

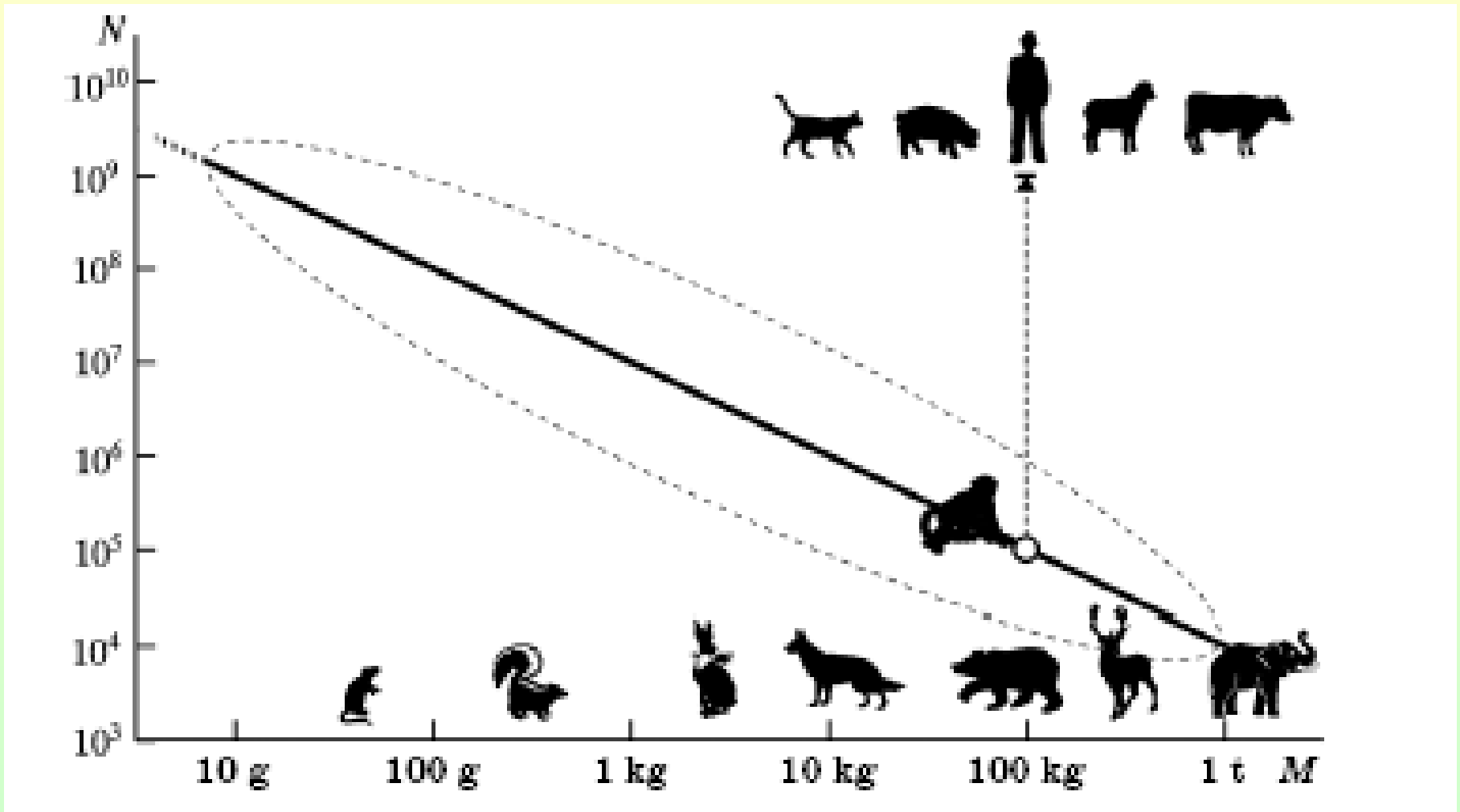
GLOBAL POPULATION BLOW-UP AND AFTER

**HISTORY SEEN AT LARGE
AND THE
FUTURE KNOWLEDGE-BASED
INFORMATION SOCIETY**

Sergey P. Kapitza

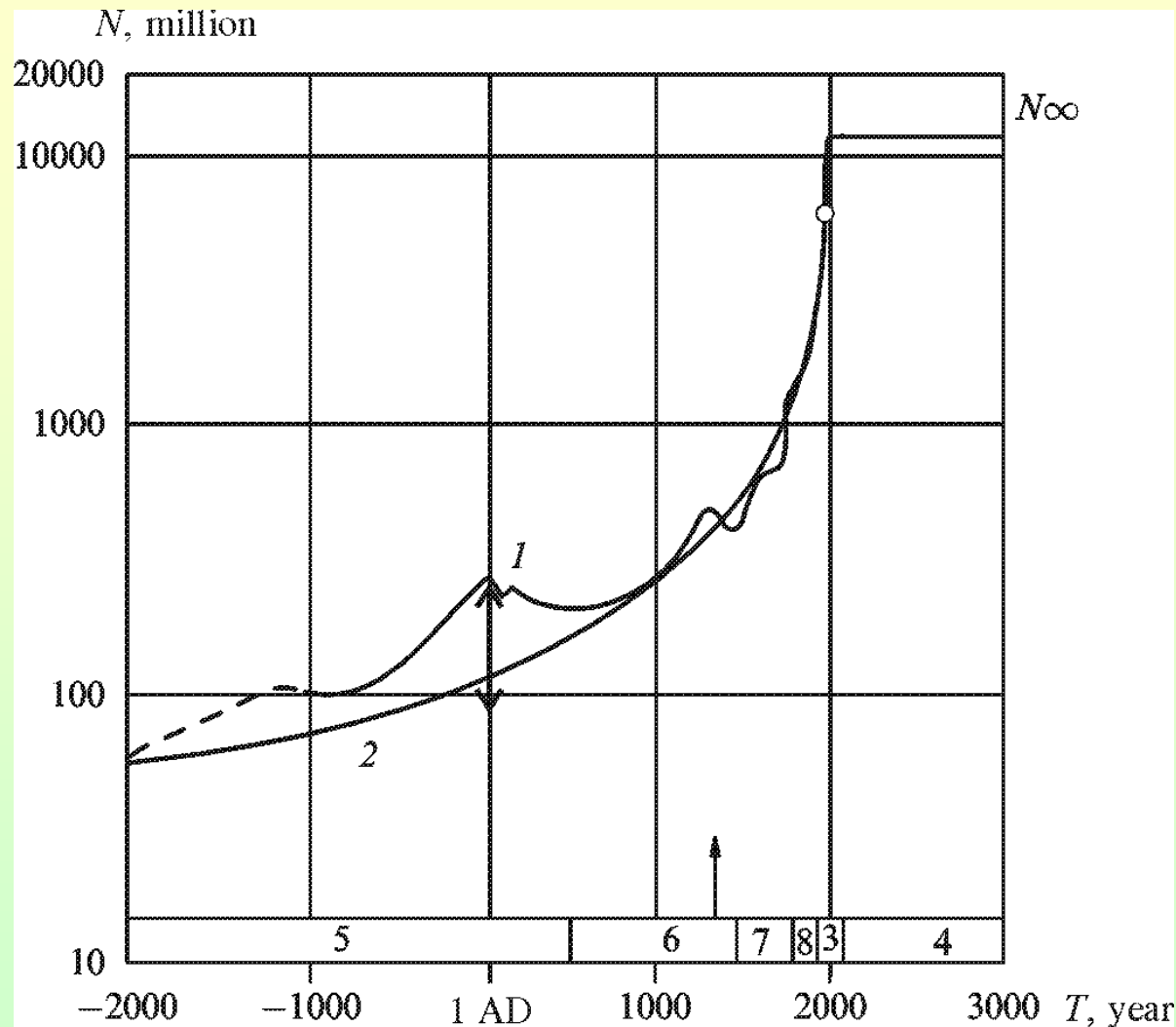
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HOW MANY PEOPLE ARE THERE ON EARTH?



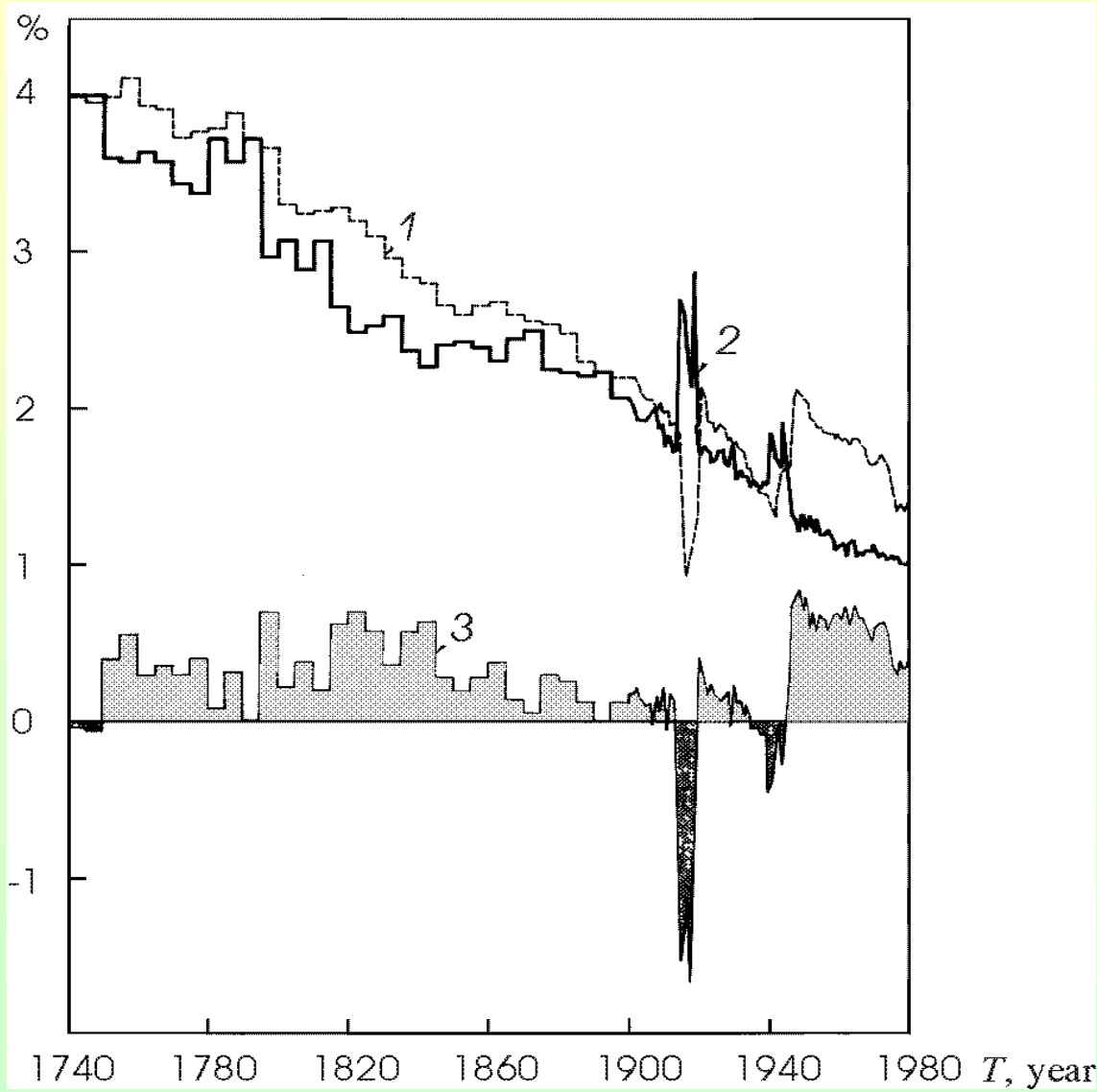
NUMBERS OF A GENERA DEPENDING ON BODY WEIGHT

