INTERACTION MAXIMIZATION AS AN EVOLUTION PRINCIPLE FOR SOCIAL SYSTEMS

Lectures given in China and Japan

September–December 2008

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Working Report

Alle Menschen werden Brüder wo dein sanfter Flügel weilt.
[All people become brothers under your tender wing.]

—Friedrich Schiller, *Lied an die Freude* [Ode to Joy] (1785)

"I think that there is a small experiment which we may try to-morrow, Watson, in order to throw some light on the matter."

—Sir Arthur Conan Doyle, *The Adventure of the Shoscombe Old Place* (1927)

Sherlock Holmes: "Have you ever read of Jonathan Wild? He was a master criminal and he lived last century, 1750 thereabouts."
Inspector MacDonald: "Then he is no use to me. I'm a practical man."
Sherlock Holmes: "Mr. Mac, the most practical thing that you ever did in your life would be to shut yourself up for three months and read twelve hours a day at the annals of crime. The old wheel turns and the same spoke comes up. It has all been done before and will happen again."

—Sir Arthur Conan Doyle, *The Valley of Fear* (1915)

Interaction maximization as an evolution principle for social systems

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Lectures given at Beijing Normal University in Sep-Oct 2008

Version of 20 Oct 2012, comments are welcome.

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Please, if you happen to know people who have a working interest in this kind of exploration do not hesitate to send them a copy of the present draft. A related website on this topic has been set up at the following address:
http://www.eshia2009.org/interaction
The front page of this website is reproduced at the end of the preface.

Acknowledgments I would like to express my deep gratitude to all my colleagues who provided encouragement, help, advice and stimulating discussions, and in particular to: Yuji Aruka (Chuo University), Olivier Babelon (University of Paris 6), Zengru Di (Beijing Normal University), Susumu Egashira (University of Otaru, Hokkaido), Zhangang Han (Beijing Normal University), Taisei Kaizoji (International Christian University), Menghui Li (Beijing Normal University), Xueqin Mei (Beijing Normal University), Makoto Nishibe (University of Hokkaido), Tetsuhiko Takai (University of Hokkaido), Yougui Wang (Beijing Normal University), Tomomichi Yoshikawa (Waseda University), Jiang Zhang (Beijing Normal University).

Many thanks also to the students (graduates as well as undergraduates) who attended my lectures and offered comments and questions.

Preface

In physics it took more than a century to explore and gauge interactions at the level of molecules, atoms and nucleons but this knowledge now forms the basis of our understanding of microscopic as well as macroscopic phenomena. The following figure provides a broad panorama of binding energies.
The physical cases are well documented; on the contrary, for the living systems the required measurements have not been made so far.

The main motivation for the present lectures is that if we wish to understand social phenomena in a non-anthropomorphic way the investigation of social interactions is an essential step. Needless to say, this is a broad and challenging project which can only be carried out by a community of researchers. That is why we hope that these notes will enable us to get in touch with other researchers. This is an essential condition for the success of this project.

Naturally there are many kinds of social links. That is why their investigation can provide a unified framework in which our knowledge of social systems can be collected and stored in a orderly and cumulative way.

In the following chapters we will try to make two important points.

- In any society there have been substantial changes in the intensity and range of social interactions in the course of history.
- These changes have had noticeable effects on the "social efficiency" of the societies under consideration to the point of leading to the disparition of the most segmented societies or to their temporary subordination to more efficient and less fragmented societies.

As an illustration the Indian caste system immediately comes to mind. This rigid social stratification certainly reduced interaction in comparison with more open societies. Nevertheless, it remained in force for centuries and made India an easy prey for foreign invaders. Similarly, the conquest of Mexico by Cortez was made possible only because he was able to enrol into his army a large force of dissidents. One could mention many other examples of the same kind. However, unless we are capable of estimating the level of interactions in a given society such examples will lack real quantitative justification.

From quarks to living organisms there is a long ladder which leads to systems of ever greater complexity. The mechanism is always the same. Basic building blocks (let

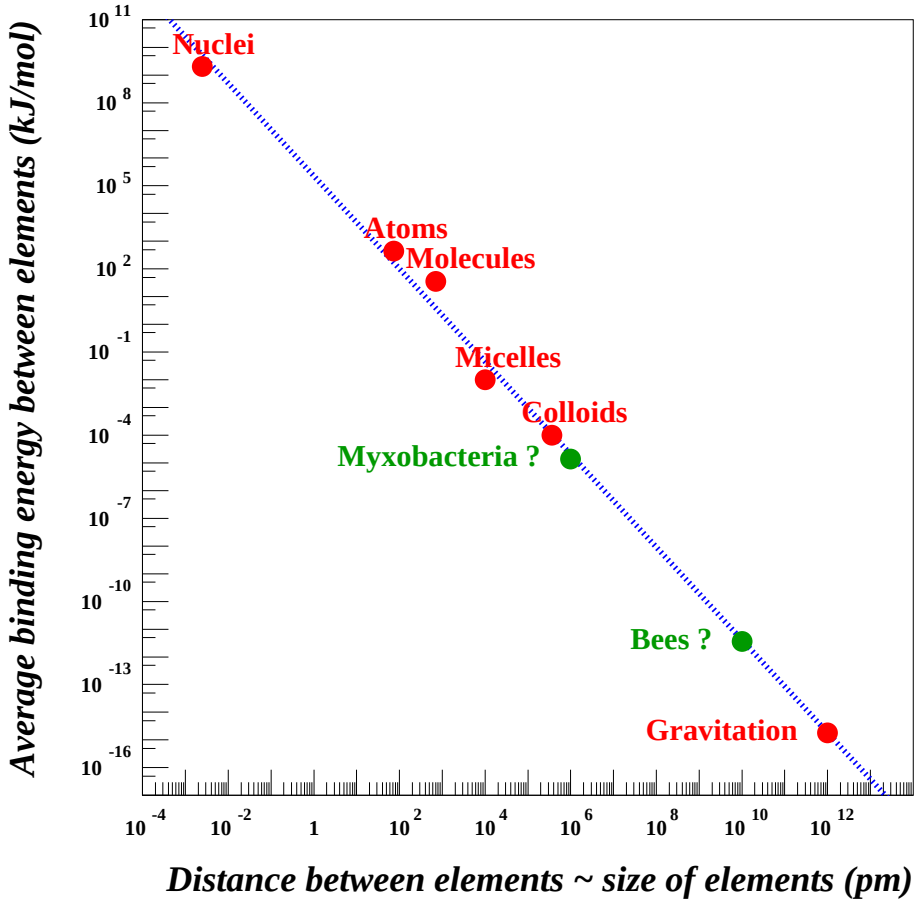

Fig. 1 Binding energy as a function of size. The distances on the horizontal scale are given in picometer (1pm=10^{-12} m), the energies on the vertical axis are given in 1000 joules per mole. The 5 points for physical systems are in red. They display three different forces: nuclear, electrostatic (for atoms, molecules, micelles) and gravitational forces. As is well known, the orders of magnitude of the strength of these forces are widely different. Micelles are aggregates of long molecules (of a molecular weight of several hundreds) which on one end have an O-H part (or similar) that is attracted toward water molecules. The heat release (or absorption depending upon conditions) for micelles is documented in Garidel et al. (2005). The colloid figures refer to an experiment involving polystyrene latex balls of an average diameter of 360 nm. (Jódar-Reyes et al. 2001). The points for living organisms are in magenta. An interrogation mark has been added because the binding energy of such systems have not been measured yet. The equation of the regression line is: $\ln E = a \ln d + b, \quad a = -1.7 \pm 0.09, \; b = 12 \pm 1$; the error bars refer to a confidence level of 0.95. *Source: The data for the nuclei are for a reaction involving the fusion of lithium and deuterium nuclei. The data for atoms and molecules follow standard orders of magnitude of the binding energy for a molecule of water and for the hydrogen bond between different water molecules. The gravitation point corresponds to two masses of 1 kg whose distance is reduced from infinity to a distance of 1 meter (for the sake of simplicity). It can be noted that for objects of macroscopic size (starting with the latex ball colloids) the notion of mole has no longer any meaning. The data for colloids and micelles are from Jódar-Reyes et al. (2001) and Garidel et al. (2005) respectively.*

us call them order 1 units) aggregate to form larger systems (order 2 units) which themselves serve as new building blocks for order 3 units and so on and so forth. Thus, atoms form molecules which themselves form cells which themselves form

living organisms.

This observation has beeen made by several scientists. The paleontologist Pierre Teilhard de Chardin called it a process of complexification; the botanist Jean-Marie Pelt (2011) identified what he calls a “principle of association” at work in the evolution of plants. In other words, the fact that attractive forces play an important role in the evolution of physical and biological systems is well recognized.

In the present study, we intend to show that a similar association principle is at work in human societies. A possible formalization of this process is to say that, whenever permitted by exogenous and endogenous constraints, systems tend toward states of greater and broader interaction. That, in essence, is the principle of interaction maximization referred to in the title.

In the next sections we describe two cases in which strong and broad interactions bring about creative episodes which lead to the apparition of units of higher order (in the sense used above).

Formation of cities and centralized states

In the early universe there were molecular clouds composed of low density hydrogen and helium gas. According to current conceptions of star formation, regions where density was high enough (as a result of random fluctuations) became gravitationally unstable and began to collapse. The gravitational collapse released a lot of heat and energy in the same way as a stretched spring releases its potential energy as it resumes its equilibrium length. Part of the energy was radiated but the remainder increased the temperature of the core until fusion ignition occurred. This marked the birth of a new star. If its mass was greater than five solar masses it had a fairly short life time. After several million years its core began to contract and as it shrank it grew hotter; this triggered a new series of nuclear reactions leading to the formation of heavier elements up to iron. Eventually, through a mechanism which is not yet clearly understood the star exploded. It is admitted that elements heavier than iron were formed during this supernova explosion. Through its disintegration all elements contained in the star were released into space to serve as raw material for new stars, planets and living creatures.

It is admitted that before the neolithic revolution there were low density populations living a largely nomadic life based on hunting and gathering. For some reason, higher than average density of population developed in some places therefore limiting the territory available to nomadism. Gradually permanent or semi-permanent settlements appeared, gathering techniques became more intensive eventually leading to crop cultivation. As the improved techniques could sustain more important

population densities, population concentration continued leading to the formation of towns and cities and to the emergence of techniques which represent important landmarks in the evolution of mankind: storing grains, making pottery, developing written languages, introducing political and religious forms of social organization. The first cities may have lasted a couple of centuries but eventually wars, diseases or internal factors made them crumble and collapse. While some of the newly developed techniques may have been lost, it seems reasonable to assume that most of them were disseminated and recycled in new settlements.

From a network perspective, the two previous scenarios comprise the following steps.

(1) Contraction brings about more interactions
(2) Greater interactions leads to the formation of more complex entities.
(3) Disintegration eventually produces a spatial dissemination of the new entities
(4) These new entities are reused as building blocks in subsequent processes.

A similar mechanism was at work in the creation of quantum mechanics.

Creation of quantum mechanics

In the three decades 1890-1920 a wealth of experimental results was produced which had received no consistent and comprehensive explanation. One can mention for instance the discovery of radioactivity, the emission spectra of atoms, the emission of α-particles by nuclei, the absorption coefficients of X-rays, the extraction of electrons from a metal by an electric field and so on. In spite of a number of scattered phenomenological attempts there was still no comprehensive theory in the early 1920s. Then, within a few years, not one but several frameworks were proposed which eventually proved to be equivalent and became what is now known as *quantum mechanics*.
One may wonder what was the role of social networks in this revolution.

As the group of physicists engaged in the exploration of the atomic world was a fairly small community they often met and knew one another fairly well; thus there were links between Niels Bohr, Albert Einstein, Max Planck or Ernest Rutherford just to mention a few of them. This community had a crucial function as a scientific filter in the sense that new theories were discussed, tested against evidence from new experiments, and (most often) were found wanting. This was a kind of potential barrier which prevented the adoption of unsatisfactory, makeshift theories. That was the normal mode of operation of the system, but between 1925 and 1928 it worked with much greater speed and efficiency. Berlin, Cambridge, Copenhagen, Göttingen, Leiden, Munich had for years been magnets attracting young talents; after 1925 it

seems that Göttingen became the center of this network. Is it not revealing that in 1926-1927 Arthur Compton, Paul Dirac, Linus Pauling, John von Neuman, Robert Oppenheimer, Edward Teller, Eugene Wigner, none of whom was German, visited Göttingen staying there for several weeks or months and meeting one another (Rival 1995)? They were young and were not the main actors in this revolution but they took part in it. The new ideas were actively discussed during many informal gatherings either at Max Born's home or at one of the inviting inns that could be found in the countryside surrounding Göttingen. In 1928, when the supernova exploded, the Göttingen researchers were scattered far and wide. In subsequent years, they would apply the new theoretical tools they had mastered to various fields from chemistry to nuclear physics to astrophysics and several other fields.

Interaction strength and efficiency

The previous examples are what can be called macro-historical cases. As often happens with events or data at macro level it is not easy to establish a clear connection between causes and effects. That is why we now describe two micro-sociological examples.

Story of the sidewalk poles in Paris

During the years 1998-2006, some 200,000 metallic poles were planted in the sidewalks of Paris. Their claimed purpose was to keep footways to pedestrians by preventing cars from parking there. However such pylons quickly became a hindrance for walkers, joggers or roller skaters because they were not restricted to the edges of the sidewalks but were also planted in their middle in any place where there was a garage exit. Even more worrying, within a few years, many of these pickets became defectious either through rust or because they were hit by car bumpers. Clearly, the municipality did not wish to spend the big money that would have been required to keep them in good order.
In coming years the situation will deteriorate further because more and more of these poles will be sheared, shortened or trimmed and what will remain of them will become safety hazards for all sidewalk users.

Why is this story an illustration of the calamitous effects of a lack of interaction? Firstly, it is revealing that these poles were put in place without any concertation[1]. Secondly, in spite of the fact that they altered dramatically the urban landscape, these poles never became a matter of debate in newspapers or on television. At the very moment when so many homeless people were living in the streets of Paris without

[1] One may wonder how the decision was taken. In such matters it is difficult to know the truth. The fact that there was a change of mayor in 2001 did not make any difference in implementing this policy. Perhaps it was a lucrative long-term contract for some company.

receiving any help from the municipality nobody questioned the rationale of such expenses and whether this money could have been used otherwise.

In short, because of a blatant lack of interaction, it was possible to take an absurd decision.

Following this example which was at the level of a city we give a similar one at the level of a building.

Ill-conceived building design

Recently my laboratory moved to a new building located on the largest French scientific campus. Built by a major French building company (namely Bouyghes), the building was supposed to be state-of-the-art. Yet, we were all surprised to see how many defects there were which showed that a complete divorce between designers and users.

- A key was needed to enter and leave the elevators. What about our visitors? Will they have to take the ugly staircase? Of course, in a building in which visitors are greeted by a receptionist, this would not be a problem but university research centers rarely have receptionists and in France this is even less likely than anywhere else.
- The lights would turn off when nobody was moving. While this may be fine in a lobby, we were surprised to see that it was the same in our offices. After 10 minutes the light would turn dark. It took us some time to figure out what wire had to be disconnected to keep light on[2].

How does this story illustrate the calamitous effects of a lack of interaction? On paper there had been a concertation betwen the builder and the university. As a matter of fact, an organization had been set up especially for this purpose. However, for some reason, there was no *real* communication, even for features which would have been obvious to everybody.

So, once again, because of a blatant lack of interaction it was possible to take absurd decisions.

The two previous examples were fairly qualitative. The weakening of interactions at Boeing Corporation which we describe in the next section is a case for which one can get semi-quantitative evidence.

Weakened interactions at Boeing Corporation

Globalization and outsourcing to subsidiaries operating in various countries has become a common trend in many industries in the 1980s and 1990s. Companies such

[2]These problems were only two examples among many other design failures.

as Coca-Cola, MacDonald's or Starbuck have developed globally with great success. Standardization of design allowed important economies of scale and cost reduction.

The real question is: can this model be transposed to the design of complex and technically advanced products such as aircraft? Our previous examples suggest that innovation requires strong interaction. Is this conjecture supported by the recent history of Boeing?

One of the incentives for outsourcing is to improve "Return on Net Assets" (RONA). However there are two ways to improve RONA: it can be enhanced by either increasing the numerator or by decreasing the denominator (Hart-Smith 2001). It seems that Boeing followed the first of these routes in the 1950s and 1960s, but switched to the second in the decades after 1985.

- In the decades following World War II Boeing took advantage of its experience in designing and selling military aircraft. Many of its airliners were derived from similar military aircraft. The Boeing 377 (Stratocruiser 1947) was a civilian version of the C-97 (1944); the 707 (Boeing's first jetliner, 1957) was a civilian version of the B-47 (1947) and KC-135.

Military versions: B-47 (1947), KC-135

Airliner version: Boeing 707 (1957)

This period ended with the 747 (1969) which was derived from the C-5 Galaxy aircraft manufactured by Lookheed but for which Boeing conducted design research. By relying on military orders, Boeing was able to increase both its return and its assets; in addition risks and technical uncertainties were reduced.

- With the 777 (which entered service in 1995) began the globalization trend. International contributors included Mitsubishi and Kawasaki (fuselage panels), Fuji (center wing section), Hawker de Havilland (elevators), and Aerospace Technologies of Australia (rudder). But to accommodate production of the 777, Boeing also doubled the size of the Everett factory near Seattle, the historic craddle of the company.

After the 777 there was a lull of several years without any clear project (there were the aborted 747X and Sonic Cruiser projects). The 787 project marked the first highly innovative project after the 747 thirty years earlier and it was also the first which was not, at least to some extent, preceded by a military version. With the start of the 787

project there was not only an acceleration in outsourcing but also a will to reduce labor costs. This took two forms.

- Part of the production within the United States was attributed to a new (union-free) plant in South Carolina.
- Moreover, even in the Everett plant more and more employees were working for subcontractors rather than for Boeing.

Perhaps for the first time international outsourcing affected not only production but also design. A large part of the conception work was carried out at the "Boeing Research and Technology Center" in Moscow which had been established in 1993[3].

One could of course argue that in the time of design by computer and communication by Internet the notion of geographical proximity becomes irrelevant. However, the previous policy options also reveal that an organization based on cost reduction and sales imperatives had replaced an organization whose main objective was to design good airliners. Cost reduction and sales promotion becomes irrelevant when it cannot rely on a good product. The inherent difficulty in maximazing RONA through a reduction of domestic assets is the need to retain and *develop* the technical skills required for the design and production of *new* products. This can hardly be done if the most innovative production techniques are outsourced.

