



ANBI 139

Evolution of Human Disease

Lecture 8: Epidemiological Transitions - Paleopathology

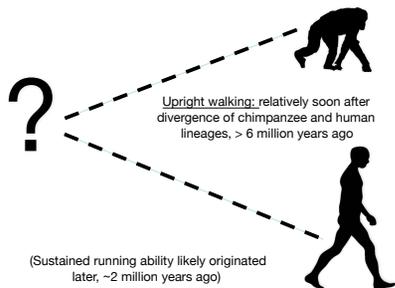


Pascal Gagneux

Spring 2019



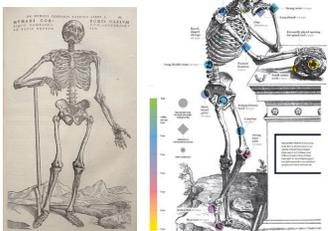
Striding Bipedal Gait: A Uniquely Human Condition



Bipedality is very old and is associated with several human ailments

Striding Bipedal Gait: Biomedical consequences

- Low Back Pains, Strains, and Injuries
- Spine Deformity Problems
- Herniated Inter-vertebral Discs ("slipped discs")
- Varicose Veins
- Hernias
- Hemorrhoids
- Knee Joint Osteoarthritis
- Obstetric Difficulties (Narrow Pelvis)



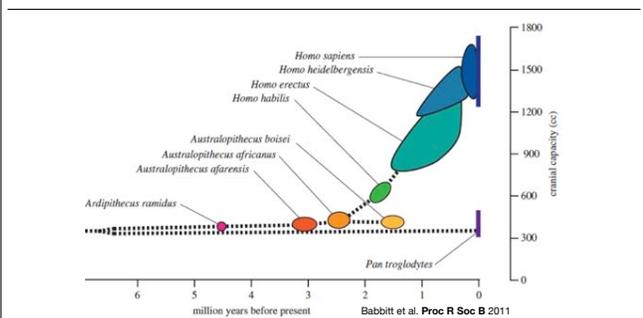
Humans are still paying the price for the switch to bipedal locomotion that occurred over 6 million years ago!

Practice question:

Name three conditions that represent costly consequences of bipedalism in humans.

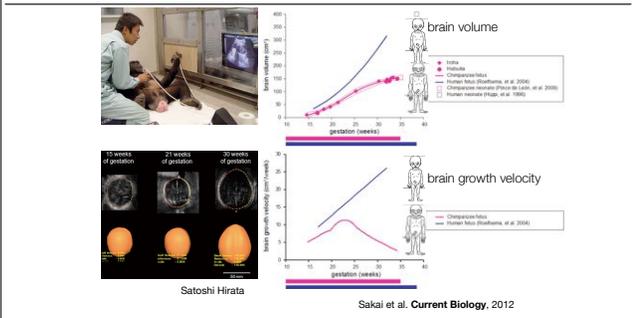
see above

Hominin Brain Size Increase Over 6 million Years



The brains of our ancestors tripled in size over that last 2 million years. What drove such a cost expansion?

How to grow a big brain

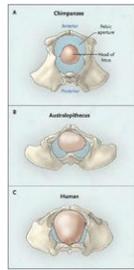


Gestational age-related changes in brain volume in chimpanzee (Hatsuka and Iroha) and human fetuses.

Gestational age-related changes in the growth velocity of brain volume in chimpanzee and human fetuses

Chimpanzee brains start slowing down their growth in mid-pregnancy, humans on the other hand continue a high fetal rate for a full year after birth.

Striding Bipedal Gait: Cephalo-Pelvic Disproportion



6-7 million years ago

3 million years ago

Today

Smith R. Mechanisms of Disease: Parturition. *N Engl J Med*. 2007;356:271-283.

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The Chimpanzee, Australopithecus, and Human Pelvises. The large aperture of the chimpanzee pelvis (Panel A) permits easy passage of the relatively small head of the fetus in an occiput posterior position. In australopithecus (Panel B), the widening of the ilium associated with upright posture and the anteroposterior narrowing of the pelvic aperture require delivery of the head in a lateral position. The human pelvis (Panel C) has an aperture just large enough to allow passage of the head of the fetus in an occiput anterior position.