WORLD POPULATION FROM 2000 BC TO 3000 AD



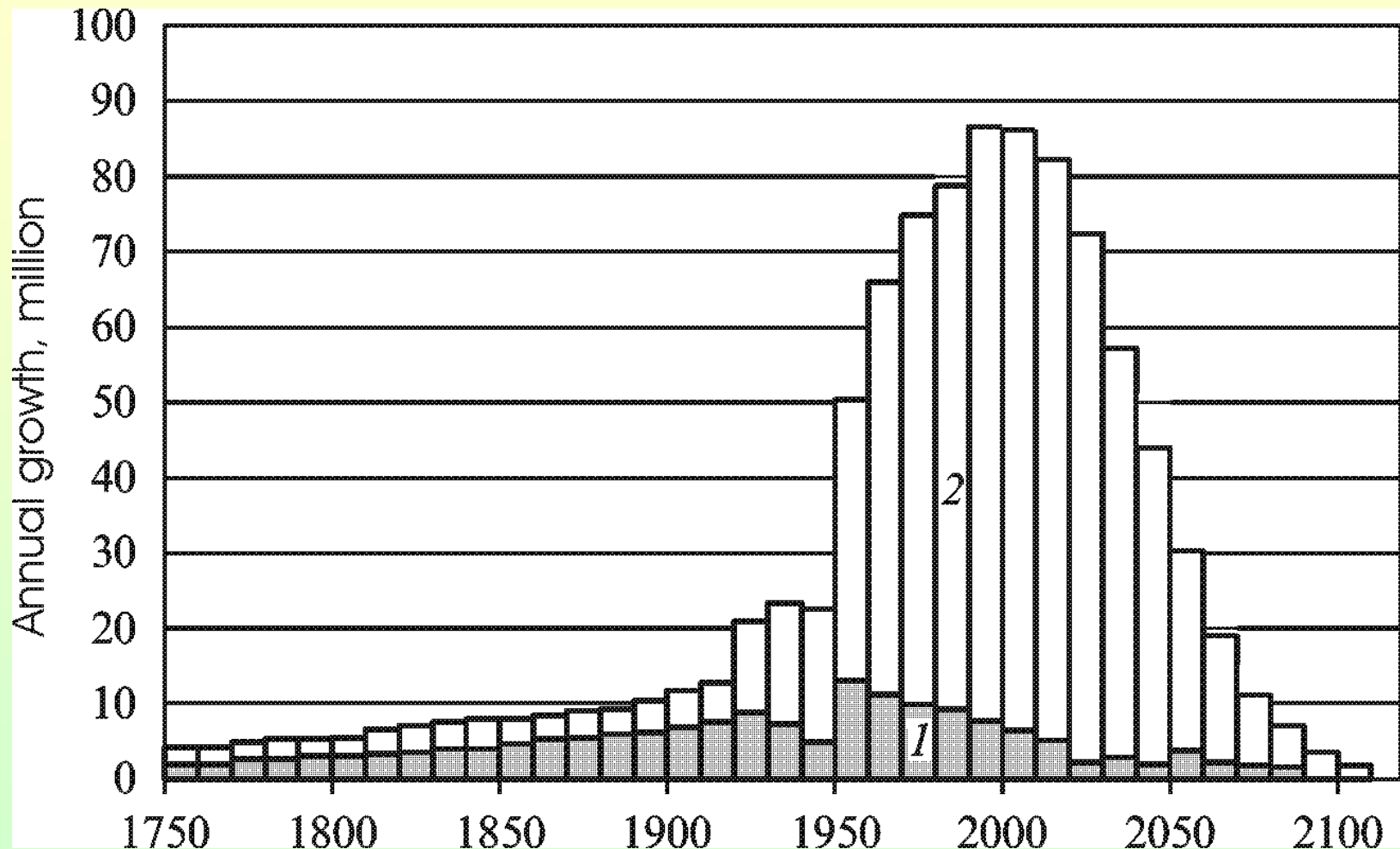
1 – DATA OF BIRABEN, 2 – BLOW-UP, 3 – DEMOGRAPHIC TRANSITION, 4 – STABILIZED POPULATION
 5 – ANCIENT WORLD, 6 – MIDDLE AGES, 7 – MODERNITY, 8 – RECENT HISTORY, ↑ – THE PLAGUE 1348

DEMOGRAPHIC REVOLUTION IN FRANCE 1740 – 1980



1 – birth, 2 – death and 3 – growth rates, % per year

GLOBAL DEMOGRAPHIC TRANSITION



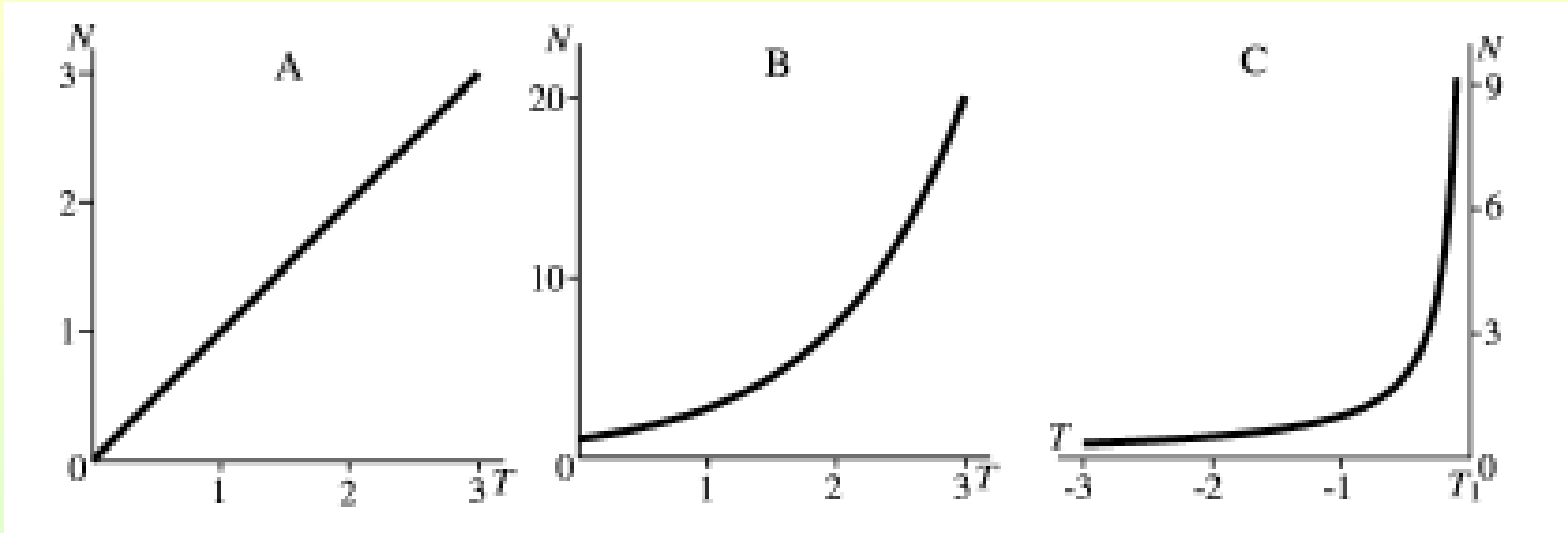
ANNUAL GROWTH AVERAGED OVER A DECADE

1 – DEVELOPED AND 2 – DEVELOPING COUNTRIES

MAIN ASSUMPTIONS MADE IN MODELING

- GLOBAL POPULATION IS AN EVOLVING DYNAMIC SYSTEM, FAR FROM EQUILIBRIUM, PASSING THROUGH AN INSTABILITY.
- MANKIND IS A SINGLE SPECIES *Homo sapiens* WITH NUMBERS **100 000** TIMES LARGER THAN FOR ALL SIMILAR ANIMALS.
- THE SYSTEM IS COUPLED BY A COLLECTIVE INTERACTION.
- GROWTH IS STATISTICALLY DETERMINED AND DYNAMICALLY SELF-SIMILAR, AND ASYMPTOTICALLY IT SCALES.
- LIMITS OF SCALING ARE SET BOTH IN OUR PRESENT AND PAST BY THE HUMAN LIFE SPAN – 45 YEARS,
- THE INTERACTION IS PROPORTIONAL TO THE **SQUARE** OF THE GLOBAL POPULATION, AND IS NON-LINEAR AND NON-LOCAL.

LINEAR, EXPONENTIAL AND HYPERBOLIC GROWTH



$$\frac{dN}{dT} = A \quad N = AT \quad \frac{dN}{dT} = \frac{N}{\tau} \quad N = N_0 \exp T/\tau \quad \frac{dN}{dT} = \frac{N^2}{C} \quad N = \frac{C}{T_1 - T}$$

REGULARIZING GROWTH AT THE SINGULARITY: T_1 $\frac{dN}{dT} = \frac{C}{(T_1 - T)^2}$ $\frac{dN}{dT} = \frac{C}{(T_1 - T)^2 + \tau^2}$

INSTANTANEOUS EXPONENT IS THE AGE OF THE EPOCH: $T_E = T_1 - T$

LINEAR AND HYPERBOLIC GROWTH ARE SELF-SIMILAR.