Aeronautical engineers face difficult challenges. They should not be treated in the same way as managers at companies such as MacDonald's or Starbuck where technical innovation has a marginal role and is completely eclipsed by cost reduction and sales promotion strategies. The environment in which they work must provide understanding, sympathy and recognition. An illustration of the fact that Boeing's policy was (and still is) lead by its sales department was provided by the rollout ceremony of the 787 on 8 July 2007. It was broadcast worldwide in 9 languages and 50,000 people attended at Everett. Nobody told them that the plane was in fact unable to fly. Although it was a nice public relation operation it made probably some employees and engineers uneasy because they knew that the plane would not fly until several months. As a matter of fact the maiden flight occurred 18 months later.

Weak interaction between Boeing and the various companies which took part in the project resulted in numerous problems. For instance, the coating used for the fasteners of the tanks located in the wings was found to be inadequate. In spite of the fact that the problem was detected in 2009, faulty wings continued to arrive from Mitsubishi until April 2011. As a result, some 20 planes had to be modified after being assembled [4] . There were similar coordination problems with Alenia's hori-

[3]Subsequently other "Boeing Research and Technology Centers" were established in Madrid (9 July 2002), Bengaluru, India (31 March 2009), Beijing (21 November 2010).

[4]Source: Fight Global website, 27 April 2011. Article entitled: "Boeing ensures sparks will not fly on 787s".

zontal stabilizer or Fuji Heavy Industries' center wing box (i.e, the component that connects the wings to the fuselage). Coordination problems between French and German engineers also resulted in delay in the production of the Airbus 380.

At the time of writing (April 2011) it is too early to say how successful the project will be eventually. Not long ago some Boeing executives made declarations to the point that outsourcing had gone too far for the 787. Of course, the real answer will come from the airlines that will fly the plane over the next decade. If it turns out to be a good aircraft the present approach will be validated, otherwise there may indeed be a shift in strategy for Boeing's next major project.

Through these examples we hope that readers will become convinced that there is indeed a connection between interaction strength and efficiency. We add a last example taken from biology.

Swarm of bees

When a swarm of bees is searching a new nesting location, some 20 to 50 scout bees are sent out out to find a suitable new nest. An individual scout returning to the cluster promotes the location she found through a dance similar to the waggle dance (i.e. the same dance as used in order to indicate the location of a new source of food.

Fig. Bee swarm. In the process of colony splitting a queen leaves the colony with hundreds (or even thousands) of workers. At first the swarm takes shelter near the previous colony before settling for a new location. This picture was taken in Victoria, Australia in February 2008. *Source: Wikipedia, entry "swarm" (Fir0002/Flagstaffotos)*

After several hours and sometimes days, slowly a favorite location emerges from this decision making process. When most scouts agree on a final location the whole

cluster takes off and flies to it. This collective decision making process is remarkably successful in identifying the most suitable new nest site and keeping the swarm intact. In short, this is the exact opposite of the process described above through which absurd decisions are taken in isolation which turn out to be harmful for the whole population.

Maximization of interaction

The title of this study contains the expression “evolution principle”. The term “principle” is used here with the same meaning as it has in physics, namely a rule based on observation. For instance the principle of the conservation of energy is a pillar of physics but it is so only because it proved correct in many observations. At this point we do not know whether interaction maximization holds in a way which is as broad and general as conservation of energy.

The empirical justification of interaction maximization is related to the fact that, in the course of evolution, elementary units tend aggregate and form larger systems. Protons and neutrons tend to form bigger nuclei; atoms and molecules tend to aggregate and form larger compounds; cells tend to aggregate to form larger organisms; people tend to aggregate to form larger cities, and so on [5] .

In some of the cases mentioned above the elementary units attract one another. Such is the case for molecules. For instance, a molecule of water is attracted by a molecule of ethanol. This attraction provides a fairly clear explanation of the reason for interaction maximization; indeed, when the distances between water molecules and alcohol molecules decrease their interactions do indeed increase. However, it must be emphasized that the tendency to form larger (stable) aggregates holds even for elementary units who do *not* attract one another. For instance protons do not attract one another (except at short range) but they nevertheless manage to form aggegates when they are thrown in close contact by energetic collisions due to high temperature.

If the tendency to form aggregates is so conspicuous in the long term evlution of the universe how does it come that it is not really obvious in human history? There are two different answers to this question.

- First of all, it should be observed that in some respects there *is* in fact a trend toward aggregation. This can be seen at the level of cities or companies which become ever larger in the course of time.
- The second answer is that in many cases there are structural constraints which prevent the growth of interactions. If groups are kept apart in different areas or in

[5] This “complexification” process was a key notion in the philosophical conceptions of the French Jesuit Teilhard de Chardin; see for instance some of his books such as “The human phenomenon” or “The divine milieu”.

different segments of a society they will not be able to interact even though such an interaction would benefit the whole society.
As a matter of fact, the same difficulty also arises in physical systems. Because combustion of carbon leads to a lower state of energy, diamonds should in principle burn spontaneously. Obviously, they do not. This is because of a so-called "activation barrier" which must be overcome before the combustion can start. Similarly, different social groups may be isolated by barriers with the result that the system does not reach its "natural" state of highest interaction.

During revolutionary episodes (e.g. during the French Revolution) such barriers may be removed with the result that the whole society becomes able to move toward a state in which it is more integrated and hence more efficient.

An illustration of this discussion is provided by many Indian Bollywood movies in which two lovers from different castes must overcome all sorts of obstacles before being eventually able to get married. Such stories illustrate both the attraction between people from different groups and the structural segmentation which prevent such interactions.

Needless to say, to make the previous descriptions more quantitative (and therefore more scientific) one must be able to measure the strength of interactions. This is the central topic of the present book.

How to measure interactions

Any statement about the conservation of energy in physics requires as a precondition that one is able to *measure* energy in its different forms: mechanical energy, thermal energy (heat), electromagnetic energy (light or other forms of radiative energy). Each of these forms of energy requires specific tools and methods of measurement. Similarly, before one can check whether or not there is a trend toward greater interaction a necessary precondition is to be able to measure (or estimate) levels of interaction.

Apart from specific techniques that will be considered in subsequent chapters one can mention three qualitative characterizations of interaction.

Frequency and range of interaction

Every time the means through which an interaction takes place are clearly identified [6]one can use the frequency and range criteria. Frequency means that we will count the number of contacts per day or per month. Range means that we will count the

[6]One must be aware that fairly often interactions occur in indirect ways. For instance, in a given area parents are in contact through their children when the latter are in the same school. Similarly, households are affected by housebreakers who operate in the vicinity even though their own house was never burgled.

number of neighbors with which every unit is directly in contact.

For instance, people who belong to the same family would talk to one another, may be, half an hour a day while neighbors would have, may be, two 5-minutes discussions in a week.
In a gas the molecules interact during less than 1/1000 of their time. This ratio corresponds approximatively to the rate of 10 minutes per week that we assumed for neighbors. On the contrary, in a solid, the molecules interact permanently with their nearest neighbors.

In order to illustrate the notion of range it is perhaps best to consider two extreme cases.

- As was just said, molecules in a solid interaction with their nearest and perhaps second nearest neigbors. This represents at most 20 molecules.
- On the contrary, in the human brain individual neurons are directly connected to thousands or even hundreds of thousands other neurons. As a result the level of complexity of the brain is much higher than the level of complexity of a solid.

Collective attributes due to interaction

What visible consequences does this difference in complexity between solid and brain have? In a general way for a system of interaction elements the global system is “more” than the sum of its parts. It is not obvious to see how this sentence should be understood.

One possible meaning is that the system has properties that individual elements do not have. For instance, a solid is characterized by a certain hardness. Hardness is clearly an effect of interaction. The “hardness” of a gas is several million times smaller than the hardness of a solid[7]

A brain has many abilities that an individual neuron does not have. For instance, it has the ability to deliver the signals which enable a person to speak, sing, read, write or play music. Clearly, the collective abilities of a brain are much broader than those of a solid. However, such a comparison remains very much at a qualitative level. In the next section we consider more closely the hardness attribute.

Mixing criterion

All gases are miscible in any proportion. On the contrary two solids are almost not at all miscible. With liquids we are in an intermdiate situation.

All liquids are miscible in *some* proportion but for some liquids this proportion is so small that in common language they are called immiscible. That is for instance

[7] On the contrary, color is an attribute of *individual* atoms. The fact that gold vapor looks less yellow than solid gold is only due to the fact that its density is smaller.

the case of oil and water. Basically, two liquids are immiscible when because of the structure of their molecules they are not able to establish strong interactions.

At the other end of the spectrum there are liquids (such as water and ethanol) which are miscible in all proportion. The molecules of water and alcohol are able to estabish strong interactions.

Many liquid mixtures fall between these two extremes. Two liquids are ”partially miscible” if shaking equal volumes of the liquids together results in a meniscus visible between two layers of liquid, but the volumes of the layers are not identical to the volumes of the liquids originally mixed.

This may seem a fairly crude criterion. What nevertheless makes it useful is the fact that it can be used very easily to broadly estimate the level of interaction. Let us give some examples.

- Two galaxies are miscible as shown by photographs of colliding galaxies.
- Ant populations of same species but from different nests are (usually) immiscible: they will fight one another.
- In some conditions ant populations of different species are miscible. This happens for instance when the eggs of species A were brought back into the nest of species B[8].

[8]For more details see: Dictionnaire universel d’histoire naturelle, Paris 1844, entry: fourmi [ant]. This is similar to the institution of the Janissary soldiers in the Ottoman Empire in the sense that the Janissaries were Christian children levied in conquered countries and brough up in Turkey. Between 1400 and 1800 they provided the elite troops of the Ottoman army.

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Genesis of this project

Determining the interaction strength between molecules, atoms or nucleons was a major task for physicists during the 20th century. They used various experimental techniques and introduced different concepts to define such interactions, such as the binding or dissociation energies, bond length and so on. The section entitled ``Measurement of interactions in physics'' (in the menu entitled ``Interaction measurements: known methods'') provides a summary of experimental technics used in physics.

In the early 2000s econophysicists began to study many different systems from the perspective of network science. It soon became apparent that in order to provide a realistic description these networks had to be WEIGHTED networks. Indeed, except for systems in which the interaction is of a binary type (0: no link; 1: existence of a link) as for instance between an author and the references that he gives in a paper, the vast majority of interactions differ in strength. In an unweighted network representation, the earth would experience the same attraction from the stars of the Andromeda galaxy as from the Sun and similarly a vegetable retailer in Beijing would be as connected as closely to farmers in California as to those in the vicinity

This website was set up in mid-October 2008 in collaboration with Prof. Jiang Zhang at the Department of Systems Science, Beijing Normal University. Its purpose is to share and spread the results obtained by various researchers in the measurement of the strength of social interactions.

Lecture 1
The viewpoint of systems science

Lecture given at Beijing Normal University, Department of Systems Science on 24 September 2008, and at Chuo University, Tokyo on 29 November 2008 [9].

I welcome all of you to this series of lectures on systems science. It is really a privilege for me to be able to give these lectures. Perhaps I should begin by explaining why. According to my experience, this department is one of the few in the world where systems science is studied in a cross-disciplinary perspective. Why is this so? In order to understand this point, one must recall the meaning of the expression "systems science".

Systems science

Well, this expression can be defined in different ways, but one of its most basic meanings is that it is an attempt to provide a unified view of phenomena which at first sight appear to be different. As this is a key point let me illustrate it by an example.

Consider the phenomenon of economic speculation.

- There can be speculation in stocks.
- There can be real estate speculation in houses or apartments.
- There can be speculation in commodities such as oil, wheat, cotton or gold.
- There can even be speculation in more exotic items such as rare stamps, that is to say stamps collected by collectors.

For all these items, there are what can be called "speculative price peaks" by which I mean a period of time, usually lasting several years, during which prices go up, which is followed by a period also of several years during which prices go down. The important point is that by studying such price peaks for stocks, houses, commodities one finds out that they are basically similar. In other words, the mechanism which is at work in these different phenomena seems to be the same. It is precisely the purpose of systems science to establish a link between these different phenomena

[9] The text is a blend of the two lectures. While the beginning mainly reflects the lecture given in Beijing, several historical illustrations which were only given in the Tokyo lecture have also been included.

and to provide a unified description.

Has systems science something to do with physics?

You may ask: “Has systems science something to do with physics?”
The answer is “Yes, absolutely”.

When physicists (or chemists) study a new phenomenon they use the unifying approach of systems science even if they do not explicitly use the expression “systems science”. As an example I will consider the phenomenon of free fall. It may occur in several forms.

(1) the fall of an apple
(2) the fall of a feather
(3) the “fall” of the moon on the earth
(4) the “fall” of the earth on the Sun.

We now know that all these phenomena are ruled by the same mechanism namely the force of gravitation and the resistance of the air, but this was not always obvious. It was Newton who showed that the astronomical phenomena 3 and 4 are ruled by the same laws as the fall of objects such as 1 and 2. This was a major breakthrough. In short, when Newton established a link between these phenomena he was using the approach of systems science.

Hyper-specialization versus systems science

Let me now come back to the question of why there are so few departments across the world who are using this approach. The reason is very simple. It is because of the high degree of specialization which currently prevails in scientific research.

- The economists who study stocks are not the same as those who study house prices.
- The economists who study house prices are not the same as those who study the prices of oil or cotton.
- The economists who study the price of oil are not the same as those who study the price of rare stamps.

If in addition these different kinds of economists have but few opportunities to interact one with another, there is absolutely no chance that they may ever realize the existence of a common mechanism behind the phenomena that they are studying separately. In short, narrow specialization is a big obstacle to the development of systems science. This explains why econophysics was, in my opinion, an important step forward and also why I am fortunate to be able to give these lectures in your

department.

You may ask:

"Why is systems science more developed in China than in Western Countries?" I must confess that I have no real answer to this question. It may have something to do with the philosophy of life that prevails in China. As far as I understand it is more global and more open to analogies than the way of thinking in western countries. Perhaps it may also have something to do with the Chinese language. Many Chinese characters represent concepts; for instance the character "gong" represents the idea of working together for a common goal. This can be at the level of a village, or of an industrial company or at the level of the whole nation. In other words, "gong" represents a basic mechanism in the sense in which it is defined in systems science. Needless to say, you will certainly be more able than myself to find the reasons why Chinese researchers are more inclined toward systems science than are western researchers. Whatever the reasons, it is a fact that in China systems science is a recognized field as attested by the existence of the Institute of Systems Science at the Chinese Academy of Science. Of course, I do hope that in coming years systems science will thrive and develop in China and will not be swept away by the trend toward greater specialization[10].

How can one measure interaction strength?

You may say:

"Econophysics appeared in 1995. During these past 13 years did econophysicists develop the approach of systems science?"

To some extent yes, but progress was slow. Why was progress so slow? There is a major difficulty which I will explain now. Any system consists of units which interact in some way. For instance the system corresponding to a falling apple consists of three units: the apple, the earth and the air which surrounds the apple; the interactions are expressed by forces between these units. The most important information is not that one unit is an apple because we have seen that the phenomenon is basically the same if the apple is replaced by a feather; the most important information is the fact that it is the gravitational interaction which is at work. In other words, in the definition of a system the most important information is the interaction between the units which compose the system.

The big problem is that for most social systems we do not know these interactions. For instance, I see the people who compose this audience; of course, I know that there are interactions between them, but these interactions are not visible and so far,

[10] It can be noted that Japan also played a prominent role in the development of econophysics, albeit in a different (more institutional) way than China. The approach of systems science had been popular in the United States in the 1960s but in the following decades it was progressively eclipsed even in multidisciplinary institutions like the Santa Fee Institute.

we have no method for measuring them. In physics, the interactions are not visible either. We do not see gravitational or magnetic fields but physics has developed experimental means for measuring these interactions. We must do the same for social systems that is to say we must develop experimental methods for measuring interaction strength in social systems. This is a key point. Two lectures in this series will be devoted to this question.

Physical systems versus biological systems

In the upcoming lectures, I will often establish parallels and make comparisons between physical systems and systems composed of living entities such as biological or social systems.
You may say:
“Well, such comparisons cannot really make sense because there is a fundamental difference between physical and living entities. Living entities have a finite lifetime whereas non-living entities never die.”

There is a simple answer to this objection: in fact, physical entities also have a limited lifetime. I will give you two examples.

- The first example is based on an effect called metal fatigue. When a piece of metal is bent up and down several times, it becomes fragile and eventually it breaks. This phenomenon is of great importance for airplanes. It can be demonstrated in an experiment in which a thin piece of metal is bent several times. It turns out to break after being bent between 10 and 20 times (the phenomenon is somewhat stochastic).
- For the second example consider light bulbs. As we all know, light bulbs have a limited lifetime. There is a mechanism by which they become more fragile as they become older. For some light bulbs such as halogen light bulbs there is even a self-healing mechanism through which light bulbs can (to some extent) repair themselves.

After this fairly long introduction I come to the second part of my talk in which I wish to present some empirical observations. These observations suggest that the strength of interaction is a crucial parameter in the evolution of all systems whether they are physical or social systems.

“Creative” systems are systems with strong interactions

Observation of our universe shows that systems in which there is a high degree of interaction are places where the most important creation processes take place. The following slide summarizes two such cases.

- The first view shows a star. As you know, stars are the places where the atoms which compose the earth were produced. The atoms (carbon, oxygen, calcium,

potassium and so on) which compose my body as well as your bodies were produced in stars a few billion years ago. Why can we say that stars are characterized by strong interactions? The interaction is generated by gravitational attraction. During the formation of a star as the hydrogen atoms are brought closely together the temperature increases until eventually nuclear reactions begin which produce the new elements. At the end of their life, the stars explode, their atoms are dispersed and eventually form solar systems as the one in which we live.