Pregnancy & Parturition: Human vs. "Great Ape" Differences



Medically mediated human birth



Chimp birth at AtticaPark Athens, Greece

Feature	Human	Chimpanzee
Variation in gestation period (days)	~35	~10
Duration of labor (hours)	> 10 HOURS	= 1 HOUR
Pain (vocalization, wincing, etc.)	High	Low
Time of day for delivery	Unpredictable	Night

Lee J.B., Belmonte C.S., and Novak E.R. Normal labor: Mechanisms and function. *Obstet Gynecol Clin North Am*. 2009;36:145-62
 Galvão M.P., and Roberts J.B. The Chimpanzee. *Volume 4: Chimpanzee: Reproduction and Development*. S. Yeager, New York, 1979.
 Johnson L., and Clark R. Parturition in non-human primates: pain and auditory communication. *Prim*. 1993;21:243-262.

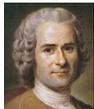
Birth in humans has become much more risky for baby and mother due to the large size of the babies head and narrow pelvis of mothers.

Contrasting European Views on the Past



Thomas Hobbes 1588- 1676

"No arts; no letters; no society; and which is worst of all, continual fear, and danger of violent death: and the life of man, solitary, poor, nasty, brutish and short."

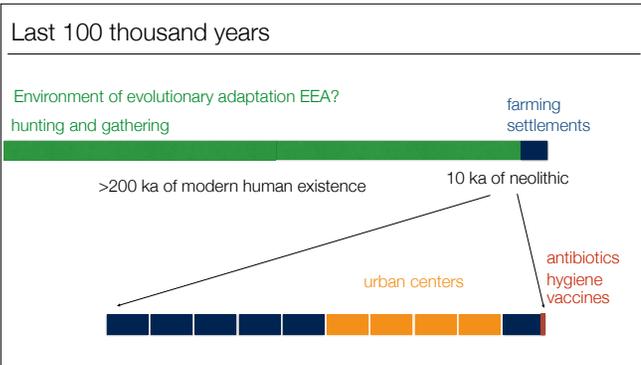


Jean Jacques Rousseau 1712-1778

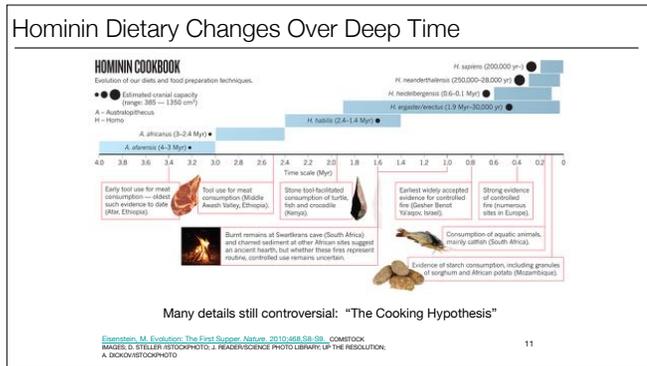
"Civilization is a hopeless race to discover remedies for the evils it produces."

"Nature made me happy and good, and if I am otherwise, it is society's fault."

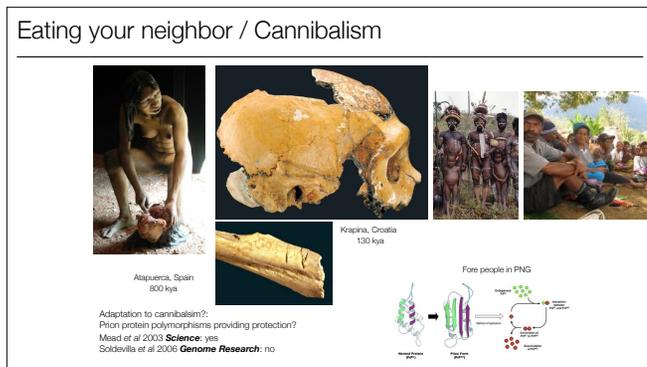
Two opposing views of the past, both clearly flawed.



The environment of evolutionary adaptation refers to the extremely long time span during which humans lived in small scale societies and by gathering and hunting their food.



Dietary changes have also had both immensely positive and very negative effects on human health.