RESULTS OF MODELLING GLOBAL GROWTH

BLOW-UP OF POPULATION GROWTH:
$$N = \frac{176 \cdot 10^9}{2025 - T} = \frac{C}{T_1' - T}$$

GROWTH RATE:
$$\frac{dN}{dT} = \frac{N^2}{C}, \quad \frac{dN}{dT} = \frac{C}{(T_1 - T)^2} \rightarrow \frac{dN}{dT} = \frac{C}{(T_1 - T)^2 + \tau^2}$$

GROWTH BEFORE AND AFTER CRITICAL DATE T_1
$$N = \frac{C}{\tau} \cot^{-1} \left(\frac{T - T_1}{\tau} \right)$$

CONSTANTS: $T_1 = 2000, \quad \tau = 45, \quad K = \sqrt{C/\tau} = 62000, \ln K = 11$

POPULATION LIMIT: $N_\infty = \pi K^2 = 12 \cdot 10^9, \quad \text{MAX. RATE: } \left(\frac{dN}{dT} \right)_1 = \frac{K^2}{\tau} = 87 \cdot 10^6$

THE BEGINNING OF GROWTH: $T_0 = -\frac{\pi}{2} K \tau = 4.4 \cdot 10^6,$

NUMBER OF PEOPLE WHO EVER LIVED: $P_{0,1} = 2.25 K^2 \ln K = 100 \cdot 10^9.$

NUMBER OF CYCLES: $1 + \ln K = 12$

INSTANTANEOUS EXPONENTIAL GROWTH RATE:
$$\frac{1}{N} \frac{dN}{dT} = \frac{1}{T_e} = \frac{100}{T_1 - T} \%$$

DIMENSIONLESS TIME AND POPULATION

$$t = \frac{T - T_1}{\tau} \qquad n = \frac{N}{K}$$

$$\frac{dn}{dt} = \frac{n^2 + 1}{K}, \quad n = -\cot \frac{t}{K}$$

EQUATIONS FOR GROWTH SHOW
THE CONJUGATE SYMMETRY OF
TIME AND POPULATION.

$$\frac{dn}{dt} = \frac{n^2}{K}, \quad nt = -K$$

$$\frac{dn}{dt} = \frac{K}{t^2 + 1}, \quad n = -K \cot^{-1} t$$

IF IN THE BEGINNING TIME IS THE
INDEPENDENT VARIABLE, LATER
POPULATION TAKES UP ITS PLACE.

$$\frac{dt}{dn} = \frac{t^2 + 1}{K}, \quad t = -\cot \frac{n}{K}$$

THE NUMBER OF PEOPLE WHO EVER LIVED DURING $\ln K$ CYCLES:

$$P_{0,1} = K \int_{t_0}^{t_{1/2}} \cot \frac{t}{K} dt + K \int_{t_{1/2}}^0 K \cot^{-1} dt = \frac{1}{2} K^2 \ln K + \frac{1}{2} K^2 \ln(1 + K) \cong K^2 \ln K$$

SUMMING EXPONENTIAL CYCLES FROM BEGINNING OF DEVELOPMENT TO DEMOGRAPHIC REVOLUTION

WHEN $\ln K$ CYCLES: $\Delta T = K \tau \exp(-\theta)$ ARE

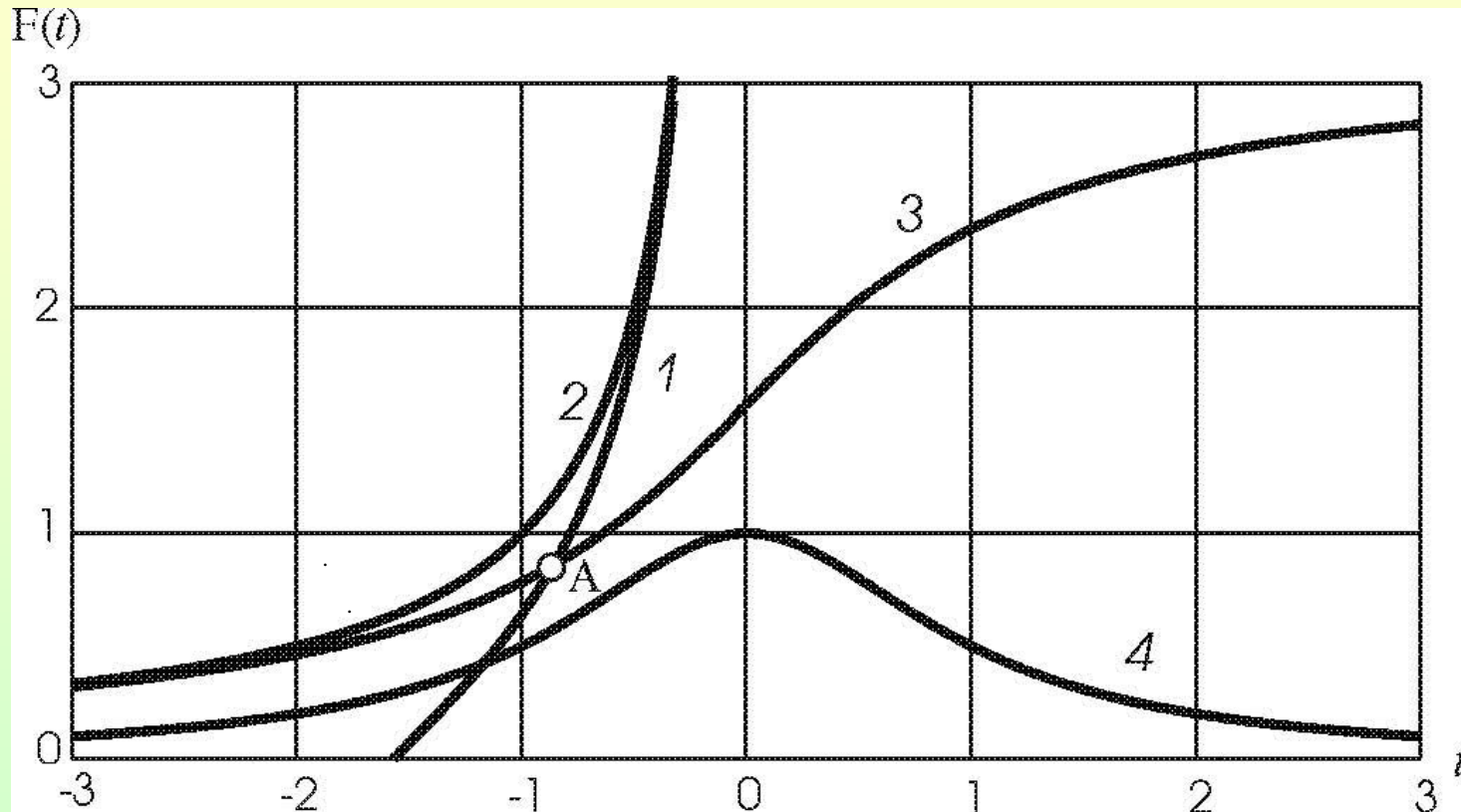
SUMMED UP THE TOTAL DURATION OF THE PAST IS OBTAINED:

$$T_1 - T_0 = K \tau \sum_0^{\ln K} \exp(-\theta) = K \tau [1 + \exp(-1) + \exp(-2) + \dots$$

$$+ \exp(-\ln K)] \approx \frac{e}{e-1} K \tau = 1.582 K \tau \approx \frac{\pi}{2} K \tau = 1.571 K \tau$$

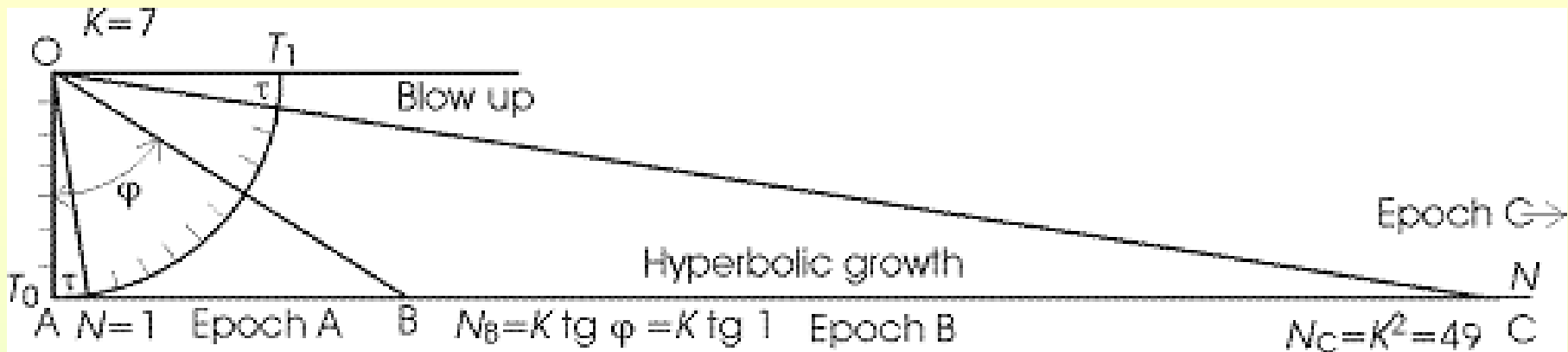
WHERE $\theta = \ln T$ IS **TIME - 2** – THE LOGARITHM OF **TIME - 1**

FUNCTIONS DESCRIBING GROWTH FOR $K=1$



$$1 - \cot t, \quad 2 - -1/t, \quad 3 - \cot^{-1} t, \quad 4 - 1/(t^2 + 1)$$

AT HALF-WAY POINT **A** CURVES (1) AND (3) INTERSECT



Tangent construction, showing asymptotic limits.