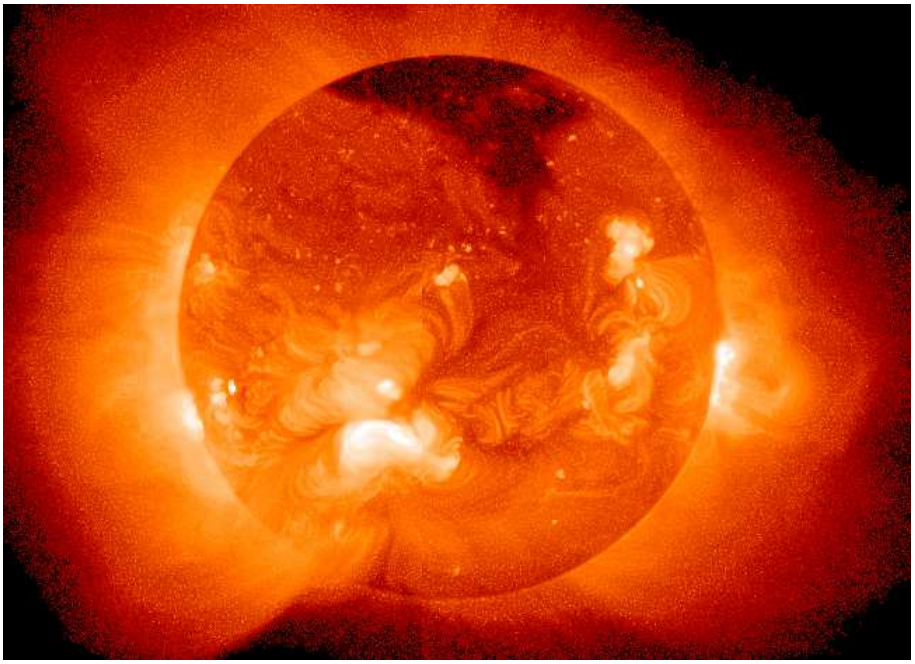

Fig. 1.1 The Sun. In the Sun, as in all stars, there is an ongoing creation process of heavy atoms up to the atomic weight of iron. All the atoms that compose the Earth, including those which compose the bodies of living beings have been created in stars, mostly in big stars because their lifetime is much shorter than the lifetime of small stars.

- The second picture represents a city. Cities are places where people who were previously dispersed on a broad area are living closely together. History suggests that some five thousand years ago the first cities were places in which the structure of modern states emerged. This structure comprised several organizations such as tribunals, tax collection, water distribution, on so on which gave more cohesion to human societies[11].

- As a third example of a system in which a high degree of interaction brings about a major creation process, one can mention the advent of the theory of quantum mechanics in the mid-1920s. In the previous three decades many new phenomena

[11] However, it must have taken some time for such benefits to emerge. In terms of food supply the new structure was less efficient than a uniformly distributed population because more transportation work was required to collect commodities and carry them to the cities. Apart from greater protection afforded by the city's wall it is not clear what other benefit could be expected in the short run.

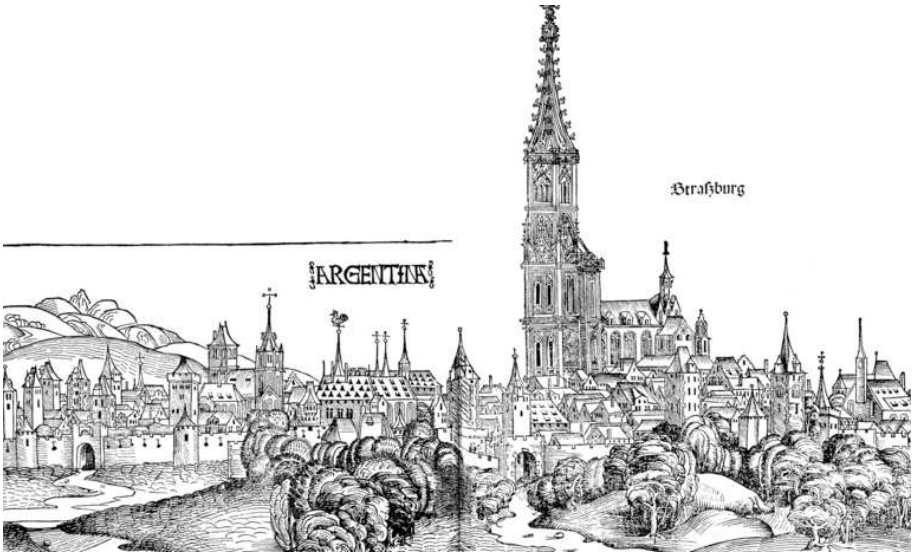

Fig. 1.2 The City of Strasbourg in the East of France. The area around the cathedral is closely packed with houses which suggests a high population density which is the main characteristic of cities. With this high density comes also a high level of interaction. Note that the cathedral does not have the two-pillar structure that it shows nowadays, probably because its construction was not completed. The word Argentina probably stands for Argentoratum, the name of the city in Roman time.

had been discovered experimentally for which there was no convincing and unified explanation in the framework of classical physics. One can mention for instance radioactivity, the photoelectric effect, the extraction of electrons from a metal by an electric field, the Wien-Planck law which describes the distribution of power emitted by a black body as a function of temperature and wavelength, and many other effects. Some basic ideas of a "new" physics had been already put forward around 1900, e.g. Planck's assumption of energy quantization and Einstein's photon hypothesis. However, no comprehensive theory had emerged.

This occurred within a few years between 1925 and 1928 in a process which, in terms of interaction, resembles the increase in density and interaction which leads to the formation of a star. During these years, many renowned physicists gathered and worked together in a few German universities and especially in Göttingen. For instance Arthur Compton, Paul Dirac, Linus Pauling, John von Neumann, Robert Oppenheimer, Edward Teller, Eugene Wigner, (none of whom was German) visited Göttingen, staying there for several weeks or months. They were young and were not the main actors in this revolution but they took an active part in the discussions. The new ideas were actively discussed during many informal gatherings either at Max Borne's home or at the inviting inns that can be found in the countryside surrounding Göttingen.

In 1928 when the "supernova" exploded, these researchers returned to their respective fields and countries. In subsequent years they would apply the new ideas of quantum mechanics to various subjects from chemistry, to nuclear physics, astro-

physics and many other topics. Through their interaction and collective contribution a completely new physics would emerge within a few decades.

These examples suggest a question:

"How can one increase the interaction in a system?"

There are basically three ways.

(1) The first method is simply to bring the elements of the system closer together that is to say to reduce the spatial distance between them. It is this process which we have seen at work in the formation of stars and cities.

(2) The second method is to remove barriers between different groups of agents which prevent them from interacting. The French Revolution of 1789 provides an illustration of this method.

(3) The third method is to change the type of interaction between the elements of the system. For instance, antagonistic relationships can be replaced by friendly relationships. I will give an illustration in a moment.

The French Revolution seen as a jump in social interaction

Before the Revolution of 1789 the French society was segmented. This observation also applies to the societies of other European countries with possibly the exception of Britain. There were three separate groups between which there was little interaction.

(1) The clergy, that is to say priests, monks, and other church personnel
(2) The nobility which represented about 5% of the population
(3) The common people which represented 90% of the population.

The rules about this division into groups were fairly strict. For example, to claim nobility status a person had to prove that his parents and grand-parents already belonged to the nobility; also only persons from the nobility could become army or navy officers; but on the other hand, persons from the nobility could not open a shop and become traders. The clergy was also a separate group which was hated by farmers because it owned about 15% of the land and collected special taxes. Moreover, the church had total control over education. The French Revolution abolished these separations and by so doing greatly increased the interaction between French people.

Almost overnight common people were able to become army officers. This was not only theoretical. Quite a few common people became not only officers but even generals: Lazare Hoche who came from a poor family was corporal at the age of 21 and became general at 25. As to Napoleon Bonaparte with whom you may be more familiar, he became a lieutenant at the age of 16 and a general at the age of 24 (as his family had a low nobility status, he would never have been able to become a general

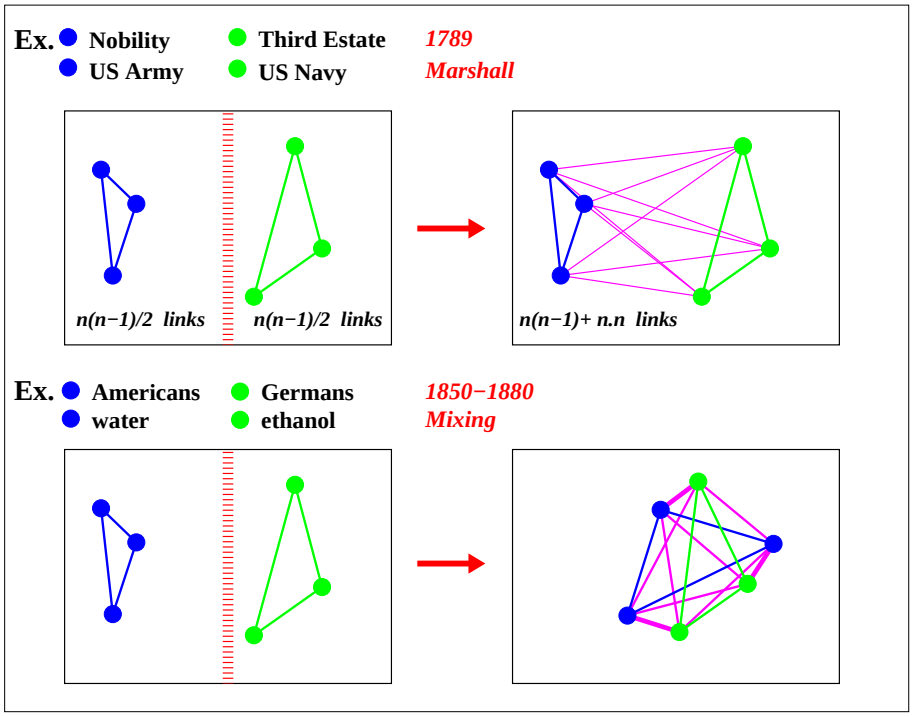

Fig. 1.3 Increasing interaction by removing barriers The increase in interaction may happen in two ways: (i) Removal of the social barrier between unchanged blue and green populations (diagrams in first line); for instance before the French Revolution there was a rigid barrier between the nobility and the common people (referred to as the Third Estate).
(ii) Removal of social barriers and in addition relocation of the blue and green populations in a way which brings them closer to one another; an illustration is provided by the arrival of German immigrants in the United States after they have crossed the Atlantic. The removal of social barriers consists in the fact that the immigrants learn English and get used to American customs.
The example of the US Army versus the US Navy refers to the fact that prior to World War II these two organizations were largely independent. The combined operations of the Second World War compelled them to work closely together. As chief military adviser to President Roosevelt and Chief of Staff of the US Army it was the duty of General George Marshall to enable them to do that successfully.

before the revolution).

Why is it important to increase interaction between people?

I will answer this question by describing 3 case-studies.

- The first case was suggested to me in recent days by the milk powder problem in China. Imagine a farmer who sells his milk to the people of his village. Would he be tempted to add melamine in order to increase the protein content? Certainly not because he knows the children who are going to drink the milk. On the contrary, a farmer who sells his milk to a dairy company does not know who will drink the milk. In addition his milk will be mixed with the milk of many other farmers which weakens even more the link between farmers and consumers. In other words, interaction with consumers brings a kind of social self-control. If there is no interaction, farmers

will just seek their best interest. To prevent problems such as the melamine problem the authorities must issue regulation and perform controls. But it is always possible to get around rules and regulation. Social self-control is much more efficient.

- As a second example consider the process of outsourcing that has been used by many organizations in recent decades to reduce labor costs. Take for instance a university like this one. For the personnel who cleans streets, classrooms, offices there are two possibilities. They can be employed by the university or by a private company which is payed by the university. Observation shows that in the first case, provided they are employed in good conditions, employees develop a kind of loyalty to the university; as a result they are likely to carry out their work with personal motivation. In the second case the employees have no interaction with the university; unless their work is closely monitored by a supervisor, they are likely to do it as quickly as possible. The same argument also applies to other organizations such as subways, airports and so on. Once again we see that interaction can replace controls in a more effective way.
- The third example will illustrate what happens when the nature of the interaction changes. We will consider the case of Enron Corporation. As you may remember Enron was a big American company which declared bankruptcy in December 2001. The turning point in fact occurred 5 years earlier in late 1996. Before that date the president of Enron was Rich Kinder and in 1996 he was replaced by Jeff Skilling. The two men had completely different conceptions. My information on this question comes from a very interesting book written by Robert Bryce in 2002. Here are some observations extracted from this book. Under Kinder, Enron was a relationship business which means that loyalty, trust and personal relationships among employees were very important. On the contrary, under Skilling relationships counted for zero. Reportedly, he once declared:

  > "Trust doesn't matter, all that matters is money. You buy loyalty with money, don't ever forget that. Traders are mercenaries, their job is to kill."

In order to implement his policy, Skilling hired a great number of bright traders from Harvard, the University of Chicago, West Point and from the best American business schools. As soon as they were hired they began to compete and fight one another. For instance, instead of cooperating with his colleagues, a project developer would refuse to share with them the details of the project because he would fear that the colleagues might steal his project and get the financial bonus that would reward its successful completion. In the book that I mentioned several other episodes are described which suggest that the shift from cooperation to competition had detrimental effects in many respects. Of course, at this point it is impossible to *prove* that this change of interaction played a key-role in the failure of the company. To prove that, one would have to study other similar cases in order to make comparisons.

In the third lecture I will explain how it is possible to base a broad explanation of historical cycles on the conclusion reached in the present talk, namely that improved efficiency goes hand in hand with increased interaction.

- The fourth example is the change which occurred in labor relations at Boeing Corporation. It can be illustrated by the following comment made in the Seattle Times on 30 July 2009[12].

> I recently worked for Boeing as a contractor on the 747-8. Before that I was in the IAM as a assembly mechanic on the 747 for 10 years starting in 1979. In between, I worked for many Boeing suppliers. When hired by Boeing back in '79, I was fully trained by experienced senior mechanics before being allowed to work on my own. When I recently returned to Boeing as a contract mfg engineer, I was shocked by how much this great company had changed over the last 2 decades. Gone where the experienced people. Foreign contractors were everywhere. No one was communicating and contractors hired to temporarily help were shunned by the SPEA direct workers. There is something very wrong at Boeing. Things have changed. In the 80's, Boeing was constantly cited as one of the best managed companies in America. No one is saying that now. Boeing workers hate their management and management has lost control of the workforce. Working at Boeing was a horrible experience and I left them.

Once again we have a case of lack of interaction both among workers and between employees and management. Hiring temporary workers (who presumably earn smaller wages than permanent workers) is a form of (inside) outsourcing. It may be cost effective but it is also a sure recipe for bringing about bad working relations. It is probably because the adverse impact of worsening labor relations cannot be easily assessed that management was lured into thinking that it would be a good solution.

At the time of writing (8 August 2009) and in spite of the fact that the Dreamliner was not scheduled to make its maiden fly until 2010, Boeing was planning to establish a second production line in South Carolina. The first production line is in Everett in the state of Washington which is the historical craddle of Boeing. For the management the main advantage of this project would be that, in contrast to the one in Everett, the second production plant would be union free.

[12]This comment contains several acronyms; here are possible meanings: IAM=Integrated Area Management, mfg=major functional group, SPEA=Service Platform Enginering Associates.

Lecture 2
Effects of increased interaction

Lecture given at Beijing Normal University, Department of Systems Science, on 8 October 2008, 14:00. and at Chuo University on 10 December 2008, 17:00

This lecture heavily relies on a parallel with physical phenomena[13]*. At first sight such a parallel could seem weird. Although it can also be justified by technical arguments, its ultimate rationale is that physics is the only field which provides a clear understanding of interactions. As a guide the physical world may perhaps not be perfect, but I think it is not misleading and it is probably better than to have no guide at all. Anyway, it is through its fruits that this approach will eventually get justified.*

Main conclusions of the first lecture

I welcome all of you to this second lecture in systems science.
In the first lecture I gave a number of general ideas about systems science.

- I noted that research in systems science seems to be more developed in China than in western countries.
- I gave some evidence which suggests that the stronger the interactions in a system the more efficient and "creative" it seems to be.
- I mentioned two ways by which interaction can be increased (i) Bringing the elements of the system closer together (ii) Abolishing the barriers which separate different subgroups within the same system.
- As an illustration of the first way, I gave the examples of stars and cities, two systems characterized by strong interactions because their elements are drawn closely together.
- As an illustration of the second way, I gave the example of the French Revolution of 1789 which abolished the barriers between the nobility, the clergy and the rest of the population. A similar effect probably occurred in China in the wake of the

[13] It should be emphasized that the parallel is not with physical theories or with mathematical methods of theoretical physics but with what we know about the physical world itself.

Revolution of 1949. As my knowledge of Chinese history is fairly limited, I prefer to leave this point to your discussion.

- I also gave the counter-example of Enron Corporation where an atmosphere of exacerbated competition prevented employees from cooperating one with another.

I also briefly discussed the recent powder milk problem. In the meanwhile I gave this question a closer look. If you wish to discuss it further from the perspective of systems science, please do not hesitate to visit me in my office at any time.

What can we learn from physics?

This lecture more than any other relies on a parallel with physics. At first sight such a parallel could seem weird. One can try to justify it by technical arguments but the most fundamental In my first talk I emphasized that the most serious difficulty that we face in the field of systems science is the fact that, so far at least, we cannot measure the strength of social interactions. This prevents us from building weighted networks in a realistic way and it makes it very difficult to identify the effects of stronger (or weaker) interactions. Fortunately, for physical systems we know how to measure the strength of interaction. For such systems it is therefore possible to identify and study the effects of stronger interactions. Thus, a natural route is to study a number of physical systems from the perspective of systems science that is to say by focusing on general rules that may possibly be transposed to social and biological systems.

To illustrate that approach I will in this talk consider a specific physical phenomenon, namely the mixing of two liquids. You may ask, why liquids rather than gases or solids? Well, the response is very simple. We know that between social agents there are *permanent* interactions. Yet, in gases there are only short-lived shocks. For instance for hydrogen in standard conditions of pressure and temperature the duration of a collision is 1/1000 of the mean time between shocks, 0.1 picosecond as compared to 100 picoseconds. A similar situation in social interactions would mean that people would talk with their family and friends only one day every 1,000 days that is to say one day in 2.7 years! Naturally, in solids there are permanent interactions as in liquids.

Mixing of two liquids: qualitative experiments

Here I have three liquids: a liquid A which is water on the one hand and on the other hand a liquid B which is either soya sauce or a red liquid which is used in cooking as a food coloring substance.
If I add the liquids B to the water, do they mix? From the observation of a drop of

liquid falling into water it is not immediately clear that the two liquids are able to mix. However, if I stir the liquids which is what I will do in a separate container, then it becomes clear that the liquids mix. We will say that the liquids are miscible. They form a new liquid C which is different from A and B: $A + B \longrightarrow C$

If I try to repeat the same experiment with water and oil, we see that a drop of water falls in oil by forming a small sphere which goes to the bottom of the container without mixing. If I stir the liquids they first seem to mix but fairly quickly they separate into two layers. We say that the two liquids are immiscible.
The fact that oil is not soluble in water seems a fairly trivial observation, but in fact it is not. First of all, it is not really true: oil *is* soluble in water but in small proportion. This effect becomes more obvious if we increase the temperature and pressure: at a temperature of 300 degree Celsius and a pressure of 20 atmospheres (which ensures that water is still liquid) water and oil are completely miscible. This observation clearly suggests that the phenomenon is not as trivial as it may seem at first sight.