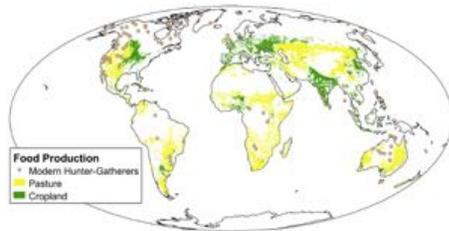
Cannibalism has been documented in several fossil hominids, from Atapuerca, Spain to Krapina, Croatia, it has also been documented for chimpanzees. It appears to be a last resort and is clearly very risky for biological and social reasons.

Environment of evolutionary adaptation EEA?



Is there a particular environment that shaped human biology? Could mismatches caused by the many changes in our modern environment be among the causes for disease?

Living Foragers and their Plight



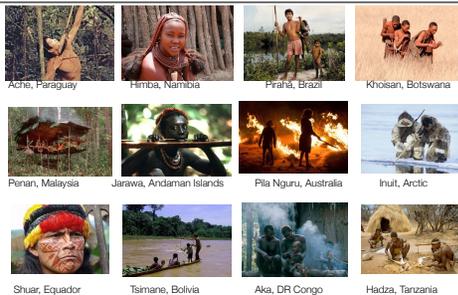
Gatherer-Hunters!

data from Navin Ramankutty and Ohio State University Hunter-Gatherer Wiki

Modern agriculture and hunter-gatherers. Map shows area used for major agricultural and pastoral production in 2000, and locations of societies that have depended on hunting and gathering for a significant portion of their food in the modern era.

data from Navin Ramankutty and Ohio State University Hunter-Gatherer Wiki

Last Living Hunter Gatherers/Foragers



All these populations are in the process of losing their traditional ways of life, they represent the last examples of our shared foraging past.

Pre-agricultural life span was not short!

MICHAEL GURVEN / HILLARD KAPLAN

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TABLE 4 Modal ages at death

Population	Modal age at death	Standard deviation	Percent of adult deaths at mode year	Percent of adult deaths at and above mode
Hadza	76	6.0	2.5	24.1
Hivi	68	3.3	3.3	17.9
Ache	71	7.7	2.1	24.5
Yanomamo Xilixana	75	7.3	1.9	22.8
Tsimane	78	5.9	3.0	30.5
Huang 1963-74	74	7.8	2.7	35.4
Ache reservation	78	5.9	3.0	30.5
Aboetigines	74	7.8	2.7	35.4
Wild chimpanzees	15	16.8	4.6	100.0
Captive chimpanzees	42	7.5	2.6	38.5
Sweden 1751-59	72	7.4	2.3	24.3
United States 2002	85	1.7	3.5	35.3

NOTE: The extent of variation around the mode is usually defined as four standard deviation units around the mode (Cheung et al. 2005).

Longevity Among Hunter-Gatherers: A Cross-Cultural Examination Gurven and Kaplan 2 0 0 7 *Population and Development Review*

Epidemiological Transitions (A.R. Omran 1971)

Age of low-density hunter gatherer life:
few famines
balanced nutrition
long inter-birth intervals

Age of pestilence and famine

Age of receding pandemics

Age of generative and man-made diseases

Practice question:

Why is Omran's concept of the earliest stage of epidemiology as one of "pestilence and famine" not necessarily correct?

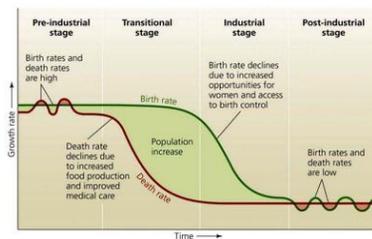
Because prior to agriculture in the last 10 ky low-density hunter gatherer life included

few famines

balanced nutrition

long inter-birth intervals

Epidemiological Transitions

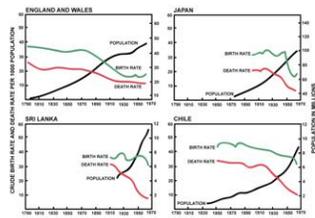


Omran, A.R. The epidemiologic transition: A theory of the epidemiology of population change. *Milbank Q.* 1971, 49, 509-538.

Birth rate and death rates have both changed during transitional and industrial stages.

Epidemiological Transitions

Shift from high mortality due to acute infections to death via chronic, non-infectious degenerative disease



Harper and Armelagos *Int. J. Environ. Res. Public Health* 2010

Three Epidemiological Transitions?