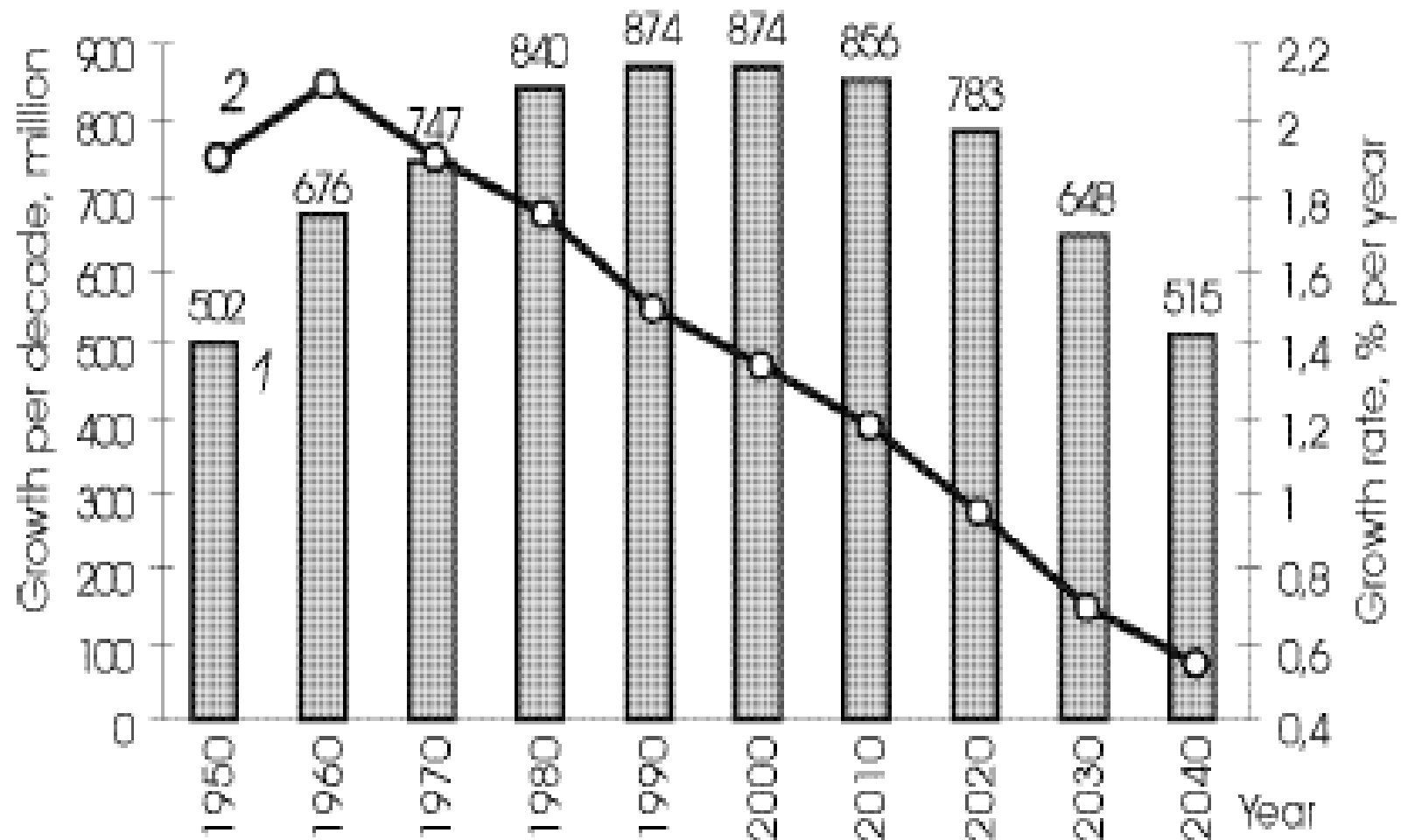
For $K=7$ the number of cycles $1+\ln K=1+1.95\sim 3$

Epoch A: initial singularity with linear growth
up to $N = K = 7$

Epoch B: growth up to $N = K^2 = 49$

Epoch C: singularity of demographic transition

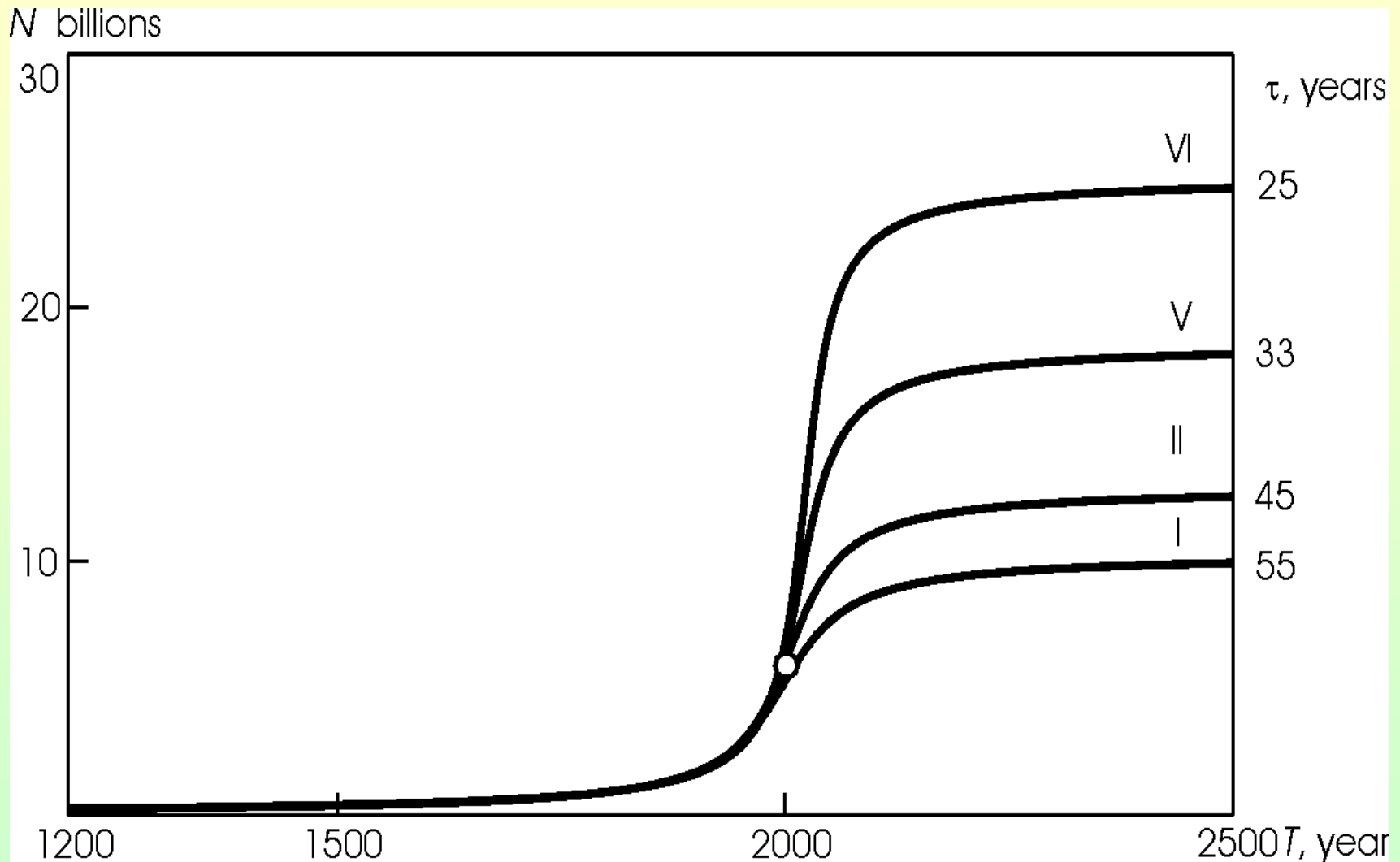
GLOBAL DEMOGRAPHIC TRANSITION IN DETAIL



1 – growth, averaged in a decade, (left scale).

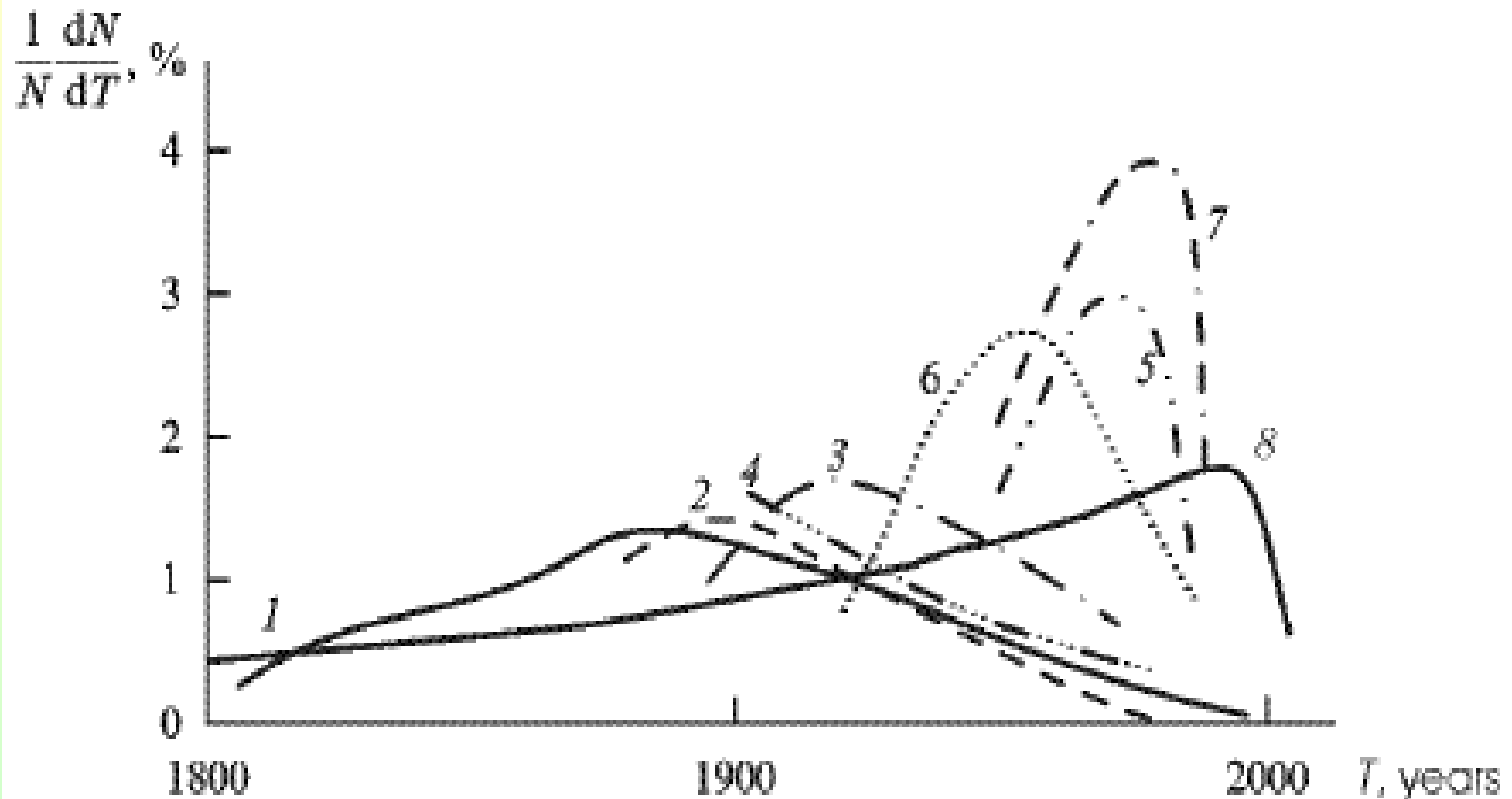
2 – relative growth rate in % per year (right scale). UN data