At this point you may say that as stirring seems to play a crucial role, perhaps we did not stir the oil and water vigorously enough. By putting the two liquids in a bottle I will be able to stir them more. Yet, after about half a minute they begin to separate (though the complete separation may take several hours).

Interpretation of the phenomenon of mixing

From the perspective of our inquiry, two questions are of particular interest: (i) How can one explain the phenomenon of miscibility in terms of molecular interactions? (ii) What parallels can one draw with social systems?

Regarding the first question, I will just say that the stronger the interaction between the molecules A and B as compared with the interactions $A-A$ and $B-B$ the better the two liquids will mix (more explanations are given later on). In short if we denote the interaction strength by I one has the following rule[14]:

$$I(A,B) < \text{Max}[I(A,A), I(B,B)] : \quad \textbf{no mixing}$$

$$I(A,B) > \text{Max}[I(A,A), I(B,B)] : \quad \textbf{mixing}$$

I will now illustrate this rule by examples taken from sociology.

"Gedanken" experiments about the mixing of groups

Gedanken is a German word which means "by thought and imagination". The expression "Gedanken experiment" is used by physicists in English and French (and

[14]This is a rather approximate rule because there are other characteristics which also play a role, for instance, the size or shape of the molecules, temperature, etc. At this point the exact expression to be used in the right hand-side is not really important. We considered the Max of the two interactions but other writers use the average of the two interactions.

probably in other languages as well) to refer to an experiment whose outcome can be predicted through plausibility arguments but which has not actually been carried out. Such examples can be useful for strengthening explanations but of course they cannot replace real experiments.

- Consider what can be called an ancient style family with grand-parents, parents and children. Between these family members there is a strong $I(A, A)$ interaction. Thus, it will not be possible for somebody from outside to be accepted in the family unless that person B is able to develop a $I(A, B)$ interaction which is stronger than $I(A, A)$ (in this case $I(B, B)$ plays no role because B consists of only one unit). The standard way for generating such an interaction is to marry one of the persons of the family: the strong interaction between husband and wife will allow B to become integrated.
- Consider a club of chess players. The interaction between club members is largely based on playing chess. Any good chess player will be readily accepted.

Playing chess with somebody else does not seem to create a very strong link between these persons. How then can we understand that clubs of chess players are relatively stable[15]?

One can think of two reasons. (i) Playing chess during an evening once in a week is an occupation which is easily compatible with other social duties such as working obligations or family life. In other words there is no real conflict or competition with other activities[16]. (ii) Intuitively one would say that the cohesion of a group can be maintained all the more easily if it is fairly homogeneous. What makes a chess club homogeneous is that only one facet of the members plays a role namely their ability to play chess. For instance the fact that the members may belong to different political parties would cause a serious problem in a union but is completely irrelevant in a chess club. Thus, one can understand that even the weak interaction resulting from playing chess together will be sufficient to maintain the cohesion of the club.

To discuss a case of mixing we must consider a situation which involves two clubs. So, suppose that the chess club of city A makes an arrangement with the chess club of city B to spend a week in the same vacation resort. One would not be surprised to see the players of A playing with those of B. In terms of interactions, one would expect that:

$$I(A, A) \sim I(B, B) \sim I(A, B)$$

[15] In fact, unless we can find data about the evolution in chess club membership, we do not know how stable such clubs are. How often does the marriage of a member or the birth of a child in his family result in his resignation from the club? One would expect the fluctuations in the number of married members to be larger than those of non-married members.

[16] Actually, this argument is perhaps not really necessary. Consider a club in which the members play not once a week but every day. Obviously, this will make them very good players with the result that playing chess will become more important for them. Thus, the interaction will be stronger and in spite of the fact that attendance is more demanding the cohesion of the club may nevertheless be maintained.

What makes this situation of particular interest is the fact that the actual level of interaction can be estimated quantitatively by counting the number of games of each kind, thus if $n(A, B)$ denotes the number of games opposing A and B players.

$$I(A, A) \sim n(A, A)/n_t \quad I(B, B) \sim n(B, B)/n_t \quad I(A, B) \sim n(A, B)/n_t$$

where: $n_t = n(A, A) + n(B, B) + n(A, B)$

Now, suppose that in city B there is a team of figure skaters. which some reason spends a vacation in the same hotel as the chess player club of city A. Apart from a few casual contacts at breakfast or dinner time one would expect little interaction between them. This would be a case of no-mixing: $I(A, B) = 0$. To generate more interaction there must be other channels of communication between the two groups. Chess players are mostly men; if the ice skaters happen to be a team of pretty girls, it is likely that interaction will be increased. However, quantifying that interaction will be more difficult than in the previous case.

What is the usefulness of such *Gedanken* experiments? They may help us to identify interesting situations. The data describing such situations may not yet be available, but they may become available subsequently or perhaps there may be data for situations which, although slightly different, allow similar observational tests.

Next, I consider a number of historical episodes which show situations in which two groups do not mix well, or cases in which they mix subsequently to a first rejection reaction.
In contrast to the previous *Gedanken* experiments, these are real situations for which data are (more or less) available. The main drawback is that such historical episodes usually are complex situations which have many different facets. They provide what we may call “soft qualitative evidence”. That kind of evidence can make our interpretation sound more plausible but it does not allow to test it in a significant way.

No mixing: historical examples

Such cases are usually described as reactions of intolerance, but this term is more a moral judgment based on our current vision of human rights, rather than an objective description. This becomes clear when one realizes that such reactions were the rule rather than the exception during long historical periods of time. The most well-known example was religious “intolerance” that was the standard attitude during the 17th and 18th centuries in almost all countries from Britain to France, Spain or Japan. The case of the inquisition in Spain is fairly well known, as is the St Bartholomew’s Day Massacre (1572) of Protestants in France, but it is important to realize that this phenomenon was not limited to Catholic countries. It was in fact fairly universal and in order to emphasize this point I will give examples taken from the history of Britain and Japan.

- To become a priest, or to harbor one, or be present at mass, were crimes punishable with death. A total of 389 Catholics are known by their names to have been officially executed in England and Wales[17]. This list does not include those who were massacred subsequently to rebellions; for instance after the "Northern Rebellion (1569)" (also known as the "Rising of the North" a large number of Catholics were killed in reprisal[18] nor does it include the numerous Irish Catholics who were killed during and after failed uprisings or because they were priests.
The Clarendon Code (1661) severely limited the rights of Catholics and nonconformists (e.g. Quakers) effectively excluding them from national and local politics. By 1662 thousands of nonconformists were in prison.
- In Japan the list of Catholics who were killed is of course much shorter than in Britain. About 229 are known to have been killed between 1597 and 1639.
- It seems that the only countries where tolerance seemed to prevail were countries such as the Netherlands or Switzerland which had a federal structure and where the central government was weak.

This brutal rejection of one group by another is difficult to understand if one does not realize that at that time religion permeated the whole society. Data about the printing of books show that around 1650 about 50% of the books were about religion[19]; schools and universities were almost completely under the control of the Church; marriage was a purely religious matter (as a result it was impossible for dissidents to become married officially); all vacation days were for religious purposes; the king (or queen) was seen as deriving his (her) power from God as emphasized by the coronation ceremony.
The fact that the nation was embodied in the religion can be illustrated by two facts.
(i) Catholic priests who were caught in Britain were not indicted as heretics but rather for high treason which implies that they were hanged, drawn and quartered, the mode of execution reserved to traitors.
(ii) In 1609 a statute required candidates for British citizenship to take the sacrament according the Anglican rite.

In brief, because almost all social interactions were based on religion, the $I(A, A)$ interaction between people belonging to the same religion was very strong but at the same time the $I(A, B)$ interaction between people of different religion (this interaction was based on the few aspects of life which did not depend on religion) was small. As a result the society was segmented into two groups which had very little

[17] 1530-1560: 93, 1561-1600: 167, 1601-1680: 107, unknown date: 22; the source is the website of Wikipedia, article: "List of Catholic martyrs of the English Reformation".

[18] At least 70 noblemen were executed and 800 Catholics perished on the gallows; http://www.tudorplace.com.ar/Documents/NorthernRebellion.htm

[19] As a matter of comparison medical books represented only 5%, Roehner (2002): "Pattern and Repertoire in History", p. 91

contacts. As will be seen in the fifth lecture, when two persons a and b have little contacts, a does not mind punishing b if he has some reason to do so.

Rejection followed by slow mixing

Now, consider the case of the African-Americans. Before the Civil War (1861-1865) most of them were slaves, but even after 1865 their rights were restricted in several ways. In many states, marriages between African-Americans and white people were prohibited until 1967[20] .

Even after the Civil Rights movement in the 1960s, the housing areas of the Black and White populations to a large extent remained separated. As a result, few links were established between these two communities. Even nowadays the percentage of mixed Black-White married couples remains very low of the order of 0.4% of all married couples in 2006.

In short, the situation is similar to the case of two liquids whose $I(A, B)$ interaction is weak (which means that they will not mix well). Of course, in contrast to liquids, $I(A, B)$ can change in the course of time. But for this to occur the institutional barriers (at residential or occupational level) must be lowered. Whether this will happen or not is an open question.

Rejection followed by rapid mixing

Around 1848 a great number of people from Ireland emigrated to the United States because there was a terrible famine in Ireland. At first, they were not well accepted and in many places there were rejection riots in which Irish Catholic churches were burnt down and Irish people injured or even killed. Little by little, however, Irish people became integrated in the American society: instead of speaking Irish they switched to English, they married non-Irish men or women, and adopted American ways. Yet, it must be emphasized that by becoming integrated and accepted they also changed the American society. For instance, the Catholic religion became an important component of the US society. In other words, as in the mixing experiment, a new society C took shape.

Implication of a shift in interaction strength

During the 19th century for a number of reasons there was a secularization of west-

[20] In this year the US Supreme Court who had previously avoided such cases agreed to hear a miscegenation case. In its decision, it ruled that anti-miscegenation laws were “designed to maintain White supremacy” and recognized the right to marry a person of another race. Yet, it took South Carolina until 1998 and Alabama until 2000 to officially amend their states’ constitutions to remove language prohibiting miscegenation. In the respective referendums, 62% of voters in South Carolina and 59% of voters in Alabama voted to remove these laws. Through personal testimonies it is known that in these states, although no longer officially prohibited mixed marriages were made difficult by using various bureaucratic pretexts.

ern societies[21]. With education becoming more widespread, language began to play an important role as a cohesion factor. This shift had far reaching consequences for the cohesion of states. In a general way, the states which held together because of a common religious identity but included different languages disintegrated. At the same time nations which had a common language were able to become unified even if there was a plurality of religions. In the first category one can mention:
(i) Denmark; in 1658 it lost to Sweden the province of Scania along with the neighboring provinces of Blekinge and Halland which together constitute the southern part of Sweden; it lost Norway in 1815, Schleswig-Holstein (German speaking) in 1865, Iceland (Icelandic speaking) in 1945.
(ii) The Austrian Empire; it disintegrated in 1918 with the secession of Hungary and Bohemia (Czech speaking) and northern Italy.
(iii) The Ottoman empire; it lost its Arabic speaking provinces in 1918.
(iv) Belgium (partly French-speaking); it separated from the Netherlands (Dutch speaking) in 1830 and nowadays the country seems to be tempted by a division into two parts: the Flemish-speaking part in the north and the French-speaking part in the south.

In the second category one can mention the creation of the United States and the unification of Germany in 1871.

Miscibility of languages

In this paragraph I consider still another case of miscibility, namely miscibility at the level of languages.

Examples of words transferred from one language to another

It is quite common for words and expressions from a language A to be integrated into a language B. After all, the English language was the result of centuries of invading Romans, Danes, Saxons and French layering their languages over older British dialects.

For instance, *beau geste* (fine gesture), *beaumonde* (high society), *bête noire* (somebody who is disliked), *bon mot* (witty remark), *crème de la crème* (something superlative), *cuisine* (style of cooking), *cul-de-sac* (blind alley), *entre nous* (confidentially) are some examples of French words and expressions which have been integrated into English. However, they are still recognizable as having a foreign origin which suggest that their integration is not yet complete. Fully integrated words are characterized by the fact that nobody but etymology experts would suspect that they have a foreign origin. For instance, it is not obvious that the verbs “to abate” or

[21] Many reasons may have played a role, for instance the progress of science and the development of education.

"to abridge" are English forms of French verbs, namely *abattre* and *abréger* respectively; or that "algebra" is an English adaptation of the Arabic word *al jebr*. In other words, these words seem to be better integrated.

In this process of integration the date of the transfer seems to play a key-role. For most of the words in the first list the transfer occurred in the 18th century [22] whereas for the words in the second list the transfer occurred around the 14th century that is to say much earlier.

Miscibility versus immiscibility

In the previous section I gave examples of foreign words that became integrated into English but it also happens that the integration process fails. In those cases the foreign words are used for a short time and then are dropped.
An example is the word "railway" which was commonly used in French during the late 19th century but which is no longer used and has been replaced by French words such as "train" or "chemin de fer". Another similar example is the English term "wattman" (i.e. driver) which was still used in French in the 1950s: "Il est interdit de parler au wattman" (i.e. it is prohibited to talk with the driver) but is no longer used nowadays.
Can we interpret such rejections by using the ideas that we have developed to explain the miscibility of two liquids?
In order to establish a parallel with the miscibility of liquids, one should first observe that a language is a system in which words (or characters in languages such as Chinese) interact according to specific rules. Naturally a word has a much stronger interaction with the words in the same line than with words which are several lines below. In short, the interaction between words decreases with distance just as the interaction between molecules.

What happens when a word from a language B is incorporated into a language A? Two things may happen.

- If it develops enough links with other words it will be integrated. Examples are the words "weekend", "bye" or "ciao" which are commonly used in French. Other examples are the words of French origin in English that we mentioned above.
- If the word does not develop enough links it will eventually be rejected.

Although this explanation seems fairly reasonable, it is obvious that it makes little sense unless one has been able to define the term "enough" in a quantitative way. This can only be done by empirical observation: for each word w_i under examination and based on a fairly large sample of texts one would establish a list of the words which

[22] Here are some dates of transfer given by an online etymological dictionary (http://www.etymonline.com) beaumonde (1714), crème de la crème (1738), cuisine (1786), cul-de-sac (1738).

precede and follow w_i [23]. Then one would order the words w_i according to their numbers of different closest neighbors. Once this is done, it will become possible to check if the w_i which have been dropped after a few years are indeed those which have only few neighboring words[24].

Apart from the number of closest neighbors, other factors may play a role, for instance the length of the word. It seems natural that short words will be used more often than long words. An illustration is provided by the Italian words *ciao* (good bye) and *arriverderci* (which also means good bye but with a more formal expression of goodwill at parting). Both words are used in French but *ciao* is used much more frequently than *arriverderci*.

Quantitative mixing experiments

Before coming to my next point, I will carry out two quantitative mixing experiments with the purpose of convincing you that, if one looks at it closely, the process of mixing of two liquids is quite complicated.

- The first experiment will show that the mixing of water and alcohol (ethanol) results in a rise in temperature. Before getting mixed the two liquids are at room temperature that is to say about 20 degree Celsius. By adding the water to the alcohol, the two liquids will mix; indeed, because of its higher density the water will fall to the bottom. At the same time the temperature increases to about 26 degrees.
- The second experiment will show that the mixing produces a contraction in volume. This time I slowly add the alcohol to the water because I do not want the two liquids to mix immediately. Then I mix them by turning the bottle upside down; the volume decreases by about 10%. You may object that the finger that I put on the top of the bottle may have absorbed some liquid. As a check I put only water in the bottle; when I turn the bottle upside down the level of the water changes very little.

At the beginning of this talk I said that physical systems may help us to better understand what happens when an interaction is increased. As an illustration I will focus on boiling temperatures.

Influence of interaction strength on boiling temperature

Physicists have been able to measure boiling temperatures of various liquids for almost three centuries. This became possible as soon as reliable thermometers were

[23] In the language of statistical mechanics this would correspond to a model with an interaction restricted to closest neighbors.

[24] This is only one mechanism through which a word can become better integrated. It is possible to imagine others. For instance a word w_i may establish a very strong connection with another word that is already well integrated. In this way it may become integrated so to say by association.

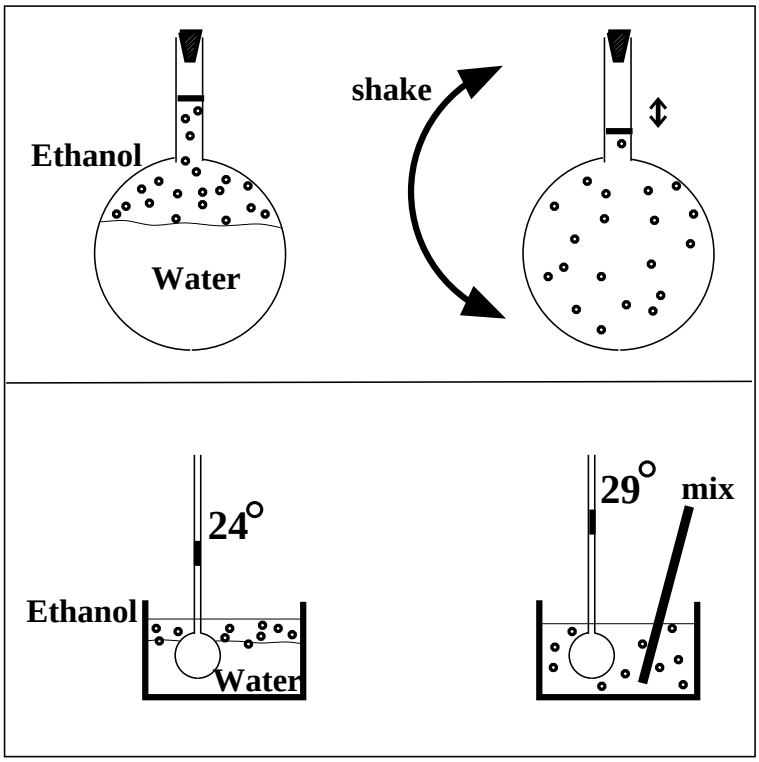

Fig. 2.1 Two experiments on the mixing of water and ethanol (C_2H_5OH). These experiments can be performed easily by anyone who wants to get a more intuitive feeling of the mechanisms described here. When ethanol is added to water there is a volume contraction and a release of heat. Both phenomena are affected by respective proportion and initial temperature (see Fig. 2.2).
Similar experiments can be performed with many compounds. The mixing of acetone (C_3H_6O) and chloroform ($CHCl_3$) is even more exothermic, whereas the mixing of acetone with carbon disulphide (CS_2) is strongly endothermic and results in a volume increase. Note that because carbon disulphide is more toxic and dangerous to handle (it catches fire very easily) than the previous compounds, the last experiment should rather be done in a chemistry lab. *Source: Moelwyn-Hughes (1961, p. 812)*
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available. In this respect, one can recall that it is around 1735 that Anders Celsius, a Swedish astronomer, proposed the temperature scale which bears his name. Naturally, after having measured the boiling temperatures of many liquids, physicists tried to understand what are the main factors which determine them. They tried to establish correlations with density, viscosity, and several other variables but all these attempts were unsuccessful. We now know that the major factor is the interaction strength, but physicists were not able to measure this variable until the 1930s. Thus, boiling temperatures remained a mystery for almost two centuries.