Transition	Paleolithic Baseline	First Transition	Second Transition	Third Transition
Time Period	Pre-Neolithic Cultures: More recent hunter-gatherer cultures with little outside contact	Neolithic cultures Early Modern Times in Western Europe and United States; Still characteristics many low-income countries	Early Modern times to 20th century in Western Europe, United States Occurred more recently in most other high-income countries and is in progress in lower income countries	End of the 20th century to the present, global
Characteristics	<ul style="list-style-type: none"> • Pre-agricultural • Low mortality and fertility rates • Small population size • Varied diet 	<ul style="list-style-type: none"> • Agricultural • High mortality and fertility rates • Large population size • Diet heavily reliant on crops 	<ul style="list-style-type: none"> • Agricultural • Low mortality and initially high then low fertility rates • Large population size • Increased life expectancy • Varied diet, overnutrition common • Discovery of antimicrobials and vaccines, improved hygiene 	<ul style="list-style-type: none"> • Agricultural • Large population size • Declining life expectancy? • Failure of antimicrobials • Rapid spread of novel infectious • Age of onset of chronic diseases delayed in high-income countries

Harper and Armelagos *Int. J. Environ. Res. Public Health* 2010

Driven by cultural changes? From foraging to farming/herding, from farming to industry, from traditional medicine to modern pharmaceuticals including vaccines, anti-bacterial (antibiotic), anti-helminthic, anti-protozoan, and anti-viral drugs.

Three Epidemiological Transitions?

Transition	Paleolithic Baseline	First Transition	Second Transition	Third Transition
Common causes of morbidity and mortality	Infections such as tapeworms, body lice, pinworms, typhoid, staph, and possibly yaws	<ul style="list-style-type: none"> • Infections such as malaria, smallpox, measles, tuberculosis • Nutritional deficiencies 	<ul style="list-style-type: none"> • Degenerative diseases such as heart failure, stroke, diabetes, cancer • Allergies, asthma, autoimmune diseases • Sexually transmitted infections such as HSV-2, gonorrhea, HIV 	<ul style="list-style-type: none"> • Those diseases present in the 2nd transition • Antibiotic resistant forms of tuberculosis, strep, staph, etc.

Harper and Armelagos *Int. J. Environ. Res. Public Health* 2010

The types of disease threats have changed.

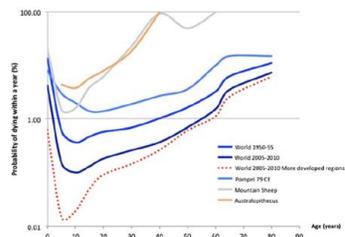
Epidemiological Transitions

Heirloom species:
head and body lice
M. tuberculosis (TB)
Helicobacter pylori
Yaws (bacterial infection related to syphilis)
Salmonella typhi
Staphylococci etc

Souvenir species:
Clostridium tetani
scrub typhus (*Orientia tsutsugamushi*)
relapsing fever
Trichinella

Harper and Armelagos *Int. J. Environ. Res. Public Health* 2010

Probability of dying within a year around the world



Saniotis, A., Henneberg, M., 2011. Medicine could be constructing human bodies in the future. *Medical Hypotheses* 77 (4).

Postnatal mortality expressed as a probability of dying within a year (logarithmic scale) at various stages of the human biological history.

Data for Australopithecine, mountain sheep (an average mammal), and humans from Pompeii (from Saniotis, A., Henneberg, M., 2011. Medicine could be constructing human bodies in the future. *Medical Hypotheses* 77 (4), 560e564.), and others (from World Health Organization (WHO) life tables.).

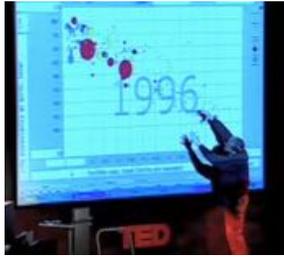
World Population



https://www.youtube.com/watch?v=PUwmA3Q0_OE

How long ago was the world population 1 billion?
In the late 1800s.

Population and health (Hans Rosling)



<https://www.youtube.com/watch?v=hVimVzgtD6w>

How valid is the concept of first world vs “third world”?

The was true in the 1960s, but most human populations now have small families and much longer life expectancies.

Double burden of disease



Bygbjerg, I. C. (2012) Double Burden of Noncommunicable and Infectious Diseases in Developing Countries. *Science*, 337 (6101).

