will also detect outliers and anomalies that may not otherwise have been noticed, leading to a re-examination of these particular datasets (Conolly *et al.* 2011). Compiling such a supra-regional database of plant bioarchaeological data is one of the methodological aims of *People, Food and Society*, with the purpose of creating a representative overview of current archaeobotanical knowledge through prehistory and onwards. Earlier syntheses of isolated Danish datasets (e.g. Henriksen 1992, Robinson *et al.* 2009) have shown that there is great potential for pattern searching not otherwise possible with single datasets.

Our aims are to establish when and where our common food crops appear in the archaeological record, and to investigate the nature of the economic strategies applied in the growing, harvesting, processing and preserving of food prior to consumption, and the meals subsequently constructed from these crops. Coupled with archaeozoological data we shall be able to get a good perspective on the Danish "food-scape" through time, challenging, among other things, traditional ideas on the relatively late arrival of "exotic" food and spices, and the ancestry of traditional Danish cuisine. New Nordic food has been around for a long time and we believe that the results of our research will be able to throw new perspective on the current national debate on nutrition and traditional Danish food.

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Appendix.
People, food and society:
Towards an interdisciplinary research initiative on the dynamics of food production, nutrition, health and society from prehistory to the present

Lars Jørgensen, Mette Marie Hald, Mads Dengsø Jessen,
Morten Fischer Mortensen, and Niels Lynnerup

Abstract

The National Museum of Denmark proposes to launch an interdisciplinary research initiative focusing on a number of factors that are highly relevant to and of global interest for our modern society. The initiative, entitled "People, Food and Society", is partly the result of a major and critical assessment of the strengths, academically and collection-wise, of the Museum. The National Museum of Denmark has access to an extensive and unique body of material that can elucidate the dynamic interaction of food production, nutrition and culture. The Museum has built up extensive collections of archaeological and historical material and data, spanning a period of almost 15,000 years. The research initiative employs a collaborative research platform involving the humanities as well as the social and scientific disciplines. Within this interdisciplinary collaboration, "People, Food and Society" will investigate the economic, technological and cultural developments connected with the production and consumption of food through the ages and compare our results with data on human health and nutrition in order to identify the possible underlying causes and dynamics. In order to explore the current state of research in the participating disciplines, a two-day symposium was organized under the aegis of The Royal Danish Academy of Sciences and Letters' outreach initiative "Open Academy". Many of the symposium contributions are presented in this publication as peer-reviewed papers. This appendix outlines the aims of "People, Food and Society" and underlines the research potential of tapping into the archives and collections of long-standing research institutions in order to produce a fresh perspective on old material.

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Introduction

Anthropological studies show that patterns of action from the past can survive as socially inherited characteristics in human beings today (Latour 2013). The actions and decisions of the present can therefore be traced back to patterns of action that can perhaps already be observed in prehistoric times. In this perspective, museum collections make up a unique body of source material for the identification, interpretation and understanding of these embedded patterns.

Since the establishment of the Danish National Museum in 1807, prehistoric and historical cultural remains have been systematically collected from every county in Denmark. The gathering of such data has often been followed by archaeological excavations and descriptions of historical environments and related archaeological contexts. At the same time geo-referenced databases have been established covering all types of archaeological remains - buildings, settlements, graves and votive finds.

Full-scale, integrative analyses of these collections will make it possible to elucidate the timing of the introduction of new food types and dietary habits as well as the concomitant changes in husbandry practices and mobility patterns, and – not least – the significance of these innovations in terms of social change. Changes in food technologies and agricultural practices may provide the background for, or be a direct result of, major social changes, such as the shift from small-scale egalitarian societies to large-scale complex societies.

The research initiative

The National Museum of Denmark proposes to launch an interdisciplinary research initiative entitled "People, Food and Society". The point of departure for this initiative is the National Museum's extensive collections of archaeological, historical and ethnological objects and data. The museum's collections include "traditional" archaeological materials such as large assemblages of ceramics, lithics and architectural data, as well as material from around 60,000 soil samples taken for archaeobotanical analysis. To these can be added around 75,000 pollen samples. Both of these latter sample types were taken with a view to describing the range of crops and well as the economic and natural conditions in prehistory, and they are invaluable for the elucidation of food production in prehistoric and early historical times. Moreover, the Danish Museum of Natural History holds the collected faunal material from c. 3,000 deposits, most of which have emerged in connection with archaeological excavations, especially from Danish prehistory and the Middle Ages.

In addition to its vast holdings in historical and archaeological materials and data, the National Museum has a unique anthropological collection of human remains, mainly from graves and wetland finds, with a very strong research potential in terms of information embodied in the individuals as regards physique and activity, health, nutrition and provenance. This information can be extracted by analyses of ancient DNA and the stable isotope composition of various tissues. The collection, which is curated by the Anthropological Laboratory at the University of Copenhagen, comprises approximately 25,000 individuals from the period 8000 BCE - 1500 CE.

The museum's recent historical collections from the period after 1660 CE include extensive descriptions of everyday life in a variety of social and cultural groups, as a result of the systematic collection of objects, and several thousand reports, from the 19th-20th centuries.