This is illustrated by the graph (Fig. 2.4) of the boiling temperatures as a function of molecular weight. If for a moment we leave aside the curve for the alkanes, we see that for the other points there is no clear relationship. What distinguishes these substances from the alkanes is the fact that they have *different* interactions whereas all alkanes have the *same* interaction. There is a so-called London interaction between hydrogen atoms. I do not go into more details but you can find more explanations in

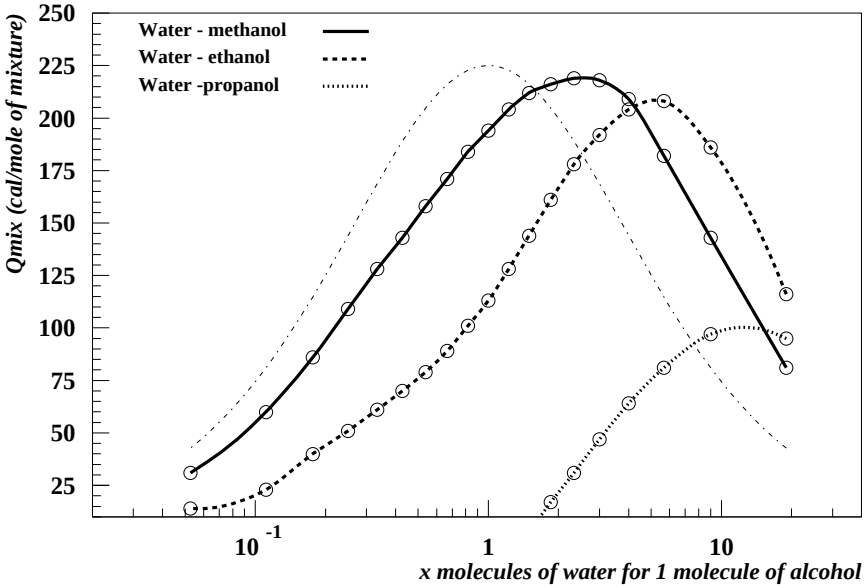

Fig. 2.2 Heat of mixing between water and three different alcohols. Methanol (CH_3OH), ethanol (C_2H_5OH) and propanol (C_3H_7OH) are the first three alcohols: $C_nH_{2n+1}OH$, $n = 1, 2, 3$. Usually, for instance for acetone-chloroform or methanol-ethanol, the corresponding curves are symmetrical with respect to molar concentration (as indicated by the thin line curve); this points to a connection between the shapes of the curves and the structures of molecular assemblages: the dissymmetry shows that several water molecules surround each alcohol molecule (as shown in Fig. 2.3). Note that when the proportion of water becomes too small, the mixing with propanol becomes endothermic. *Source: Bose (1907), Landolt-Börnstein (1976).*

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Appendix A. Because the number of the hydrogen atoms is itself proportional to the molecular weight (see Fig. 2.6) the variable on the horizontal scale is in fact proportional to the strength of interaction (at least for the alkanes). Thus, by focusing on a single interaction the picture becomes much clearer. The fact that as the interaction becomes stronger the boiling temperature increases is consistent with physical intuition because when the interaction is strong it requires more kinetic energy (i.e. a higher temperature) to extract the molecules from the liquid, that is to say to make it boil.
Other physical variables such as viscosity have a similar orderly pattern with respect to interaction strength (Fig. 2.5).

The fact that by focusing on a specific interaction one can find a hidden order behind the initial chaos is encouraging because it suggests that if in the future we are able to measure social interactions these variables may also turn out to be major explanatory factors of social phenomena.

After having considered the effect of stronger interaction in a single liquid I come back to the more complicated phenomenon of the mixing of two liquids.

Mixing mechanisms of two liquids

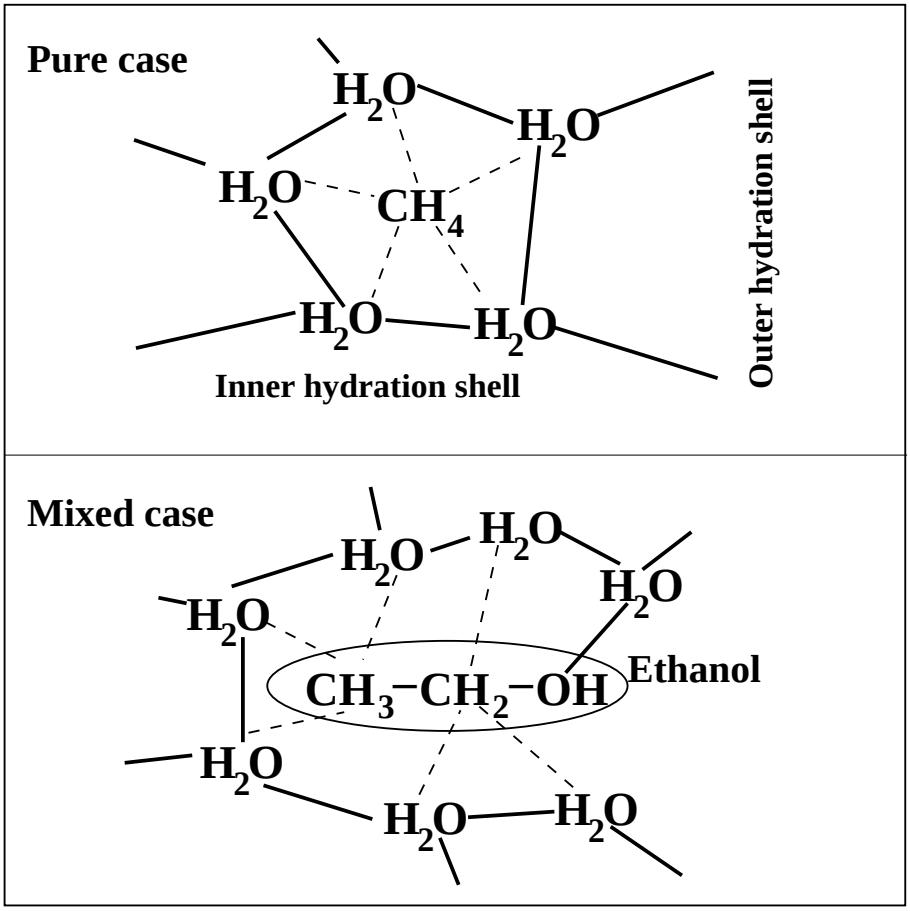

Fig. 2.3 Schematic representation of the molecular assemblage in water-methane and water-ethanol solutions. In contrast to methane CH_4 which features only weak London forces, the molecule of ethanol comprises two segments (i) the alkane-like segment $CH_3 - CH_2$ (ii) the water-like end OH. For that reason, ethanol displays a dual behavior: like methane, it attracts an hydration shell of water and like water it forms strong hydrogen bonds. According to some recent studies (Dill et al. 2003, p. 581) there may be as many as 17 water molecules in the first hydration shell. The precise shape of the molecular assemblage is of little importance for the purpose of this paper; what matters is the fact that there is a highly ordered rearrangement which results in a decrease of entropy, in contrast to the standard entropy increase in the mixing of two ideal liquids. *Sources: Baumert et al (2003), Dill et al. (2003), Dixit et al. (2002), Guo et al. (2003), Israelachvili et al. (1996).*

Is water miscible with alcohol? From our everyday experience we know that indeed it is. After all, wine is a mixture of alcohol and water, isn't it? An interesting question is whether this can be predicted from our knowledge of molecular interactions. But before coming to this discussion let me perform two experiments which show that the mixing of water and alcohol is accompanied by two effects: (i) a release of heat (ii) a volume contraction. Bearing these results in mind, we can turn to the theoretical discussion.

For the sake of simplicity we focus on just 6 molecules: 3 of water that we represent by X, and 3 of alcohol which are represented by OOOO in order to emphasize that a molecule of ethanol is bigger than a molecule of water. The mixing can schematically be represented in the following way.

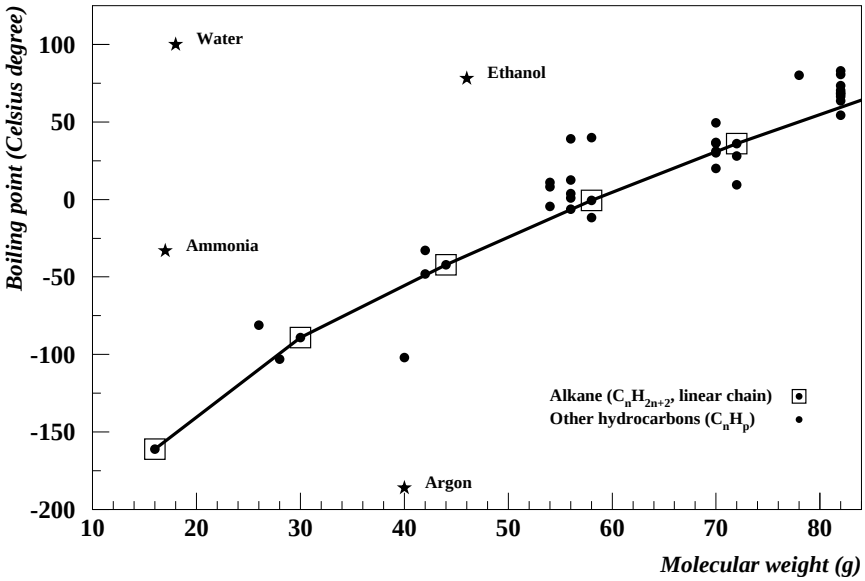

Fig. 2.4 Boiling temperature as a function of intermolecular attraction. For alkanes C_nH_{2n+2} with a linear chain, which are represented by dots surrounded by a square, the inter-molecular attraction is proportional to the number of the hydrogen atoms and hence also to the molecular weight $M = 14n + 2$. The trend portrayed by the solid line means that for longer carbon chains more thermal agitation is required in order to break the intermolecular bonds. The dots represent hydrocarbons C_nH_p whose intermolecular forces, are slightly different due for instance to branched carbon chain which results in boiling temperature differences of the order of 10%. The stars correspond to compounds whose molecular coupling are of a different nature, either much weaker as argon or much stronger as ammonia (NH_3), ethanol (C_2H_5OH), water .
Source: Lide (2001).

(i) Before mixing:

$A1$	$A2$	$A3$	$B1$	$B2$	$B3$
X	X	X	OOOO	OOOO	OOOO

(ii) After mixing:

$A1$	$B1$	$A2$	$B2$	$A3$	$B3$
X	OOOO	X	OOOO	X	OOOO

What are the changes required to go from (i) to (ii)?

- The distance between $A1$ and $A2$ must increase to make enough space available for the molecule $B1$ to position itself in between. For the same reason the distance between $B2$ and $B3$ must increase to make space for $A3$.
- The distance between the A molecules and the B molecules decreases.

In terms of interaction, this has the following consequences:
(a) The interactions within each liquid (i.e. $A - A$ and $B - B$) decrease
(b) New interactions $A - B$ are created (before mixing the distance between the two liquids was so large that this interaction was practically nonexistent).
How will the system evolve?
You know that physical systems evolve toward states of lower energy. In Appendix

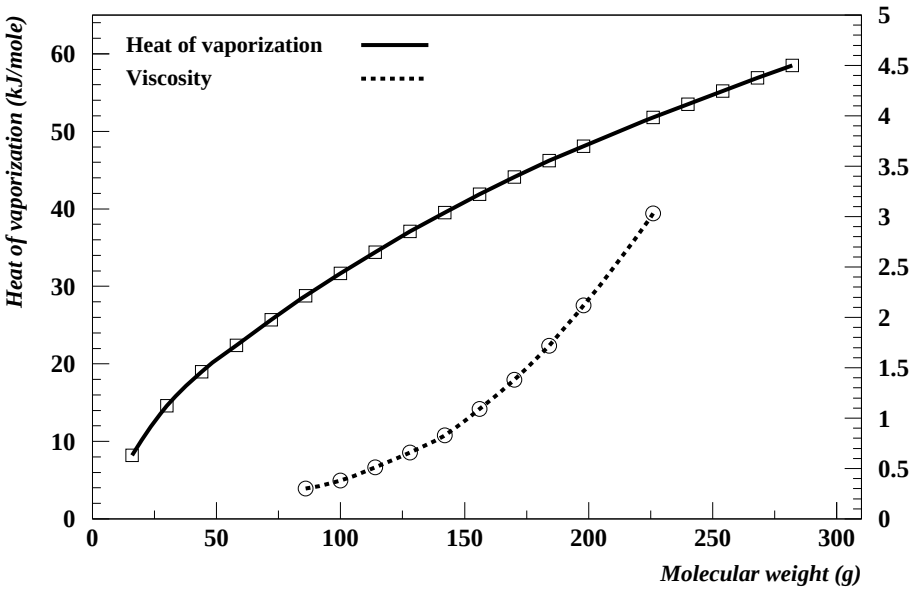

Fig. 2.5 Heat of vaporization and viscosity as a function of inter-molecular attraction for alkanes. As explained in Fig.2.6, for the alkanes there is a proportionality between attraction strength and molecular weight. The solid line corresponds to the 20 first alkanes (except $n = 15$ which is missing in data tables); it describes the empirical relationship: $L_s(\mathrm{C}_n\mathrm{H}_{2n+2}) = 1.1 + 1.7n$. The broken line represents the viscosity; it is restricted to the alkanes which are liquid at room temperature, namely $n = 7, \ldots, 16$ ($n = 15$ is again missing) *Sources: Lide (2001), Moelwyn-Hughes (1961, p.702)*

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B it is shown that for these molecules, this is equivalent to evolving toward a state of greater interaction. Thus for the mixing to occur the new interaction must more than compensate the loss of interaction which occurs within each separate liquid.

With these ideas in mind, we come back to the question of how to predict that alcohol is soluble in water. In this case the $A - B$ interaction turns out to be substantially stronger than the $A - A$ and $B - B$ attractions (see Appendix C). This implies that the interaction gain $A - B$ is greater than the decrease of the $A - A$ and $B - B$ interactions.

This leads to several predictions:
(i) The two liquids will be miscible.
(ii) Because the new equilibrium state has a lower energy than the initial state the mixing will produce a dissipation of heat; this heat will increase the temperature of the mixture.
(iii) Because the interaction $A-B$ is stronger than the interactions $A-A$ and $B-B$, it will keep the molecules closer together; in other words we expect the mixture to experience a contraction during the mixing.

As shown by the former experiments all three predictions are indeed confirmed by observation.
In a more general way, this example suggests the following conclusion. If the inter-

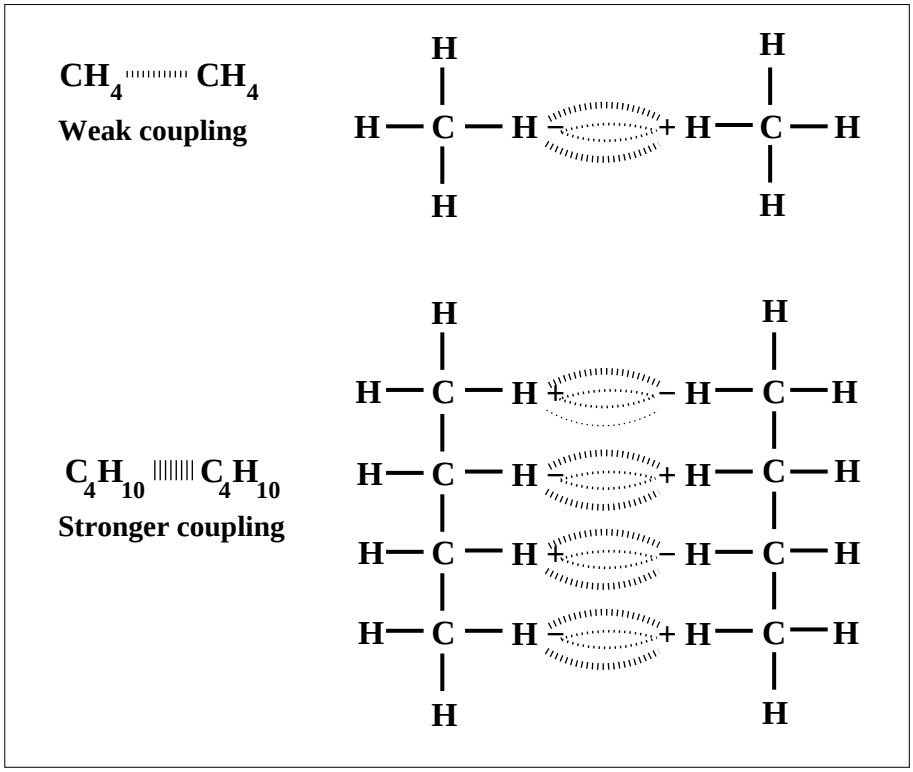

Fig. 2.6 Attraction between alkane molecules. The figure shows two alkanes: methane (CH_4) and butane (C_4H_{10}) The attraction due to induced dipoles (also called London bonds) represented in the figure is a form of interaction which exists for all molecules but besides this mode most molecules have several other modes of interaction. The particularity and simplicity of the alkanes comes from the fact that they do not have other modes of interaction. This is why the attraction between two alkane molecules is proportional to the number of their hydrogen atoms $2n + 2$ and thus to their molecular weight $14n + 2$.

action $A - B$ is substantially stronger than the interactions $A - A$ and $B - B$, the two liquids will be miscible in all proportions and the mixing will result in a release of heat and in a volume contraction.
If the interaction $A - B$ is weaker than the $A - A$ and $B - B$ interactions, then the two liquids will be only partially miscible.