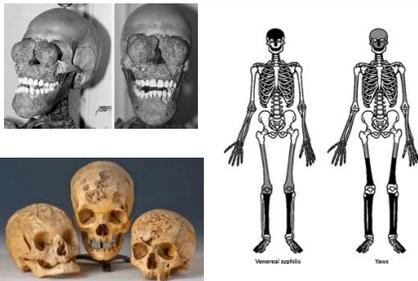
The proportional distribution of disability adjusted life years, contributable to infectious diseases and NCDs for (top) the world, (middle) high-income countries, and (bottom) low-income countries for 2002 and 2030.

Practice question:

What is meant by double burden of disease?

see above

From Yaws/Pinta to Syphilis?



Treponema pertenue/carateum to *Treponema pallidum*?

The spirochetes causing yaws, pinta and syphilis cause diagnostic skeletal abnormality and allow to teach these infections in the distant past.

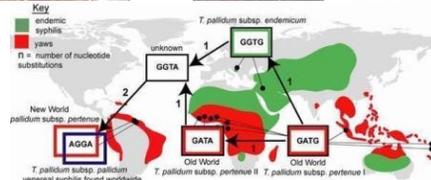
From Yaws/Pinta to Syphilis?



Treponema pertuene/carateum to Treponema pallidum?

Presentations of spirochete infections by close relatives of the syphilis causing agent.

From Yaws to Syphilis?



Treponema pertuene to Treponema pallidum?

Harper KN, Ocampo PS, Steiner BM, George RW, Silverman MS, Bolotin S, Pillay A, Saunders NJ, Armetagos GJ. On the origin of the treponematoses: a phylogenetic approach. *PLoS Negl Trop Dis*. 2008

A network path for four informative substitutions shows that New World subsp. pertuene, or yaws-causing strains, are the closest relatives of modern subsp. pallidum strains. On the map green represents endemic syphilis; red, yaws; numbers show the number of nucleotide substitutions.

From Yaws to Syphilis?

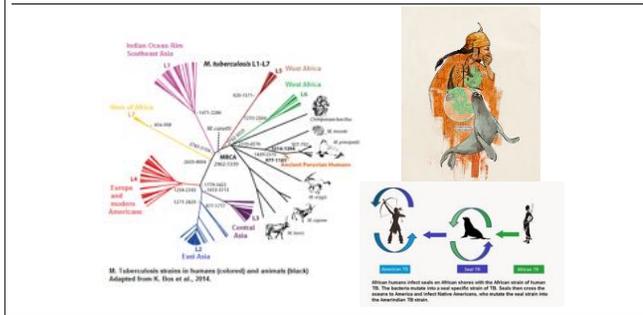


Sailors, by the nature of their profession are men without women and are therefore men with many women. We can imagine no group more suitable for guaranteeing that venereal syphilis would have worldwide distribution.

– Alfred Crosby Jr.

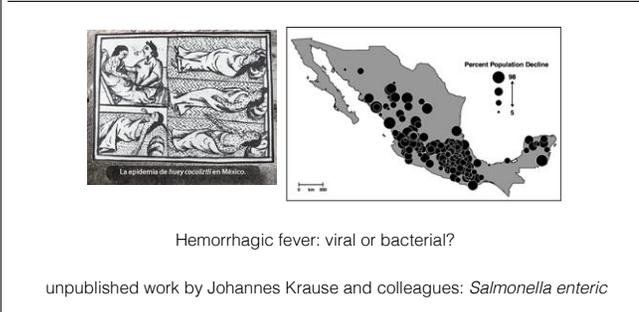
Treponema pertuene to Treponema pallidum?

Paleo TB in South America



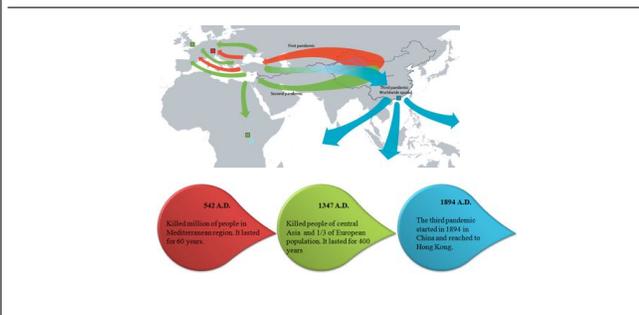
TB arrived in the Americas with humans via the Bering bridge and down into South Americas, but also via seals from Africa.