From the recent period of 1900-1970 the museum has collected up to 50,000 life stories dealing with working conditions, food and meals, and housekeeping (butchering, baking, harvesting, and the collecting of wild berries and plants) in relation to everyday life as well as major feasts and ceremonies.

Theory and methodology

"People, Food and Society" will work on the basis of a theoretical platform that covers the various material culture and data types. Adaptation and innovation are discussed within cognitive theory (cf. Malafouris & Renfrew 2010; Renfrew 2012), and will take a central position within the project. A cognitive approach, whether in history, ethnology, archaeology or science, will thus focus on the mental information processing of human beings and their experience-based responses to influences. The basic premise is that human beings can be considered to have built up meaningful understandings of the surrounding world, which are preserved today in more or less fragmentary form in the material and written culture[1]. These different types of material structures will inevitably be passed on to the next generations, thus constituting a man-made environment that future generations act and live within.

This premise has a twofold influence on the project. Firstly, this type of environmental heritage forms the backbone of any type of archaeological excavation and the research done within "People, Food and Society" makes use of the different types of recovered traces from such excavations. The traces might be very obvious such as the large-scale organization of the cultivated landscape formed by several centuries of farming, ranging over more individual features such as prehistoric grave goods or personal diaries, to the 'invisible' diet data preserved within a person's hair, skin and bone. Each of these types of source demands specific methodologies as represented by the individual study area, but they also interact due to the fact that they all are generated through people's personal actions in the past.

Secondly, the theoretical perspective will underline a distributed character of humans acting in the world. That is to be understood as an intrinsic part of the aforementioned cognitive standpoint, for the reason that the studied materials bear witness to, among other things, human actions and strategic choices in connection with internal as well as external influences. Internal in the sense of a conceptual, or meaningful, behaviour pertaining to the mind of the (prehistoric) agent, and external as (foremost) intentional acts leaving behind some kind of physical trace to be analysed as part of the project. The theoretical platforms therefore regard humans, animals, artefacts, social structures and environmental influences as equal actors in the creation of society. In relation to "People, Food and Society", this implies that the physical environment as well as the cultural practices humans are exposed to and act within, will form an essential cause for certain traditions and practices to rise or be maintained. In addition, such a theoretical standpoint provides an alternative, explanatory platform for social constructivism and relativism, which has dominated culture studies in the later parts of the 20th century.

Conclusively, the analytical and theoretical basis of "People, Food and Society" will render possible a description in which the select range of methodologies presented by the project can generate a renewed understanding of people, food and society in a long-term historical development. In essence, cognitive theory underlines the interdependency between mindful behaviour and the material record presently at our disposal. More specifically, by embracing the notion of cognitive theory the project mitigates an outdated and unnecessary distance often registered between more classical science studies and the humanities. The aims of the research initiative, outlined below, follow this approach.

Aims of the research initiative

With "People, Food and Society" we wish to investigate the dynamic interrelations among cultural, social, economic and health-related factors since the arrival of the first human beings in Denmark until the present day. The initiative focuses on three themes that will be used to investigate the historical background to, and perspectives associated with, a number of the major issues of the present.

1. These ideas also draw inspiration from Bruno Latour's argument that meaning is created in the network between material objects and social relations (Latour 2005). His basic principle can be formulated as "meaning must be reconfigured within heterogeneous networks comprised of collectivities of humans, materials, media and other companion species" (Latour 1993, 136), thus creating a symmetrical and equal relationship between the different influences humans are exposed to and relate to.

People

- *What connections can be observed between the composition of the human diet and states of health through the ages?*
- *When do so-called lifestyle diseases emerge, and what are the factors underlying them?*
- *How does human mobility relate with the distribution of certain types of food tolerance/intolerance in European populations?*

Food

- *What economic, technological and climatic factors are involved in changes in food production and resources?*
- *What strategies are developed with a view to the maintenance of food security? How do cultural perceptions of food play a role in innovation and technology?*

Society

- *What changing relationships can be observed over time among access to resources, power and the ritualization of food?*
- *How do societies express their social and cultural responses to issues such as environmental and resource stresses?*
- *What strategies and cultural perceptions can be observed in the interactions involved in food consumption, meals and communities?*
- *How is inequality and differential access to resources reflected in human health conditions both in the past and the present?*

Interdisciplinary surveys have documented that the prospects offered by the coordination of approaches to the history of food in the sciences and the humanities are highly promising, not least given the rapid development of new scientific methods of analysis (e.g. Steckel & Rose 2002).

Today we see a tendency – especially in the media – to focus on monocausal explanatory models for human reactions to crises and climate change. However, the historical perspective shows that interactions among factors such as food crises, innovation, adaptation and culture are often far more complex. There are always several convergent factors where a number of natural and human actors generate changes and adaptations. "People, Food and Society" intends to investigate both long- and short-term changes and to discuss these complex dynamics.

By integrating a full range of disciplines, with their varied perspectives, in the investigations of the interaction between people, food and society, we shall be able to get a much more nuanced view of food production and its consequences through time than would have been possible when following just one or some of the strands of data available to us.

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