Appendix A: Molecular interaction

Molecules can interact in several ways but for our present purpose the two most important are the following.

- Interaction between molecules which are dipoles that is to say which can be schematized as two charges + and - separated by a short distance of the order of a few nanometers. Typically molecules which have a OH part are dipoles.
- Interactions between molecules who are not dipoles, for instance molecules that have only carbon and hydrogen atoms and no OH part. For these molecules the main form of interaction is the so-called London interaction, named after the American physicist Fritz London.

How can one intuitively explain the London interaction? In a molecule the distribution of charges changes all the time. Suppose that at some moment a concentration of + charges develops in a specific area. This will induce the creation of an area of negative charges on neighboring molecules and will result in an attraction between these induced charges. This is the origin of the London force of attraction. This force exists between *all* molecules but because it is about 10 times weaker than the interaction between dipoles, it plays a major role only for the molecules which are not dipoles. The alkanes are such a class of molecules.

Appendix B: Evolution toward states of higher interaction

Take two elements (O) between which there is an attractive force; it can be positive and negative charges which have an electrostatic attraction or it can be two masses which have a gravitational attraction. As a result of the attraction the two elements will move closer.

state 1: O O

state 2: O O

State 1 has a high potential energy of interaction; as one moves from state 1 to state 2 this energy is dissipated in some way. Thus state 2 has a smaller energy and therefore is more stable than state 1, but because the two elements are closer state 2 is also characterized by a stronger attraction than state 1. Thus somewhat equivalently, the equilibrium state can be labeled as the state of lowest energy or as the state of highest interaction.

Why is it more convenient to use the language of interaction than the language of energy? The obvious reason is that we do not know how to define the energy of a social system (even in a qualitative way) but we know how to define the interaction between two social agents at least in a qualitative way.

Appendix C: Configuration of water and ethanol molecules

Thanks to X-ray scattering experiments we know the molecular structure of the water-alcohol mixture. Without that experimental input it would not be possible to estimate the interaction strength. These observations show that the alcohol molecules (which are much bigger than the molecules of water) are closely surrounded by about 6 water molecules which form what is called an hydration shell. Because the water (H-OH) as well as the alcohol (C_2H_5OH) have an OH part, they have a dipole-dipole attraction. As all molecules they also have London interactions. Schematically, we may give a strength 10 to the dipole-dipole interaction between two water molecules and a strength 1 to the London interaction between water molecules.

The interaction strength also depends upon the size of the molecules. The smaller their size, the closer they can be and therefore the stronger the interaction. It is because the water molecules are small that they can form a hydration shell which *closely* surrounds the alcohol molecules. It is this structure that explains the high strength of the water-alcohol interaction. We see that this structure requires 6 water molecules for one alcohol molecule. Therefore one expects the mixing to be optimum when there are 6 times more water molecules than alcohol molecules. This is indeed confirmed by the experimental observation that the production of heat during the mixing is maximum for this proportion.

Lecture 3
A global view of complexification processes

Lecture given at Beijing Normal University, Department of Systems Science, on 15 October 2008, 14:00.

Main conclusions of the first two lectures

I welcome you all to this third lecture in systems science. In the first two lectures we have seen that the stronger the interactions between the elements of a system the better these elements are integrated. and the more effectively the system seems to work.

You may ask:
"How can the level of integration be defined accurately?"

In the case of two liquids this was easy. Alcohol molecules are well integrated into water because they are able to establish strong interactions with the molecules of water; from a macroscopic perspective this results in alcohol being miscible in water. But how can we define this notion for a social system? Of course, when a group of immigrants is rejected by a fraction of the population as was the case for Irish people in the first years after their arrival in the United States, one can say that the integration is not good. But how can we estimate the integration of the African-Americans, a group which has a long presence in America? One solution is to use the criterion of mixed Black-White couples that I already mentioned in my previous talk. You may remember that in 2006 this proportion was of the order of 0.4% of all married couples.

There is another possible criterion based on the infant death rate. If a group is well integrated it means that for all major social variables it should have approximately the same average as the rest of the population. The death rate of infants, that is to say of babies between birth and the age of 1 year, is certainly an important variable. It reflects several social conditions such as the health of the mother, her working conditions, the access to medical services, the healthfulness of the home and so on. On Fig. 7.8 (in chapter 7) one sees that, in contrast to the improvement for the Maoris in New Zealand and the Aborigines in Australia, for the African-Americans the ratio

has remained around 2 during the past 80 years. This may seem surprising because one would have expected substantial progress of integration in the wake of the Civil Rights movement. However, the slow pace of the integration progress is confirmed by the data about mixed marriages.

In the previous talk I also explained (but perhaps too quickly) why the standard physical principle, which says that the evolution of an isolated system is toward states of lower energy, can be expressed by saying that it maximizes its interactions. In its most simple form this equivalence is revealed by the following case of two particles between which there is an attractive force:

Initial state: O $\longrightarrow$ $\longleftarrow$ O (high potential energy, low interaction)
Final state : O - O (low potential energy, high interaction)

Note that this equivalence holds only for attractive forces whose intensity increases when the distance decreases, but this is the case of most forces which play a role in physics.

In the present talk we will examine the implications of these rules for the evolution of social systems. There will be two parts. In the first, we will consider the historical evolution of social systems over periods of a few centuries. In the second part we will discuss long term evolution; for social systems this means time scales of several thousand years, and several billion years for biological systems.

Social implication of interaction maximization

In human activities there are are usually two opposite forces: repetition and innovation. The first force leads to the reproduction and solidification of existing conditions. Let us give two illustrations.

- The concentration of land ownership in agricultural societies is basically a cumulative process. Once it has begun it tends to get re-enforced. Indeed, because of their political dominance big landowners are able to shape to their advantage the distribution of income. We can think of many societies of Latin America as an example. This widens the gap with the rest of the population. As a result the society becomes more segmented and, as we have seen, its efficiency decreases.
- The same phenomenon can happen for business companies. Observation shows that as they grow in size, the number of their hierarchical levels also increases. In short they become more bureaucratic. Because top executives hold the decision power they are able to shape to their advantage the distribution of income. In recent years, there has been ample evidence of skyrocketing salaries and compensation of top executives while at the same time the salaries of the rest of the employees stagnated or decreased (in this respect see lecture 7) As in the previous case this produced

increased segmentation and lead to a fall in efficiency.

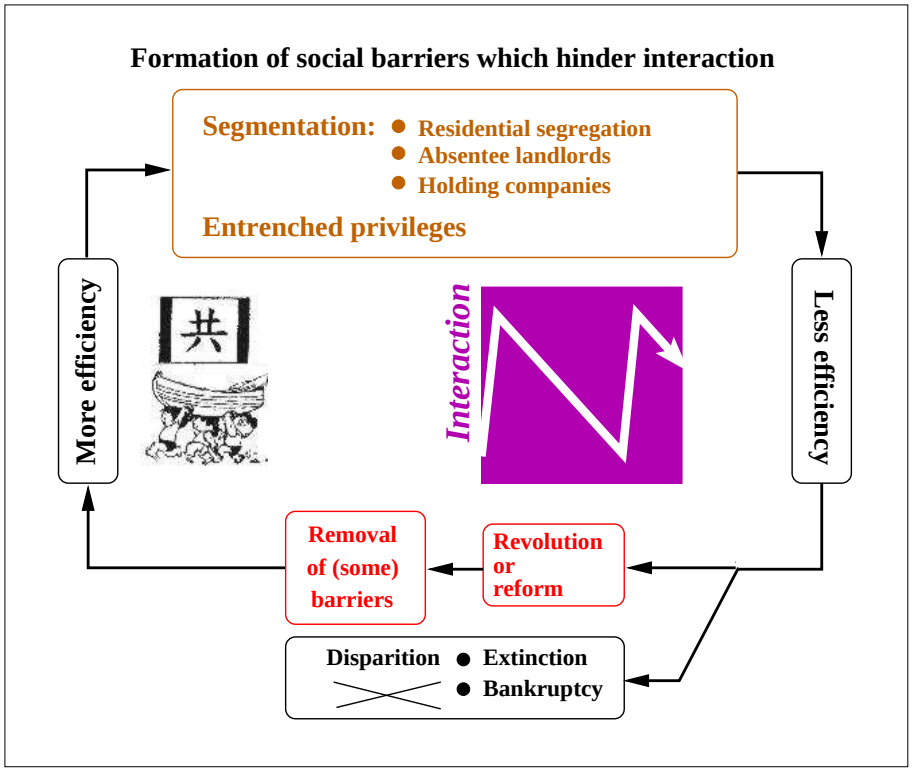

Fig. 3.1 Alternation in history of periods of segmentation and periods of unification and coalescence. The graph summarizes the change in interaction strength in the two successive stages.
This process can occur in nations, organizations or businesses.

- At nation level standard examples of revolutions are the cases of France (1789), Mexico (1911 and subsequent years), China (1949). Standard examples of transformation through reform are Russia (Peter the Great), Turkey (Mustapha Kemal), Japan (Meiji). Examples of collapses and disappearances are provided by the kingdoms of India which became segmented into hundreds of independent states and were eventually overwhelmed by British colonization.
- For organizations, standard examples of revolutions are the Cistercian movement (11th century), the Protestant Reformation (Luther, Calvin).
- For businesses an example of disappearance is provided by Enron Corporation (which was discussed in the first lecture).

The second force, namely innovation can take the form of forceful reforms or revolutions. Such a change leads to an increase in interaction and to a re-unification and regeneration of the society. In contrast, when no reform or revolution occurs the loss of efficiency may lead to bankruptcy and to the disappearance of the nation or company. In the case of a country, it may be conquered and colonized by a foreign power, in the case of a company it may be driven into bankruptcy. It is probably because India was segmented and paralyzed by its caste system that Britain, a much smaller country, was able to take it over. The same observation may apply to the conquest of Mexico and Peru by the Spanish Conquistadors. It should be noted that around the same time a similar attempt by Charles V (the king of Spain and emperor of the Holy Roman Empire) to conquer North Africa ended in disaster (1541).

After a revolution has suppressed the main barriers between social groups the whole process can start again. Note that this mechanism does not imply that there should be recurrent cycles. The system can remain in a segmented state for an arbitrarily long time. The occurrence of a revolution depends upon many factors, some endogenous others exogenous. The present model simply states that segmented systems are characterized by low social efficiency while re-unified post-revolutionary systems are characterized by enhanced efficiency.

We will now turn to the long-term evolution of social and biological systems. But before that we will briefly try to classify such systems according to the strength of their interactions.

Classification according to strength of interaction

Gases, liquids and solids greatly differ in terms of interaction.
(i) The molecules in a gas (in standard conditions of temperature and pressure) have almost no interaction: the collision time represents 1/1000 of the time interval between two successive collisions. In terms of energy (e.g. for for oxygen) the energy of interaction (Lennard-Jones potential) is about one million times smaller than the kinetic energy: 2.610^{-6} kJ/mole as compared to 3.4 kJ/mole. With regard to miscibility it is well known that gases are miscible in any proportion.
(ii) The molecules in a liquid interact much more than in a gas. Their collision frequency is several hundred times larger than in a gas. In terms of energy, their interaction energy is of the same order of magnitude as their kinetic energy. Some liquids are miscible in all proportions but many are only partially miscible.
(iii) For solids (e.g. NaCl) the bond energy is about 100 times larger than the kinetic energy. Solids are not miscible. Metal alloys that is to say mixtures of metals can only be obtained by mixing them after they have been melted[25].

These properties suggest a classification of systems based on three categories: gas-like, liquid-like or solid-like systems. Gas-like systems are miscible and have weak interaction; liquid-like systems are partially miscible and have medium interactions; solid-like systems are not miscible and have strong interactions.

How can this criterion be used to roughly estimate the strength of the interactions that hold systems together? Here are some illustrations.

- It is well known that when two galaxies collide the stars of galaxy A drift through galaxy B without being much affected. Thus galaxies are gas-like systems. Groups of bacterias also seem to be gas-like systems; for instance many groups are knows to coexist in the intestinal tract. This suggests that the interactions between

[25] However atoms can drift from one site to another.

Table 3.1 Classification of physical, social, biological systems based on interaction strength

Interaction strength	System	Does a binary collision result in mixing	Homeostatic regulation
1 weak interaction	gas	mixing	no
	galaxy	mixing	no
	cluster of galaxies	mixing	no
	prokaryotic community	?	?
•	nomads in vast plain	mixing	no
1 strong interaction	liquid	yes/no	no
	solar system	yes/no	no
	solid	no	no
•	group of farmers	no	no
•	group with same language	no	no
•	corporation	yes/no	yes
•	state	no	yes
Several strong interactions	star	no	?
	bacteria	no	yes
	swarm of bees	no	yes
	nest of ants	no	yes
	animal	no	yes

Notes:

- Homeostatic regulation refers to the capacity of maintaining constant internal conditions (temperature, concentration in calcium and other minerals) despite changing external conditions. At this point it is not clear whether stars have that capacity or not.
- As interactions become stronger systems acquire greater cohesion which results in two opposed trends: (i) systems loose their ability to mix one with another. (ii) systems become more regulated with respect to external perturbations.
- Blue dots signal social systems.
- The yes/no indication for liquids means that some liquids are miscible while other are not depending on the compatibility of their respective interactions. Similarly, the yes/no indication for corporations means that a merger (or buy-out) between two corporations may or may not succeed in creating a new entity which is commercially successful; the case of Daimler-Chrysler which eventually ended in a break-up (2007) illustrates a failed merger.
- For two groups of people speaking different languages, mergers do not result in stable mixtures. However the transient state can last several centuries as shown by the colonization of the Gaul by the Romans or the colonization of India by Britain. In some cases, as for the Hispanic colonization of South America the language of the colonizer gains widespread acceptance.

bacteria (whether of same species or not) are rather weak.

- At the other end of the spectrum animals are clearly solid-like systems: the cells which compose two animals do not mix. This suggests that there are strong interactions between such cells. Similarly, to our best knowledge there is no evidence suggesting that nets of ants or swarms of bees can mix.
- As an intermediate case one can mention industrial companies. Whereas there are indeed mergers between corporations, it is well-known that such mergers are not always successful. After a while the two companies may separate again. An example

of such a short-lived merger was the one between the American automaker Chrysler and the German company Daimler which lasted only 9 years from 1998 to 2007. Even when not resulting in a divorce, mergers often remain more formal than real in the sense that at the grass-root level of agents and everyday working methods each company keeps its own traditions, a situation which resembles the partial mixing of two liquids.

The previous criterion provides a way for estimating interaction strength which may be useful in reading Table 3.1 which lists a variety of systems. In addition to the mixing criterion (which in the table is labeled as the effect of a binary collision) the table also indicates a property labeled "Homeostatic regulation". Homeostasis is the ability of an organism to maintain its internal conditions in spite of changing external conditions. It is a capability of self-regulation. Not surprisingly, we see that the stronger the interaction, the better the system can maintain its internal conditions.

We now come to an important observation namely the fact that the processes which occurred in the course of evolution on the Earth show a trend toward greater interaction and complexity.

Trend toward ever greater interaction and complexity

Fig. 3.2 shows several processes which brought about greater interaction and complexity in physical systems.

Fig. 3.3 summarizes complexification[26] processes in biological and social systems.

- The first is the process which led from a collection of macromolecules to viruses, bacteria and cells that is to say highly complicated systems containing hundreds of different kinds of proteins. This process led from gas-like systems to solid-like systems.
- The second process led from bacteria first to primitive multicellular organisms[27] and then to more complex organisms such as insects, trees or animals. which contain several hundred different kinds of cells. This process led from gas-like systems to solid-like systems.
- Then there is the process which led from loose communities such as flocks of birds flying together to societies of ants or human societies; such societies rely on division of labor that is to say different tasks are carried out by various kinds of agents. This process led from gas-like systems to liquid-like systems.

[26] The term "complexification" is not common in English. It is used here with the meaning with which it was introduced by Pierre Teilhard de Chardin (1965), namely an evolutionary process which leads to structures and organisms of ever increasing complexity.

[27] It can be observed that the first bacteria appeared on earth 3 billion years ago while the first multicellular organisms (at least for those for which there is fossil evidence, such as sponges) appeared 1 billion years ago. Thus, the step from single cells to multicellular organisms took 2 billion years.

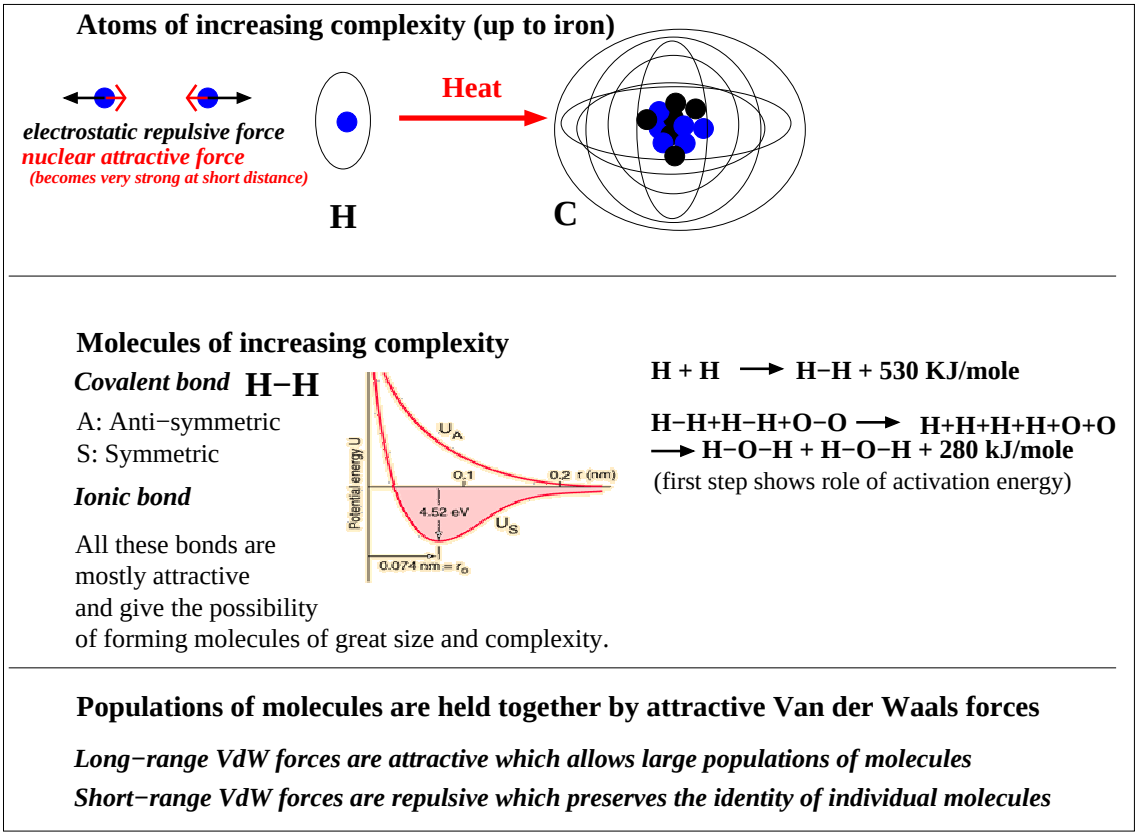

Fig. 3.2 Complexification processes for physical entities.