GLOBAL POPULATION GROWTH MODELS



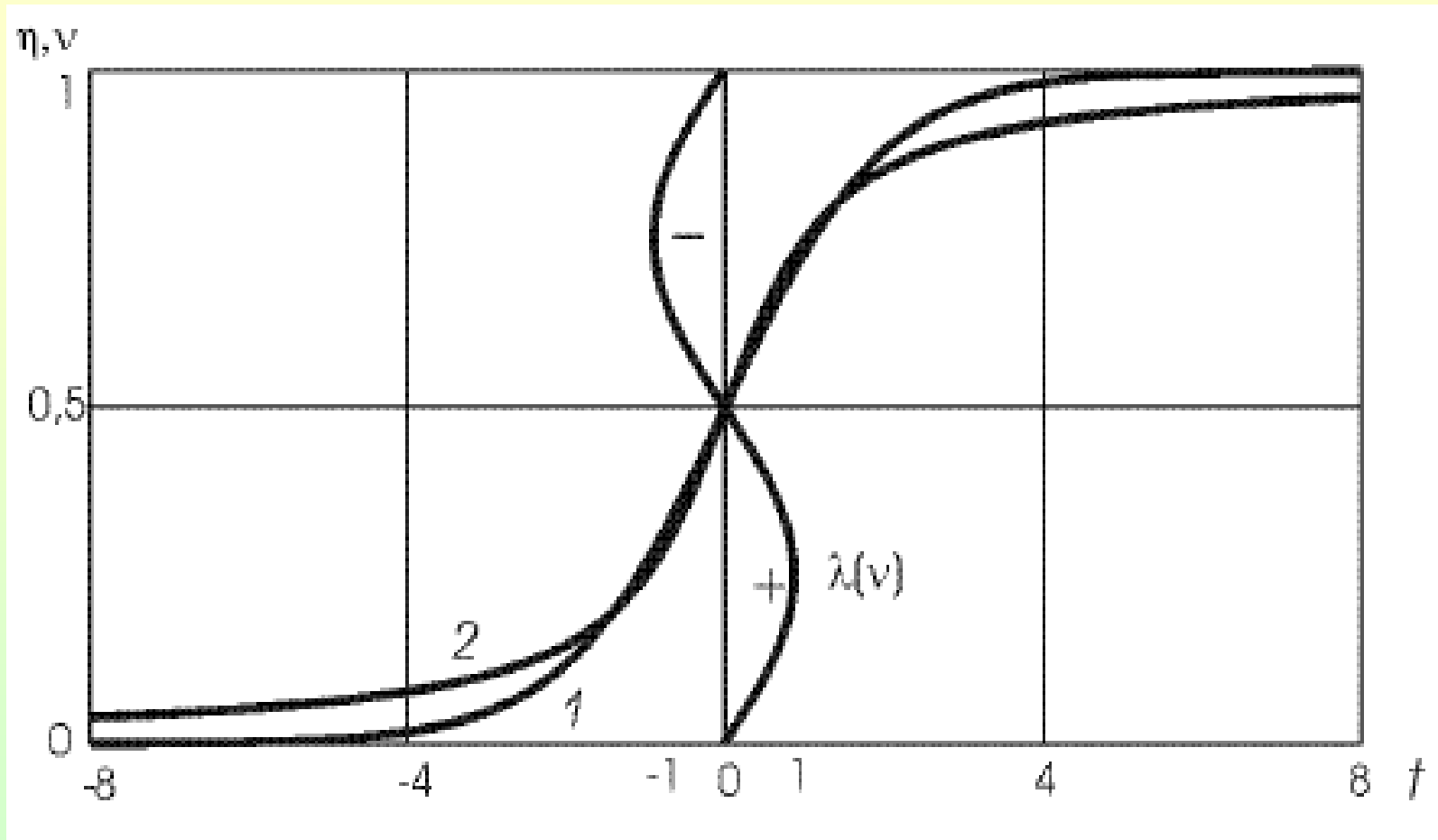
For different values of the time constant

. RELATIVE GROWTH RATE DURING THE TRANSITION



1 – Sweden, 2 – Germany, 3 – USSR (Russia), 4 – USA,
 5 – Mauritius, 6 – Sri Lanka, 7 – Costa Rica, 8 – Global Model
 The data are smoothed, so as to show the general trends

LOGISTIC AND THE DEMOGRAPHIC MODEL



The logistic -1 in the past approaches zero as an exponent.
 For the model - 2 the asymptotic approach is hyperbolic.
 The Lyapunov index indicates stability of growth.

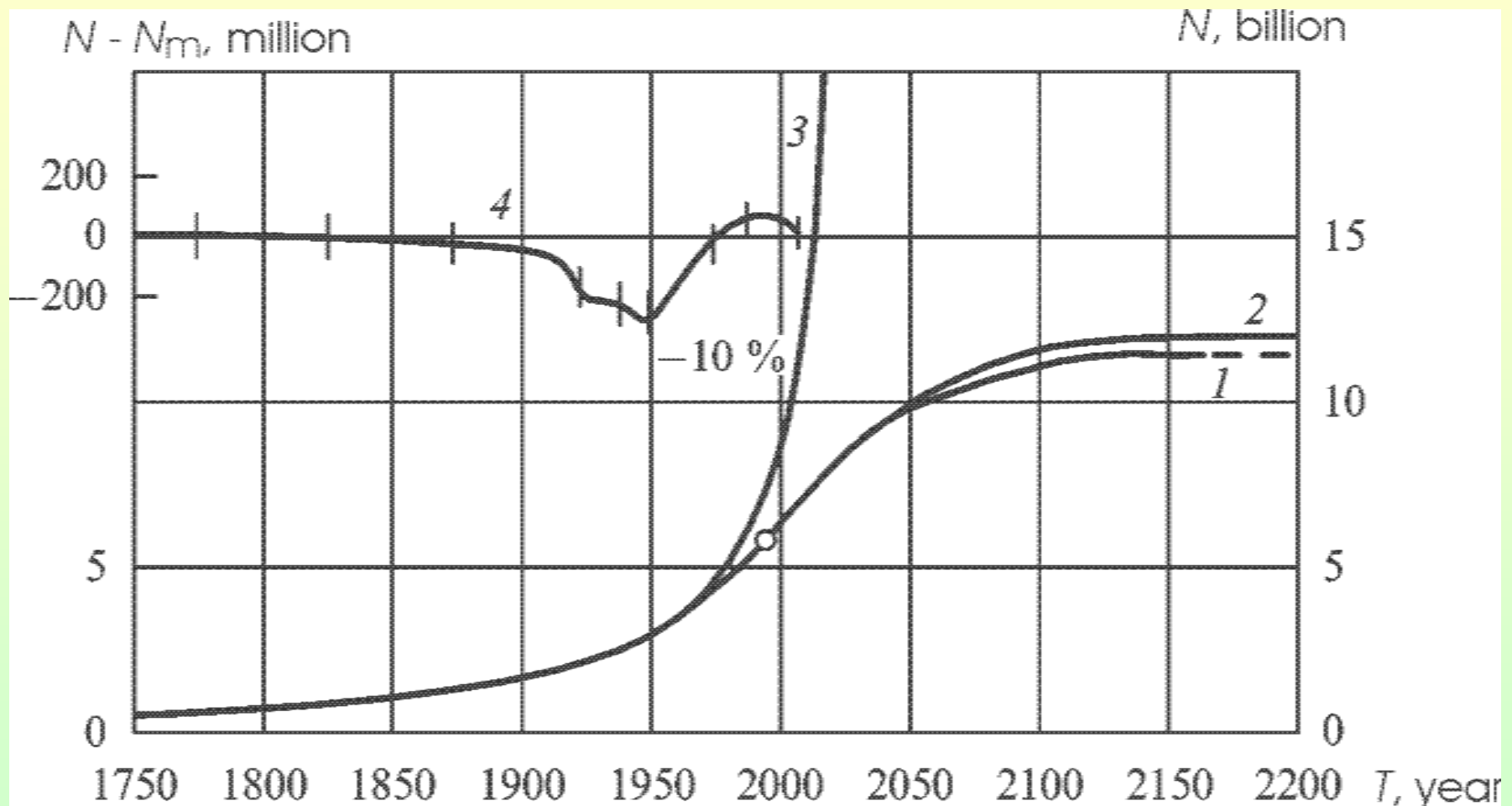
NATURE OF THE QUADRATIC INTERACTION

- THE INTERACTION IS GLOBAL AND OPERATES FOR A MILLION AND A HALF YEARS. IT'S A COLLECTIVE AND COOPERATIVE INTERACTION SIMILAR TO THE VAN-DER-WAALS INTERACTION INTRODUCED IN NON-IDEAL GAS THEORY.
- INTERACTION IS PRIMARILY DUE TO LANGUAGE. IT AFFECTS CONSCIOUSNESS OF AN INDIVIDUAL AND LEADS TO SOCIAL CONSCIOUSNESS AND BEHAVIOR.
- IN A STATISTICAL THEORY OF GLOBAL POPULATION GROWTH THE EFFECTIVE POPULATION UNIT HAS $K \sim 100\,000$ PEOPLE, ACTING COHERENTLY. THE DETERMINISM OF GROWTH IS EXPRESSED BY THE PRINCIPLE OF THE DEMOGRAPHIC IMPERATIVE.
- AT EARLY STAGES OF GROWTH PARALLEL SPECIES MAY HAVE INFLUENCED DEVELOPMENT AND COMPLICATE THE STORY OF OUR ORIGINS. RECENT STUDIES OF THE GENOME HAVE TO BE KEPT IN MIND FOR THE PREMISES AND RESULTS OF MODELLING WHEN GENETIC AND SOCIAL EVOLUTION OVERLAP.

OUTCOME OF THE QUADRATIC INTERACTION

- THE INTERACTION LEADS TO SOCIAL INHERITANCE AND EVOLUTION. AS INFORMATION IS TRANSFERRED AND IRREVERSIBLY MULTIPLIED IT LEADS TO SOCIAL DEVELOPMENT. THIS IS FUNDAMENTALLY DIFFERENT FROM DARWINIAN EVOLUTION, WHERE INFORMATION IS TRANSFERRED GENETICALLY. IN THE CASE OF *Homo* SOCIAL EVOLUTION IS VERY RAPID AND ITS FINAL OUTCOME IS THE BLOW-UP OF HUMAN NUMBERS.
- THE RATE OF GROWTH IS LIMITED BY THE INHERENT NATURE OF THE INTERACTION AND NOT, IN THE FIRST APPROXIMATION, BY EXTERNAL RESOURCES, SPACE OR THE ENVIRONMENT. THAT IS WHY THE DEMOGRAPHIC TRANSITION IS BOTH RAPID AND WORLDWIDE, A VERITABLE PHASE TRANSITION MAKING IT THE GREATEST CRISIS IN OUR HISTORY.