Cocoliztli Epidemic of 1576



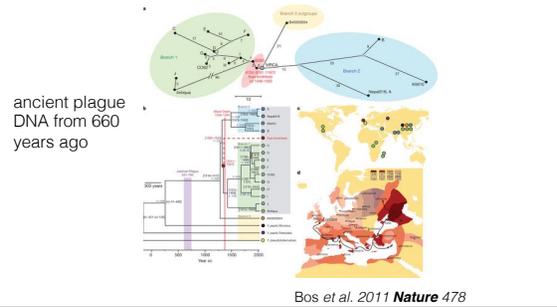
Geographical distribution of mortality in Mexico during the cocoliztli epidemic of 1576. The size of each circle corresponds to the percent population decline between the census of 1570 and the census of 1580.

Bubonic Plague



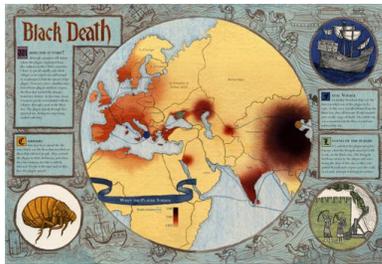
The *Yersinia pestis* pathogen uses sialic acids on the surface of animal hosts, it binds to many different hosts and can jump from species to species.

Bubonic Plague



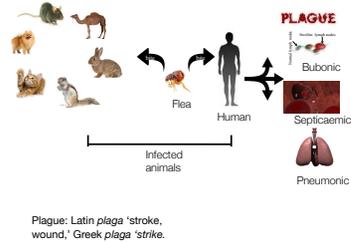
Median network of ancient and modern *Y. pestis* based on 1,694 variant positions in modern genomes. Coloured circles represent different clades. Gray circles represent hypothetical nodes. b, Phylogenetic tree using 1,694 variable positions. Divergence time intervals are shown in calendar years, with neighbour-joining bootstrap support (blue italic) and Bayesian posterior probability (blue). Grey box indicates known human pathogenic strains. A, NZ ACNQ01000; Nepal516, NC 008149; KIM10, NC 004088; B, NZ AAYT01000; C, NZ ABAT01000; D, NZ ACNS01000; E, NZ AAYS01000; F, NZ AAOS02000; CO92, NC 003143; G, NZ ABCD01000; H, NZ AAYV01000; I, NC 014029; J, NZ AAYR01000; Antiqua, NC 008150. c, Geographical origin of genome sequences used in a and b. d, Geographical spread of the Black Death from infection routes reported.

Bubonic Plague



The black death killed off between 1/3 and 1/2 the European population.

Bubonic Plague

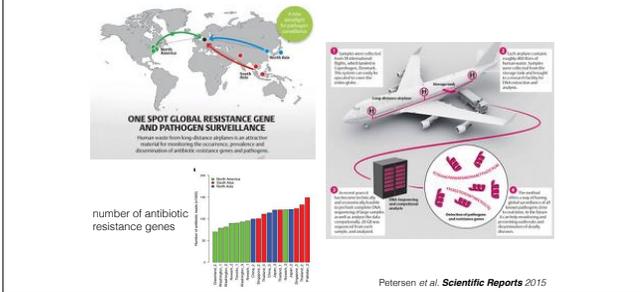


Practice question:

Is infection by the plague strictly transmitted by fleas?

No the plague can become pneumonic, i.e. transmitted directly from one human to the next (airborne).

Metagenomics of global poop (on airlines)



Modern surveillance of novel dangerous pathogens introduced via air traffic:
Sequence DNA in the sewage of airplanes!

A. Adjusted number of resistance reads (DNA sequences known to encode resistance to antibiotic drugs) identified in the flight samples. Green: North America, red: South Asia, blue: North Asia.

Summary



The disease landscape has dramatically changed over time for humans.

Three major epidemiological transition are often proposed: from hunter gatherer to settled farmers, from farming to industrial societies, and from industrialized societies to modern, globalized metropolitan societies

There may well have been earlier transitions associated with carnivory and the use of home bases.

Developing nations face double burdens of infectious and non-communicable disease.

Reconstructing distant epidemics/pandemics is mired in difficulties.

Traces in skeletal remains and ancient DNA studies are starting to shed light on diseases such as syphilis, the plague and TB.

We are in the midst of a further epidemiological transition: antibiotic resistance and human made pathogens.....