- The upper panel refers to the production of heavy atoms in stars. There is an electrostatic repulsive force between protons which can only be surmounted when they are brought closely together within the range of the nuclear force.
- The middle panel refers to the complexification process at molecular level. It begins with the formation of small molecules and eventually leads to the formation of big molecules such as the macromolecules which form proteins. The figure gives three examples (i) The formation of a molecule of hydrogen (top left); the graph shows the anti-symmetric and symmetric components of the potential between the two atoms as predicted by quantum mechanics. (ii) The formation of a water molecule. It is because the bond between the hydrogen atoms must first be broken (which requires an energy input provided for instance by a spark) that the mixing of hydrogen and water does not spontaneously lead to the production of water in spite of the fact that water represents a lower state of energy. (iii) In ionic solutions or crystals (such as NaCl) the ions (i.e. Na+ and Cl-) are held together by the electrostatic force.

- The third panel briefly explains how molecules are held together when they form gases, liquids or solids.

- The increase in the complexity of the devices manufactured by mankind is a result of division of labor. Whereas a sword can be produced by a single blacksmith, it requires the collaboration of many different specialists to built a rocket.

An interesting question would be to understand why only few species have developed into large social systems. It is true that all living entities have rudimentary forms of social groups the most common of which is the male-female association. But only few species have developed permanent societies such as those which can be observed in societies of ants, bees or humans. As a rough order of magnitude one can say that only about 0.1% of the species of insects are living in colonies of more than 1,000

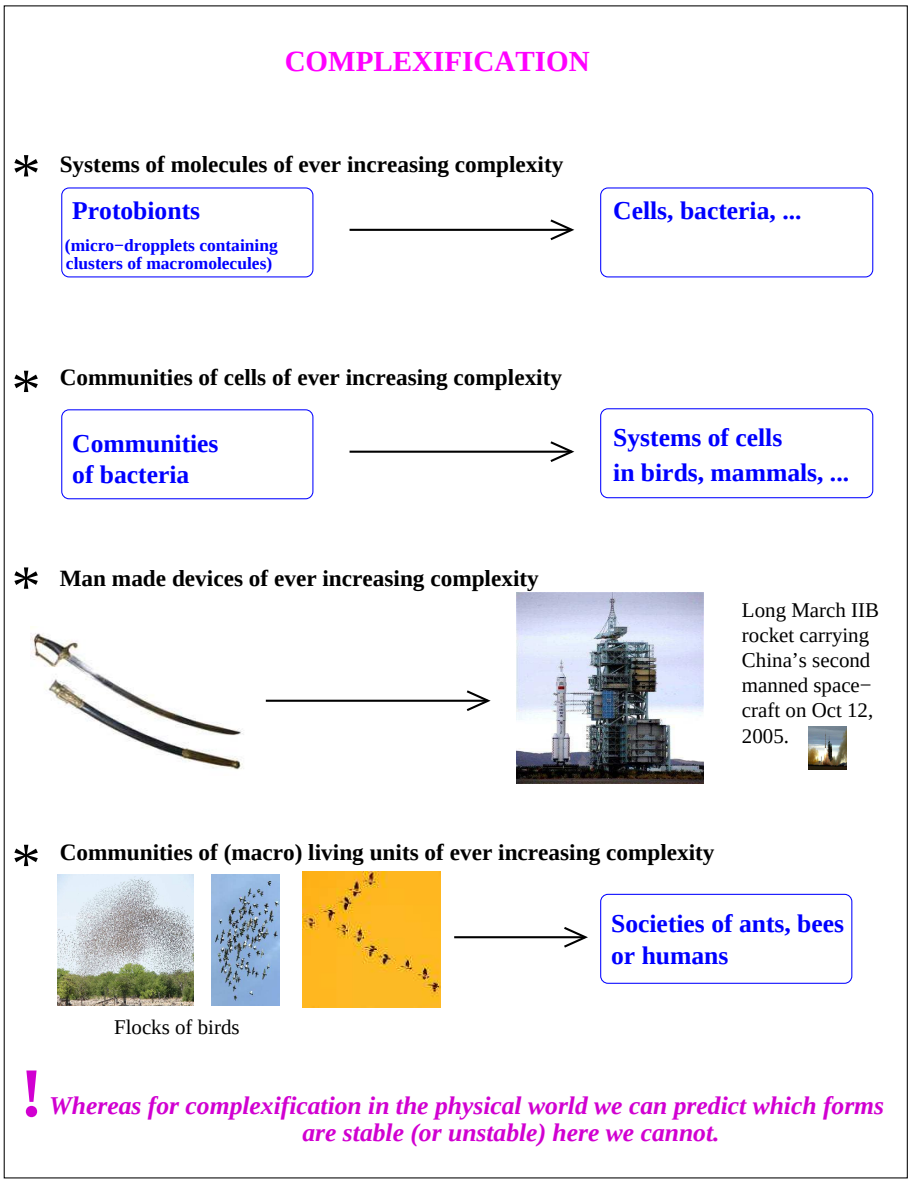

Fig. 3.3 Complexification processes for living entities. The figure lists several complexification processes which occurred on earth in the evolution of living systems. First the aggregation of big molecules lead to the formation of micro-organisms such as bacteria and cells. Then the aggregation of cells lead to the formation of living entities such a plants, insects, mammals or birds. The association of individuals lead to the formation of societies for some species of insects and for some species of mammals. In the course of the evolution of mankind technical progress led to the production of devices of ever greater complexity (from prehistoric tools to swords to rockets).

individuals. The proportion is about the same for species of mammals[28]. If the

[28]The details of these calculations are as follows (as we are only interested in obtaining orders of magnitude, we can use approximate figures). There are about 1 million known species of insects, but it is estimated that the total number could be of the order of 2 to 5 million. As a rough estimate we take 5 million. Social insects are confined to 4 groups: ants, termites, bees and ants. There are between 4,000 and 10,000 species of ants; although all of them are said to be social, many live in small colonies. Roughly we estimate the number of those which live in colonies of more than 1,000 to be around 1,000. Termites are also social insects; there are some 4,000 species and almost all are said to live in colonies of at least a few hundred individuals. As an estimate we take the number of those living in colonies of more than 1,000 to be around 3,000. Not all bees are social. The main group of bees living in big colonies is the group of the so-called Stingless bees which has 500 species. We also assume (somewhat arbitrarily) some 500 species of wasps living in colonies of more

threshold is reduced from 1,000 to 100 the proportion would be of same order. How can one explain that only 1 species out of 1,000 has been able to develop sizable colonies? Do these species share some common feature which could explain this ability or was the development of sizable colonies a fairly random process?
At this point we can make an observation about the "no free lunch" hypothesis which is a common assumption in finance.

Is there really no free lunch?

The contention that "there is no free lunch" means that one must pay for everything. This assumption may perhaps be correct in finance but in a general way it is certainly wrong. Consider two planets such as the Earth and Venus. These are closed systems except for the radiation that they receive from the Sun and the meteorites which fall on them. In terms of solar radiation Venus has certainly received a larger share than the Earth and in terms of meteorites probably the same. Yet, what a difference! The Earth has produced thousands of living species, Venus has produced none. What explains this difference? On the Earth there were processes involving increasing interactions, not on Venus.

You may think that this example is very far away from finance or economics. Yet, I think the same process is at work. Consider two companies A and B which receive the same inputs in terms of capital and working time but with A being able to create a variety of new successful products while B does not create anything. I suppose you can guess what distinguishes A and B. It is the strength and variety of the interactions among the personnel[29]. The important point is that the company does not have to pay for these interactions. It must just provide favorable conditions for their development, just as the favorable conditions which existed on the Earth were able to start the evolution which led to forms of life with increasing interaction and complexity.

In all the processes that we have considered there are in fact two characteristics which grow hand in hand: interaction strength on the one hand and diversification on the other hand. Diversification without increased interaction would bring about disintegration somehow as what occurred in Yugoslavia in the 1990s. Increased interaction without diversification would create organisms all built on the same model.

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than 1,000. Thus the proportion of social insects is:

$$(1000 + 3000 + 500 + 500)/5000000 = 0.1\%$$

Among the 5,400 species of mammals, there are only a few species which live in colonies of more than 1,000 (humans plus a few species of social prairie dogs). Thus the proportion of social species is of the order of 0.1%.

[29]Which includes (i) friendly interactions between employees (ii) positive interactions between executives (iii) constructive interactions between executives and employees.

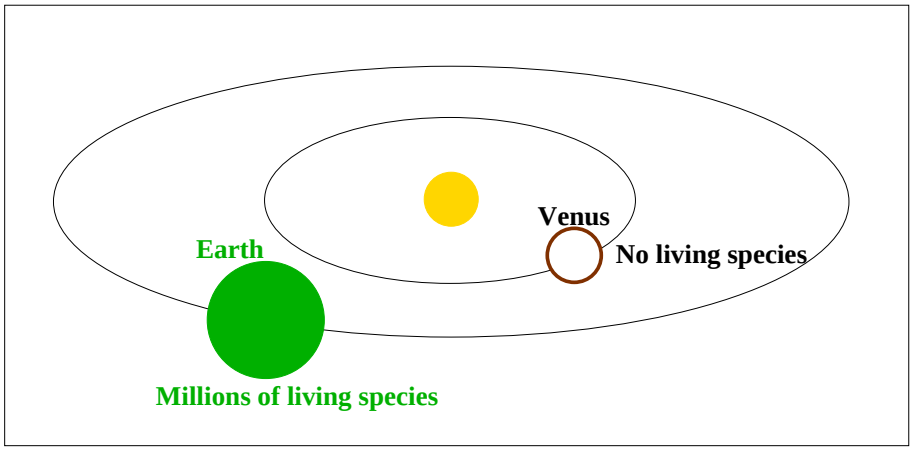


Fig. 3.4 Is there really no free lunch? The figure shows the Earth and Venus. The two planets have received the same exogenous inputs and their initial states were fairly similar. Yet, the results are very different because on the Earth, in contrast to Venus, several interaction processes occurred which resulted in complexification, diversification and the production of a great variety of living species.
Similarly for companies, the difference between those which are creative and those which are not does not depend primarily on the level of salaries but rather on the strength of interaction between employees and an overall atmosphere that is congenial to innovation. The standard assumption that there is no free lunch (which is accepted as an axiom in finance) rests on a conception in which interaction between employees is discarded as being of little importance and significance.

This leads to a key-question: how can one predict the stability of new systems?

Stability of new systems

Because physics is a much more advanced science than sociology (or even biology) one should first ask: can we predict the stability of physical systems? The answer is yes. It is possible to compute the life-time of molecules or nuclei.

For instance, the life-time of a diproton, that is to say a nucleus containing two protons is very short, but if a neutron is added the nucleus becomes stable. It is a stable isotope of helium.

Such predictions can be made thanks to quantum mechanics but they may not necessarily have an intuitive interpretation. For instance it is not obvious why the addition of a neutron to the diproton nucleus makes it more stable. However there are some stability effects which have a fairly simple interpretation. For instance, it can be predicted by an intuitive argument that the stability of very big nuclei is smaller than the stability of smaller ones. The argument goes as follows. We know that nucleons are held together by the nuclear force, a force which has a very short range. If the distance between two protons is larger than this range, the electrostatic repulsion will be predominant. Clearly the average distance between protons increases with the radius of the kernel. Thus, there will be a size above which the nuclear interaction will no longer be able to ensure the stability of the kernel. This is indeed was is observed.

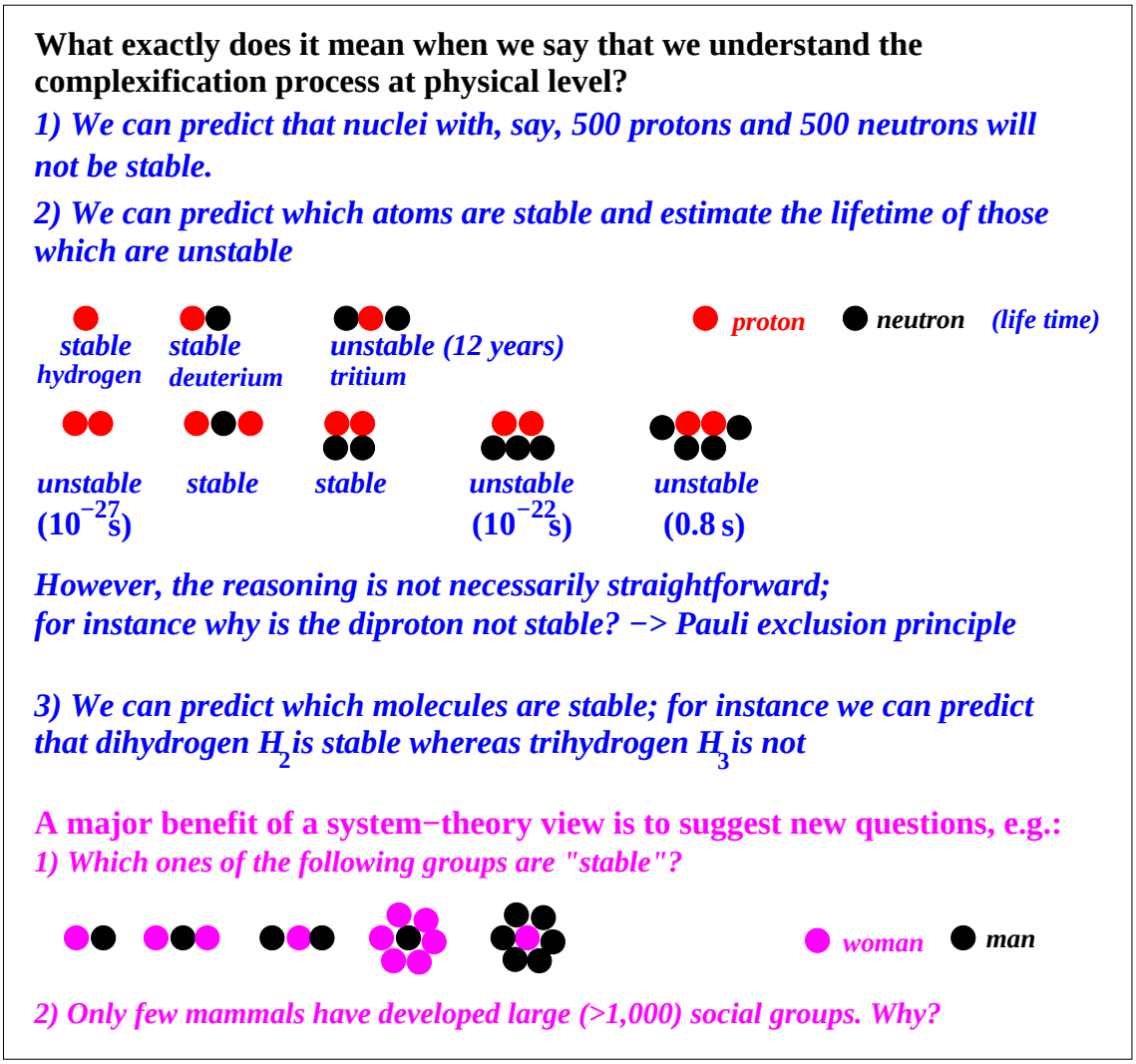


Fig. 3.5 Stability of physical versus social entities. For physical systems we know how to predict the stability of new systems. For systems composed of living entities we are unable to make similar predictions. To get a better understanding of social systems the first requirement seems to be a methodology for measuring the stability of simple social systems. This will be the topic of the next lecture.

There are about 100 stable elements; bigger nuclei containing more than 100 protons are mostly unstable.

A similar question is considered at the bottom of the figure. Present-day societies are based on monogamous families, that is to say composed of a husband and wife. However, polygamy (one husband has several wives) is accepted in Muslim societies. The opposite situation, namely polyandry, that is to say when one wife has several husbands, seems to have been a very rare historical occurrence. It would be interesting to understand why.

From the perspective of systems science a natural question is to estimate the relative stability of these different configurations. You may argue that this depends upon the social environment. Indeed, if in a society based on polygamy the number of women tends to decline this will probably result in a decrease in the number of wives per

husbands. May be if the number of women becomes smaller than the number of men will the society switch to polyandry. Has such an evolution ever been observed? I must confess that I do not know. But, as you can see, looking at social systems from the perspective of systems science brings about quite unexpected questions!

In the next lecture we will consider what is probably the main challenge faced by systems science, namely how to measure the strength of social interactions.

Lecture 4
Methods for measuring interaction strength

Lecture given at Beijing Normal University, Department of Systems Science, on 22 October 2008, 14:00.

I welcome you all to this fourth lecture in systems science. In a sense this is the most important of the four lectures that I have given so far. In the first three lectures I have put forward some guiding principles. For instance, in the previous lecture I have shown that in the course of evolution there was a dual trend toward greater interaction and simultaneously toward greater diversity. But if we want to express such ideas not only in a general way but in a precise and scientific form we must be able to quantify interaction strengths. This is a major challenge.

In physics and chemistry it took more than a century to answer such questions for inter-atomic and inter-molecular interactions. Ecology is another field in which much work has been done with respect to the measure of interaction. It is natural to take advantage of what has been done in these fields. In other words, it makes sense to try to transpose some of these methods to the social sciences.

In which units should social interactions be expressed?

Before we explain measurement methods there is a fundamental question that we must address. How should social interactions be defined and even more importantly, how should they be expressed. By this question I mean that although we have an intuitive understanding of social interaction we do not know how to express it in numbers. So, let us first examine the answers that physics and ecology provide in their respective fields.

- In physics, the strength of an interaction is expressed as the energy that it takes to break it, e.g. the bond energy of the O-H interaction in a water molecule is 460 kJ/mole. The experiment can for instance be done by directing X-rays toward molecules of water and by measuring how much energy it takes to break a certain number of bonds. The very fact that the result of the experiment is expressed in kilo-Joule per mole shows that it supposes an understanding of both the notion of energy (to which refers the definition of the “Joule”) and the constitution of matter (to which

the notion of "mole" makes reference).