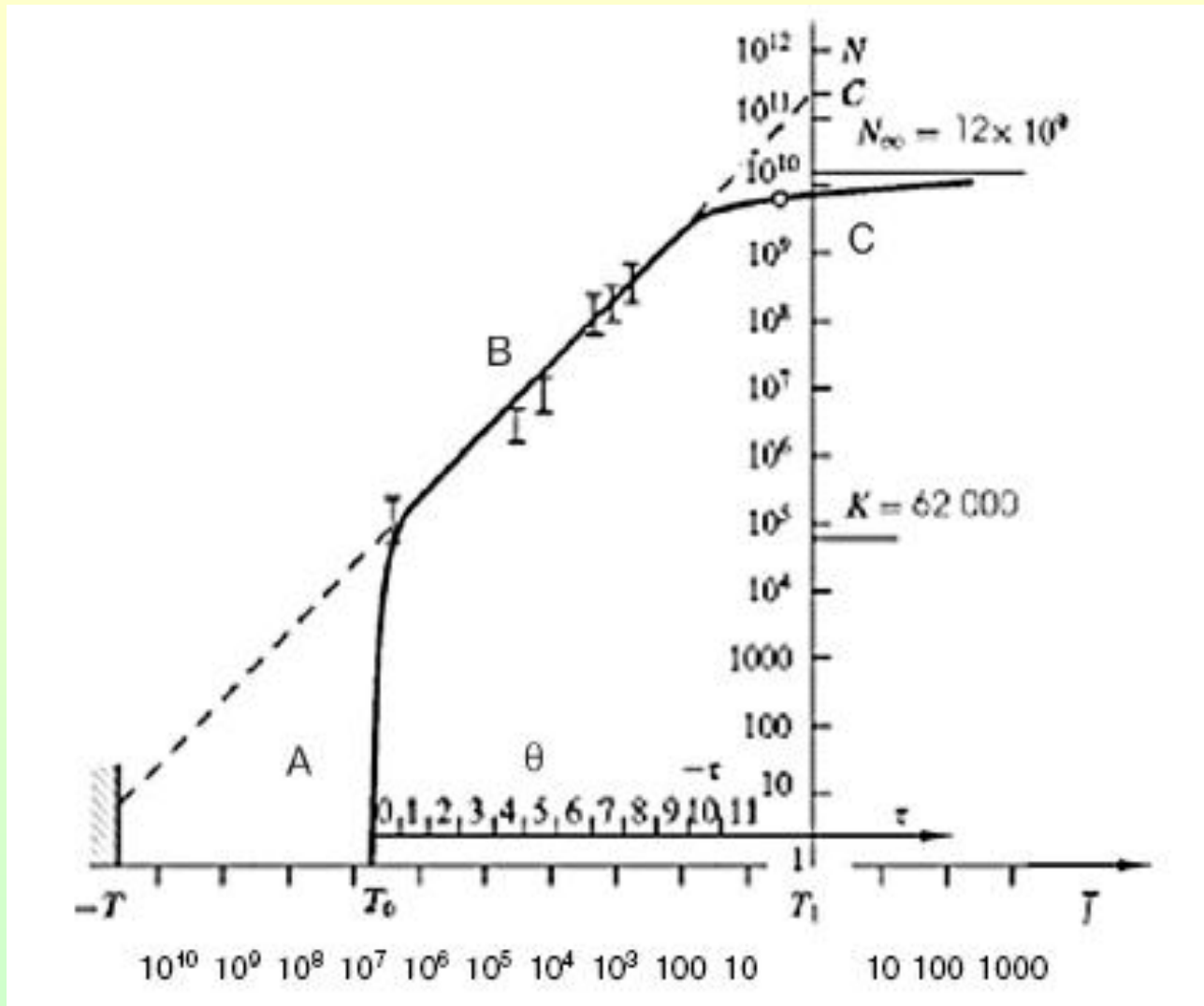
POPULATION OF THE WORLD 1750–2200



1 – PROJECTIONS BY IIASA AND UN, 2 – MODEL, o – 1995

3 – BLOW-UP, 4 – DIFFERENCE OF MODEL AND PROJECTIONS $\times 5$ times

GLOBAL POPULATION GROWTH



From the origin of mankind into the foreseeable future
 $\theta = \ln t'$, --- (2), - 1995, point zero is removed

PRINCIPAL RESULTS OF THE THEORY

- POPULATION IS THE DOMINANT VARIABLE, DETERMINING THE GROSS PATTERN OF GROWTH, THE PARAMETER OF ORDER. THE LARGE PARAMETER K DETERMINES ALL RESULTS OF THEORY.
- THIS IS EXPRESSED AS THE PRINCIPLE OF THE DEMOGRAPHIC IMPERATIVE, INSTEAD OF THE POPULATION PRINCIPLE OF MALTHUS, BY WHICH GROWTH IS LIMITED BY RESOURCES.
- GROWTH IS CULMINATED BY THE DEMOGRAPHIC TRANSITION. IT IS SIMILAR TO A SHOCK WAVE IN SUPERSONIC FLOW AND ITS DURATION IS LIMITED BY THE 'MICROSCOPIC' TIME OF THE PHENOMENOLOGICAL THEORY – THE HUMAN LIFE SPAN.
- GLOBAL POPULATION WILL BE LIMITED AT 10 – 12 BILLION AND THE NUMBER OF PEOPLE, WHO EVER LIVED IS ~ 100 BILLION.
- INTERNAL FACTORS STABILIZE GROWTH, SEEN IN THE GLOBAL CULTURAL AND DEMOGRAPHIC CYCLES INDICATING STABILITY. IT ARE THESE FACTORS, WHICH DETERMINE THE 'LIMITS OF GROWTH,' AND NOT RESOURCES OR THE ENVIRONMENT.

FORECASTS OF THE THEORY

- AFTER THE TRANSITION AN EPOCH OF EQUILIBRIUM WITH A ZERO GROWTH RATE IS TO BE EXPECTED.
- UP TO TRANSITION INEQUALITIES AND INEQUITIES ARE TO GROW, WITH A CRISIS OF FAMILY AND GOVERNANCE. AFTER THE TRANSITION A TRANQUIL PHASE MAY BE EXPECTED.
- DEVELOPED COUNTRIES ARE NOW FACING THE **TFR** CRISIS. HOW WILL IT BE RESOLVED IN THE FUTURE?
- CAN WE EXPECT LESS STRESS AND MILITANCE IN THIS NEW STAGE OF HISTORY.
WILL THE QUALITY OF LIFE IN A KNOWLEDGE SOCIETY BECOME THE FINAL DESTINY OF MAN?

MEANING AND RELATIVITY OF TIME IN HISTORY

Insight of historians and the phenomenology of the model have led to distinguishing the concept of **Time - 1** as external Newtonian time, and **Time - 2** – as the inner systemic time of development, equal to the logarithm of **Time - 1**. This has been long recognized by anthropologists who plotted the Stone age on a logarithmic scale. For otherwise they could not accommodate on the same chart the Neolithic 10 000 years ago with the million years of the Paleolithic. Thus the double logarithmic plot becomes the natural one for describing global population growth.

The exponential compression of time during the development of mankind means that the duration of each cycle is approximately twice as long as the time left up to the demographic transition. Since the end of the Lower Paleolithic half a million years are left, and after the millennium of the Middle ages 500 years have passed. During the whole development of mankind $\ln K = 11$ cycles occurred, and in each 9 billion people lived.

The sense of time of growth and development in history is intimately connected with the number of people. A million years ago of the Lower Paleolithic are equivalent to a thousand years of the Middle ages and to forty years today. At present time can be compressed no more – hence the demographic revolution. The discrete nature of time and population leads to the demographic cycles, where cultural markers identify the cycles, rather than population data. Finally, the concept of *longue durée* was introduced by French historians, influenced by the ideas of Henri Bergson, and now expressed by identifying Time -1 and Time - 2.

Table 5.3. Growth and development of mankind, shown on a logarithmic scale

Epoch	Period θ	Date year	Number of people	Cultural period	ΔT years	Events in history, culture, and technology
C	T_1	2200	11×10^9	Stabilizing global population	125	Global population limit 12×10^9 Changing age distribution Globalization
		2050	9×10^9			
		2000	6×10^9	World demographic revolution	45	Urbanization Internet
B	11	1955	3×10^9	Recent	125	Biotechnology Computers World Wars Electric power
	10					
	9	1840	1×10^9	Modern	340	Industrial revolution Printing Universities
	8					
	7	500 AD	10^8	Ancient World	2500	Geographic discoveries Fall of Rome Christ, Muhammad Greek civilization Axial time India, China, Buddha, Confucius
	6					
	5	9000	10^7	Neolithic	7,000	Mesopotamia, Egypt Writing, Cities Domestication, Agriculture
	4					
	3	29,000	10^6	Mesolithic	20,000	Bronze Microliths
	2					
	1	80,000	10^5	Moustier	51,000	America populated Shamanism Language
0						
0	0.22 Ma	10^4	Acheulean	1.4×10^5	<i>Homo sapiens</i> Speech, Fire	
1						
1	0.6 Ma	10^3	Chelles	3.8×10^5	Europe and Asia populated Hand axes	
2						
2	1.6 Ma	10^2	Olduvai	1×10^6	Choppers <i>Homo habilis</i>	
3						
A	T_0	4.5 Ma	(1)	Anthropogen	3×10^6	Hominida separate from Hominoids

CONSEQUENCES OF THE DEMOGRAPHIC REVOLUTION

DEMOGRAPHIC

- **Crisis of low TFR – the Total Fertility Rate. In developed countries the number of children per woman is too low.**
- **Zero growth rate.**
- **Stabilized population.**
- **Further urbanization.**
- **New time structure.**
- **New age structure.**
- **Ethnic changes.**
- **Massive migrations ?**
- **Predominance of older generations setting challenges for health and social security.**
- **Return of an extended family?**

ECONOMIC



- **Further globalization.**
- **Less inequities and regional instabilities.**
- **Deindustrialization.**
- **Transition to a knowledge based information society.**
- **Expansion of services: health, education, science.**
- **Emergence of new priorities and values in education, consumption, environment**
- **Is there an alternative to stagnation as a new vector for development may emerge?**
- **Short range chaos of the market.**
- **Shift from production to governance.**

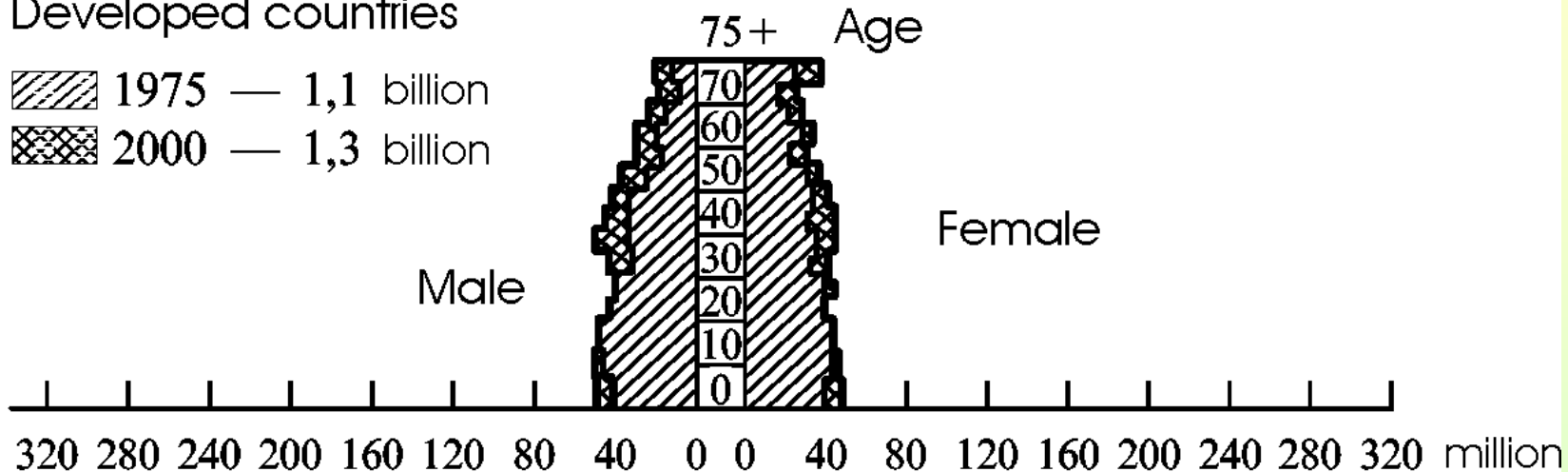
STABILITY OF GROWTH

- ALTHOUGH THE LYAPUNOV INDEX IN THE FIRST APPROXIMATION INDICATES GROWTH TO BE UNSTABLE UP TO THE DEMOGRAPHIC REVOLUTION, GROSS PERIODS OF DEVELOPMENT SHOW THAT GLOBALLY GROWTH IS STABLE.
- ONLY JUST BEFORE THE D.R. A MAJOR GLOBAL INSTABILITY – XX CENTURY WORLD WARS – HAPPENED WITH A TOTAL LOSS OF LIFE 280 BILLION, OR 8%. AFTER THIS EVENT GLOBAL POPULATION RETURNED TO ITS STABLE GROWTH TRACK.
- ALL DISTURBANCES OF A LESSER SCALE IN TIME AND SPACE, THOSE OF CONCERN TO HISTORY, ARE CHAOTIC.
BY NONLINEAR COUPLING TO THE GROSS PATTERN OF GROWTH GLOBAL MOTION IS STABILIZED.



AGE DISTRIBUTIONS IN THE DEVELOPED AND DEVELOPING WORLD IN 1975 AND 2000

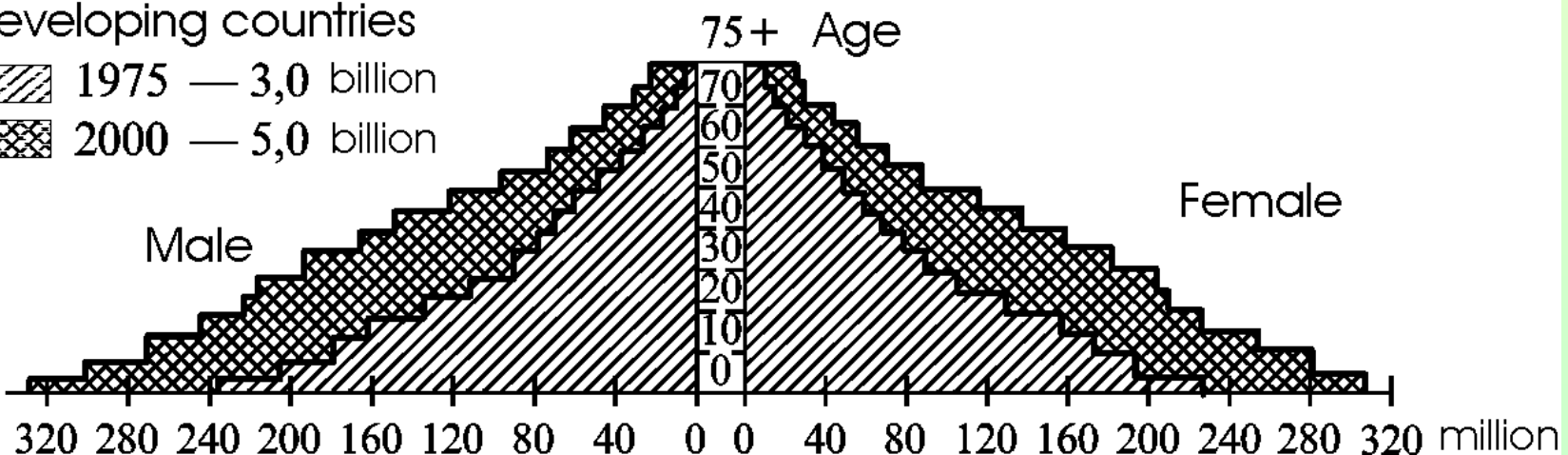
Developed countries

 1975 — 1,1 billion
 2000 — 1,3 billion

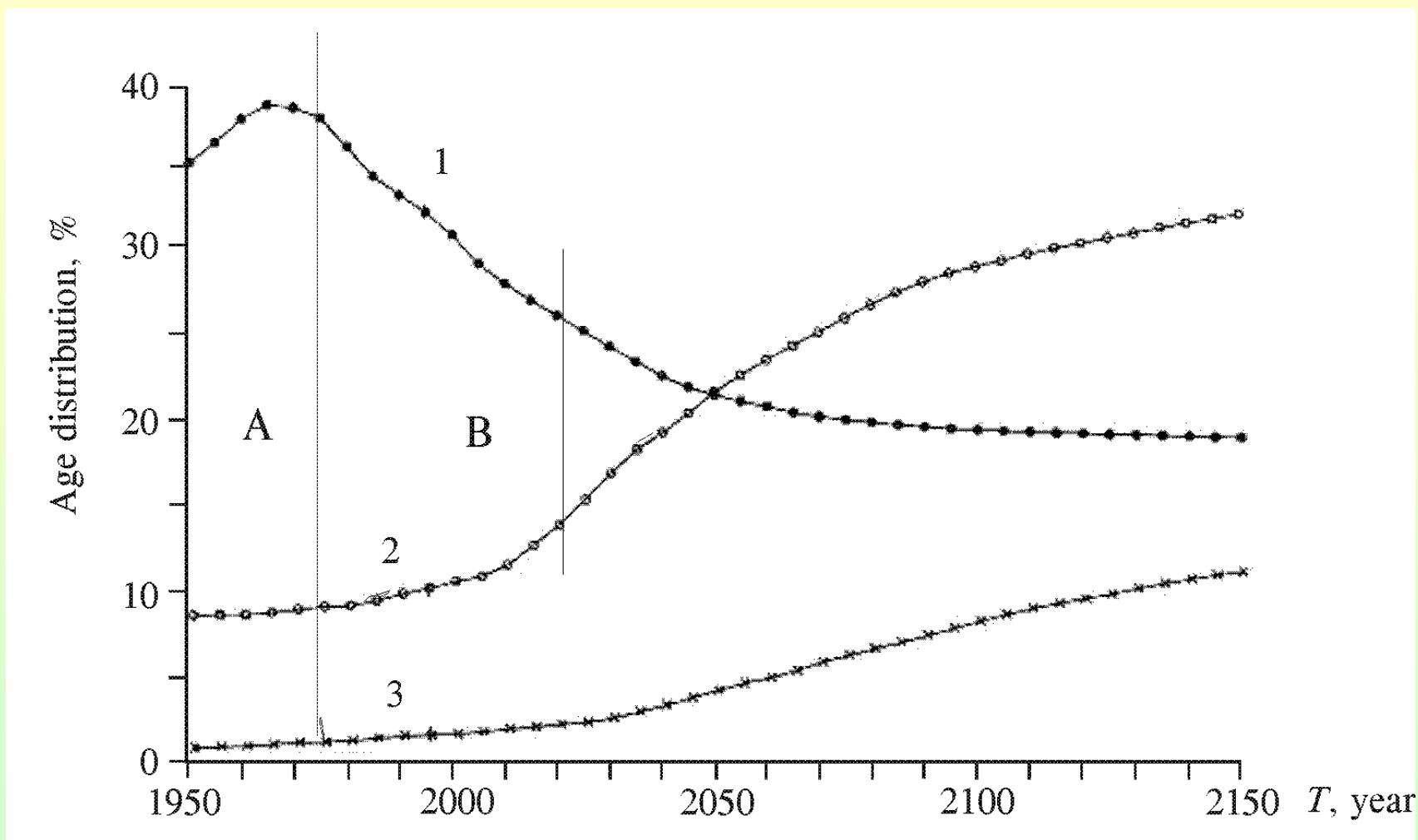


Developing countries

 1975 — 3,0 billion
 2000 — 5,0 billion

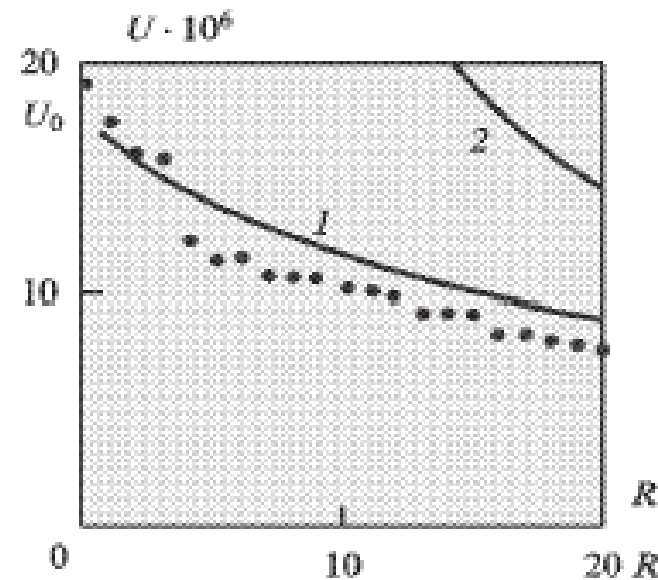
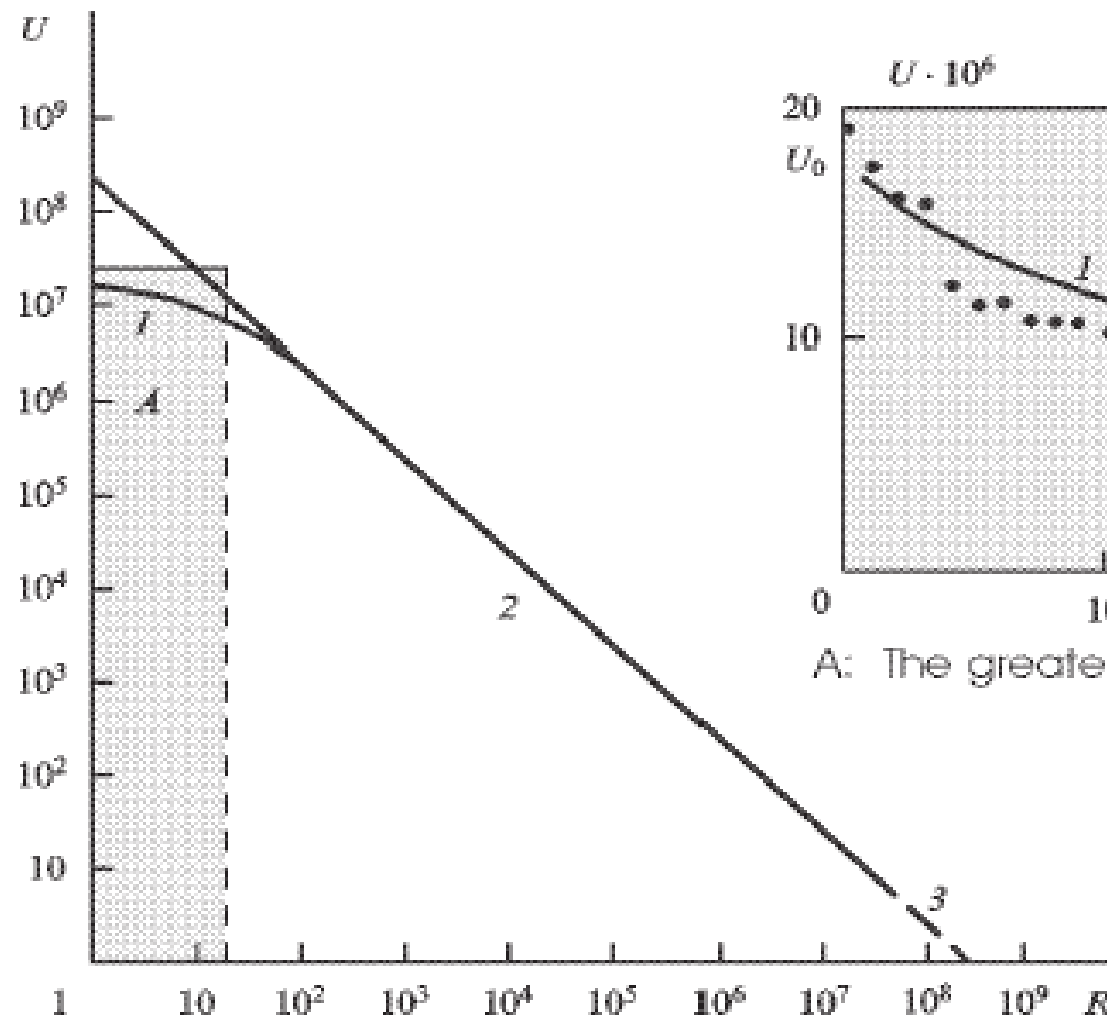


AGEING OF THE GLOBAL POPULATION



1 – AGE GROUP YOUNGER THAN 14 YEARS, 2 – OLDER THAN 65 YEARS,
3 – OLDER THAN 80, A – DEVELOPING, B – DEVELOPED COUNTRIES

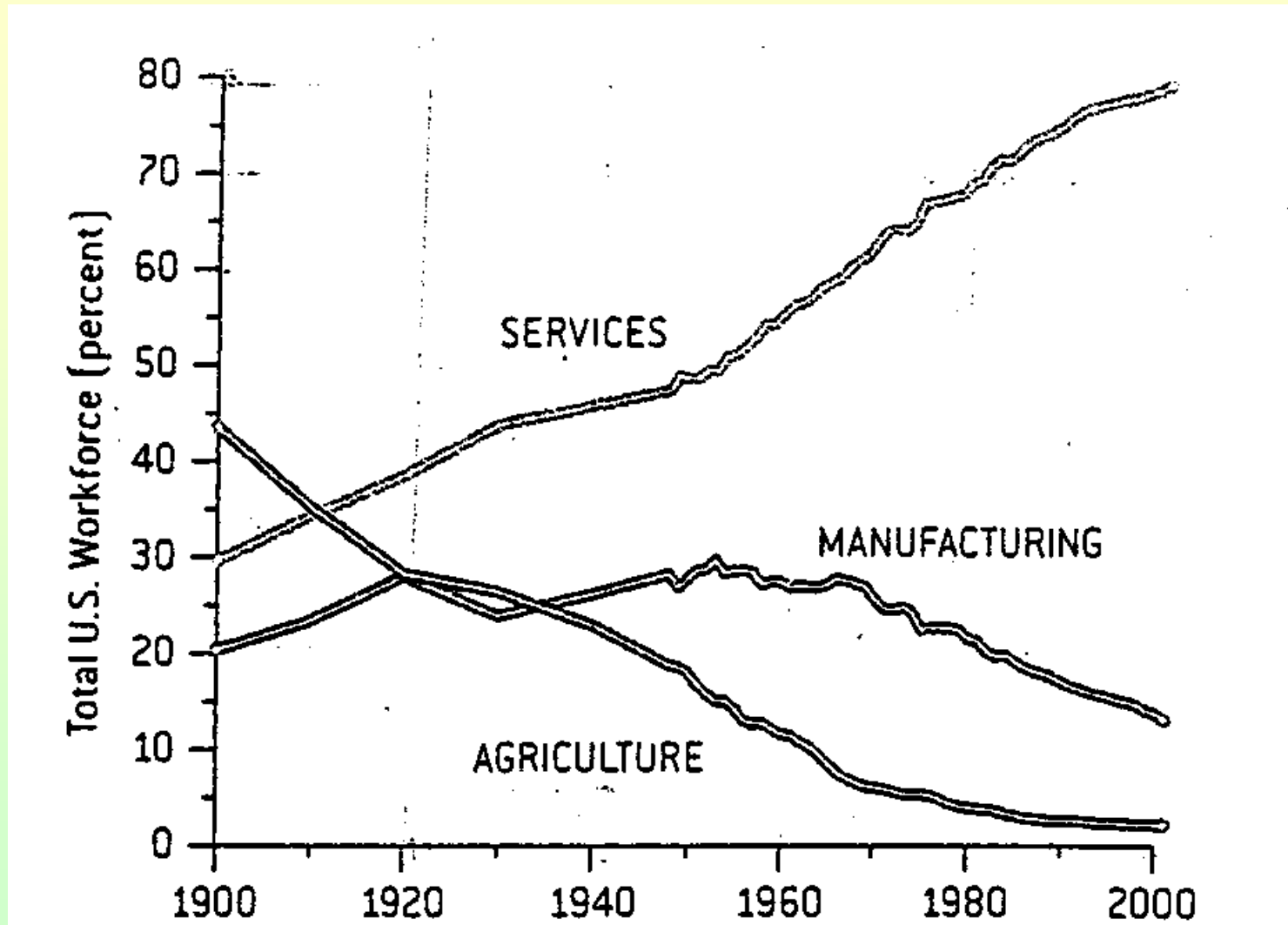
SCALING TOWNS OF GLOBAL POPULATION SYSTEM



A: The greatest cities of the world

$$1 - U(R) = \frac{U_0 \ln U_0}{R + \ln U_0}, \quad 2 - U(R) = \frac{U_0 \ln U_0}{R} = \frac{200 \cdot 10^6}{R}, \quad R \geq \ln U_0 = 17, \quad 3 - \text{vagabonds}$$

DEINDUSTRIALIZATION



DISTRIBUTION OF U.S. WORK FORCE IN 20-th CENTURY

PROBLEMS OF META-ECONOMICS

- RIGHT FROM THE BEGINNING, GROWTH OF MANKIND WAS DETERMINED BY GENERALIZED INFORMATIONAL FACTORS, WHICH MODERATED SOCIAL EVOLUTION AND ECONOMIC DEVELOPMENT.
- THE GLOBAL SYSTEM IS FAR FROM EQUILIBRIUM, – HENCE GROWTH OF INEQUITIES. HOW CAN WE THEN RECONCILE THE THEORY OF GROWTH WITH VALRASIAN ECONOMICS, BASED ON THE CONCEPT OF A SLOWLY CHANGING STATE IN EQUILIBRIUM?
- WILL THE FUTURE BE DETERMINED BY THE ‘SOFTWARE’ – CULTURE OF AN INFORMATION DOMINATED WORLD, RATHER THAN ITS HARDWARE?

ISSUES IN THE POST-TRANSITION WORLD

- IS THE DOMINANCE OF THE MARKET, WITH ITS SHORT RANGE TIME-SCALE A TRANSIENT REACTION TO THE DEMOGRAPHIC TRANSITION?
- CAN THE DILEMMA OF SELF-ORGANIZATION v.s. ORGANIZATION FIND ITS FUTURE RESOLUTION?
- CAN IN THIS NEW WORLD LONG-RANGE SOCIAL ISSUES BE FACED BY GLOBAL GOVERNANCE, NOW CONSPICUOUSLY ABSENT ?
- WILL GLOBAL PROBLEMS HAVE A BETTER CHANCE IN AN EMERGENT NEW WORLD ?
- WHAT WILL BE THE TIME STRUCTURE OF DEMOGRAPHIC CYCLES AFTER THE TRANSITION?

WHAT DRIVES DEVELOPMENT?

THE FAILURE TO UNDERSTAND THAT THE ROOTS OF ECONOMIC BEHAVIOUR LIE IN THE REALM OF CONSCIOUSNESS AND CULTURE LEADS TO THE COMMON MISTAKE OF ATTRIBUTING MATERIAL CAUSES TO PHENOMENA THAT ARE ESSENTIALLY IDEAL IN NATURE.

*Francis
Fucuyama*

Forty years of experience in modelling complex systems on computers, which every year have grown larger and faster, have taught us that brute force does not carry us along a royal road to understanding such systems... modelling, then calls for some basic principles to manage this complexity.

Herbert Simon
Nobel Prize winner

WE SHOULD THANK GOD THE
CREATOR FOR ALL THAT IS SIMPLE
IS TRUE, AND THAT ALL THINGS
COMPLICATED ARE NOT TRUE.

Grigorii Skovoroda

18th century Ukrainian philosopher

MAIN PUBLICATIONS

- Kapitza S.P. The phenomenological theory of world population growth. «Physics-uspekhi», Vol. 146, N1, 63-80, 1996
- Kapitza S.P. Global population blow-up and after. The demographic revolution and information society. Report to the Club of Rome. Hamburg, 256pp. 2006
- Kapitza S.P. The statistical theory of global population growth. In «Formal description of evolving systems». Eds. J.Nation et al., Kluwer Academic Publishers, 2003