In a general way for physical interactions there is a connection between bond strength and bond length: the smaller the bond length, the stronger the bond. This is illustrated in the following table by comparing interactions between molecules, atoms and nucleons:

Table 4.1 Relationship between interaction strength and length of bond

Interaction between:	Molecules H_2O – H_2O in water	Atoms O – H in H_2O	Nucleons proton-proton in carbon nucleus
Bond energy (kJ/mole)	16	460	8×10^8
Bond length (picometer $= 10^{-12}$m)	300	100	0.001

Thus, one can estimate the order of magnitude of the strength of an interaction by the distance between the units under consideration. Such distances can be measured by various methods for instance diffraction of X-rays or (more or less energetic) neutrons. Note that this relationship provides only rough estimates because if one looks at these interactions more closely they also depend upon a number of other factors, e.g. the size of the molecules or the electronegativity of atoms.

- In ecology field research shows (see the textbook entitled "Ecology: principles and applications" by J.L. Chapman and M.J. Reiss p. 139) that for instance the energy flow between herbivores and carnivores in Silver Springs river in Florida is on average 17 kJ per square meter and per day.

Are these two notions of interaction identical or equivalent? Probably not. First, they do not refer to interaction in the same framework. In physics The figure of 460 kJ/mole mentioned above tells us that if we allow the two atoms to come together, the process will release $460/N_A$ kJ (where N_A is the Avogadro number). In contrast, the number of 17 kJ does not refer to a spatial dependence but to a time rate. If I bring a bird, for instance a sparrow, in contact with worms the sparrow will eat a given quantity every day. Another difference is that this notion cannot account for an interaction which does not correspond to a sizable consumption such as the interaction between bees and flowers (pollen is carried from male flowers to female flowers).

The analog of the physical notion would be rather how much energy it takes for the

sparrow to find the worms (or for the bee to find the flowers) or somewhat equivalently how much energy it would take for keeping the sparrow away from the worms. If the worms are their only source of food the sparrows will certainly spend a great amount of energy for finding them, whereas if they have other sources of food they will develop less energy to finding worms. I must confess that at this point I do not see how this energy should be measured. For instance, if the sparrows are put in a cage that will of course prevent them from finding worms but with such a procedure how can we measure the energy spent by the sparrows in trying to escape from the cage? If we could measure it this notion of interaction energy would be closer to the notion used in physics. Unfortunately, it does not seem that this energy has been quantified by researchers in ecology or ethology.

Similarly in the field of social interaction, one can imagine the case of a mother who has been separated from her children; she will certainly devote much efforts to be again reunited with them. In contrast, if you have lost the telephone number of a vague acquaintance you will certainly not spend much efforts in trying to recover it. In short, the efforts consented to restore a broken link provide a reasonable approximation of the strength of interaction. Unfortunately, the social data currently at our disposal do not allow us to estimate this energy. This is why we have to use substitutes. What substitutes can be used?

One possible substitute is to see how the separation affects the life of the living unit under consideration, more specifically by what amount will the separation reduce its life expectancy. If the link was crucial to the living unit, its severance will drastically reduce its life expectancy. Thus, if the worms were the only source of food of the sparrows, the severance of this link will lead to their death within a few days. On the contrary, if the sparrows have many other sources of food, their life will be little affected. In short, the reduction in life expectancy should provide a rough estimate of the strength of the link, as defined in physics. If the normal life expectancy is L and the reduced life expectancy is θ, the ratio $(L-\theta)/L$ will provide an estimate of the interaction strength.

This method is schematized in Fig. 4.1. It shows three cases of broken links. In all three cases the starting point is a situation in which one expects that the living unit has strong links with its neighbors; the links are then severed by isolating one unit. If the life expectancy of the isolated unit is substantially reduced this will confirm that the initial link was indeed strong. The more the life expectancy is reduced, the stronger the link.
But before discussing such cases more closely I would like to mention a few systems in which estimates of interaction strength are available in different forms.

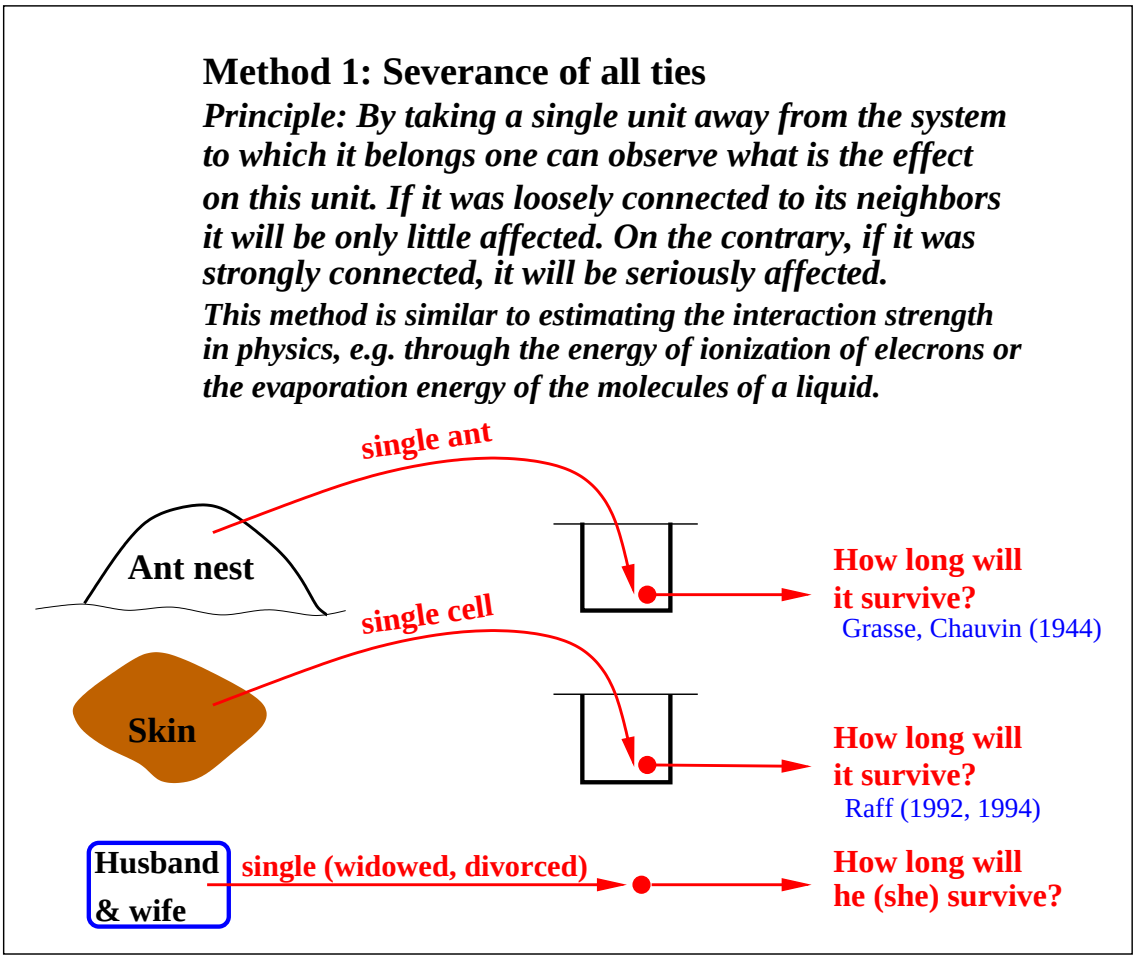


Fig. 4. A first proposal for measuring the interaction strength in biological and social systems.

Characterizations of interactions that are commonly used

Integration of immigrants

The first case is the interaction between a group of immigrants and the rest of the population. This situation is very similar to the mixing of two liquids in physics and it was already mentioned in this connection during previous talks. Can the percentage of mixed marriages be used as an indicator of the interaction between the group of immigrants and the rest of the population? Here are some figures for the percentage of people who married outside their groups in the United States; they are based on data about married couples from the census of 2000 (USATODAY 16 February 2007).

In fact, as we will see now, in their present form these data have little significance as far as the strength of interaction is concerned. An indication of what is wrong can be gained by comparing the data for Whites and American Indians; why is there such a big difference? The figure for Whites is low for the simple reason that White people represent the majority which means that in their daily life they will mostly meet other White people and it is not surprising therefore that they marry mostly White people.

Table 4.1 Percentage of people who married outside their groups.

1) Foreign-born		2) US born (i.e.after second generation)	
Asians	27%	Asian-Americans	55%
Hispanics	8%	Hispanic-Americans	31%
Africans	16%	African-Americans	10%
American Indians	66%	American Indians	58%
Whites	8%	Whites	4%

On the contrary, an immigrant which is alone of his (her) group in a given place will either not get married or marry somebody out of his (her) group. In short, the size of the group plays a key-role. This, by the way, explains why the percentage for African-Americans is also low: the main reason is that this is a large group. It is also for this reason that the percentage for foreign born Asians is so much larger than the percentage of foreign-born Hispanics which is a much larger group.

Thus, in their present form these data cannot be used to estimate the interaction unless we are able to eliminate the size effect. I will not pursue this discussion further, I just wanted to convince you that great care must be exercised before drawing conclusions from such data.

An interesting attempt at using data about mixed marriages for the measurement of social interactions was made by Yuji Aruka and Jürgen Minkes (2006). This kind of methods was subsequently extended in a book edited by Yuji Aruka (2011).

Economic interaction through international trade

The second case is the economic interaction between two countries. Let us assume that there will be a recession in the United States in 2009, that is to say a fall in GDP (Gross Domestic Product) during two successive quarters which is the official American definition of a recession. As a result, imports from China will decrease and this will in turn affect the GDP growth of China. By how much? This is a typical interaction problem.
In principle it seems easy to solve. One can be tempted to make the following argument.

We know that exports represent about 30% of the Chinese GDP and that exports to the United States represent about 20% of all Chinese exports. Thus, exports to the US represent $30\% \times 20\% = 6\%$ of the Chinese GDP[30]. In other words, for $\$10$ of exports to the US, the Chinese GDP is $G = 10/0.06 = \$167$ consisting of $B = \$157$

[30]This reasoning is not really correct, see Appendix A.

for activity not connected to the US and $E_1 = \$10$ of exports to the US. Now we will assume that in 2009 B grows by 10% and that E_1 decreases by 15%. Why did we choose this value for the fall in exports to the United States?
In recent years there were recessions in the United States in the following years (within parenthesis we give the variation of GDP and of the imports of goods, the data are from the Bureau of Economic Analysis):

1974 (-0.5%, -2.8%), 1975 (-0.2%, -13%), 1980 (-0.2%, -6.6%), 1982 (-1.9%, -2.5%), 1991 (-0.2%, -0.1%), 2001 (+0.8%, -3.2%).

These data show two things: (i) that there was hardly any connection between the fall in GDP and the fall in imports. (ii) they also show that the highest drop in imports was 13%. Thus our assumption of a fall of 15% in US imports represents a worst case scenario.

Under such assumptions the 2009 GDP of China would be:

$$(B + 10\%B) + (E_1 - 15\%E_1) = (157 + 16) + (10 - 1.5) = 181.5$$

which represents a growth rate of $(181.5 - 167)/167 = 8.7\%$ instead of 10% in the previous year. This decrease is so small that it can hardly be distinguished from fluctuations of GDP due to various domestic factors.

But you may say: "This crisis is a worldwide crisis". So let us assume that *all* exports will be reduced by 15%. What will be the effect on the GDP of China? By repeating the same calculation, one obtains a 2009 growth rate of 2.4% which represents a fall of 7.6% with respect to the 10% growth in 2008. In short, one would expect the 2009 growth rate in China to be somewhere between 2.4% and 8.7%. Of course, this is a fairly broad interval which makes the prediction of little usefulness for planning purposes. By the way, this forecast supposes that the fall in exports will not be (at least to some extent) offset by a stimulus package of the Chinese government. It also ignores the indirect effect of a drop in exports, that is to say the contraction that occurs by a contagion mechanism (the so-called Keynesian multiplier effect) in the rest of the economy. The question is discussed in more detail in Appendix A.

What should we retain from this example? The trade between two countries A and B gives a mechanical link between them. I use the term "mechanical" to emphasize that in addition there can also be other connections. For instance, foreign direct investment by country A in country B may also be changed by a recession in A. It may be reduced but it may also be increased. In this sense it is not completely "mechanical". Why should it increase? Because investing in B may appear more profitable than investing in A especially if the recession in A lasts several years. As such investments result in the construction of new factories or commercial buildings, they will affect the construction industry almost immediately; in addition they will

affect the output of country B one or two years later when the factories will begin to operate.

Political interaction

The exchange of visits by government officials ensures a political dialog between two countries. However, the interpretation of such data in terms of interaction is not as simple as it was for trade data. True, a complete lack of visits certainly reveals a serious rift between two countries. Thus, the fact that there have been no exchange of official visits between the United States and Cuba since 1960, or between the United States and Iran since 1979 certainly attests to a a deep divide.

Does the fact that a great number of officials from B visit A necessarily imply that B will align its position on those of A? Such a contention can only be demonstrated by empirical studies.

Effect of broken links

We now return to the method proposed at the beginning which consists in breaking the links and observing the effect on the life of the living units under consideration and in particular the decrease in their life expectancy.

Insects

An experiment of this kind was performed on various insects by two French biologists. In successive observations they took away from their respective nests, 1, 2 or 10 insects, put them in conditions similar to those in the nest in terms of food, humidity and so on and watched for how long the insects would survive.
They performed such observations for bees (Apis), two species of ants (Leptothorax and Formica), one species of termites (Reticuliterms) and one species of wasps (Polistes also called paper wasps).
The survival curves are shown on the graph. In order to make the comparison relevant one must take into account the respective life duration of the insects. According to information found on the Internet, the bees and ants have a life expectancy of about 40 days, the termites of 2 years and the wasps of 6 months. The reduction in life expectancy of the isolated insects is 87% for the bees, 40% for the ants, 90% for the termites, 94% for the wasps.

According to our previous argument, the larger the reduction the stronger the interactions in the nest. In this respect it should be noted that some insects (e.g. the soldiers in a nest of termites) cannot feed themselves and therefore must rely for their very survival on the other members of the nest. For such insects it is impossible to provide adequate living conditions in isolation.

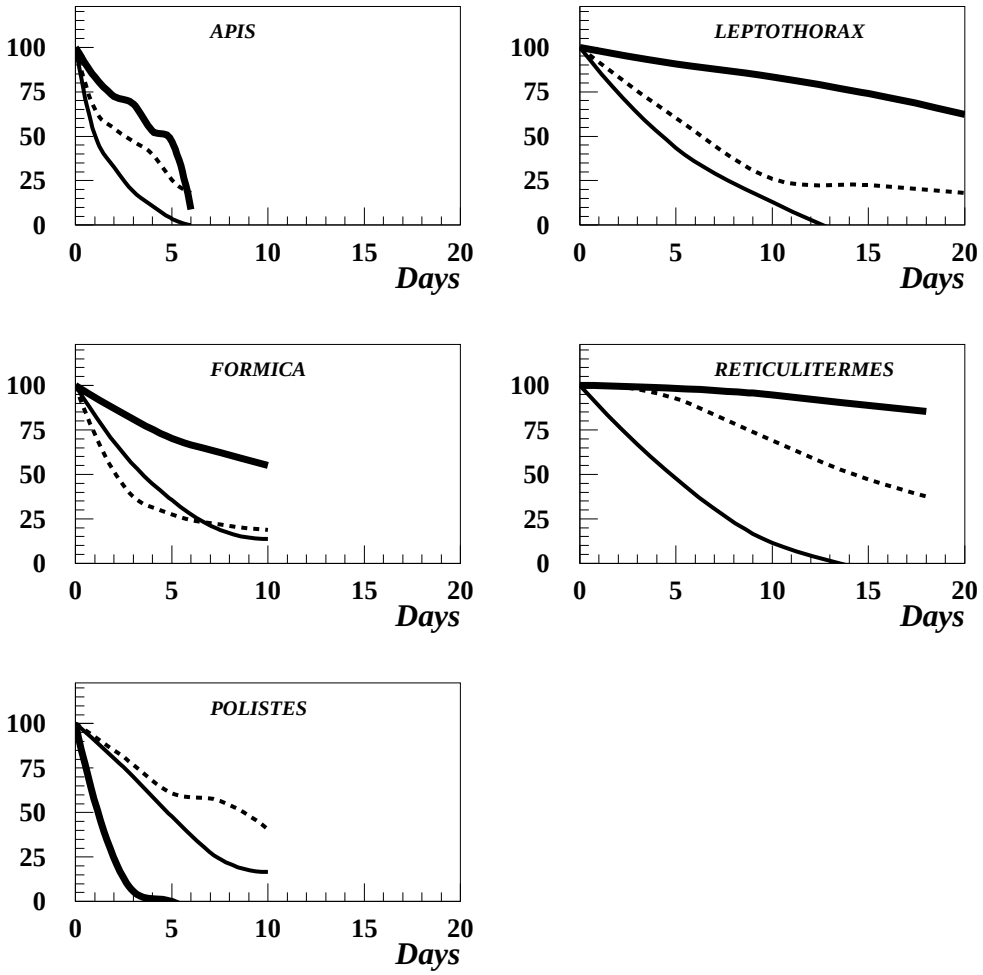


Fig. 4.2 Effect of removing insects from their colony. Several groups of 1, 2 and 10 insects were removed from their nest and kept in isolation. They received plenty of food and were kept in conditions which matched as closely as possible those in the nest. The vertical scale shows the percentage of surviving insects in each group. The thick solid lines represent the single insects, the broken lines represent the groups of two insects and the thick solid line represents the groups of 10 insects. Initiated in 1944 by P. Grassé and R. Chauvin this kind of experiment may provide a methodology for gauging the strength of the interactions in the colony. *Apis* designates a species of bees, *Leptothorax* and *Formica* are two species of ants, *Reticulitermes* are termites and *Polistes* are wasps. The insects in isolation received plenty of food and were kept in conditions which matched as closely as possible those in the nest. *Source: Grassé and Chauvin (1944).*

Married people

The marital bond between married people can be broken by divorce or by the death of one of the partners. Here we will consider this second effect. The graph shows the ratio of the suicide rate of widowed people to the suicide rate of married people. The suicide rate of widowed men is several times larger than for married people. For young widowers the difference is quite striking. Note that there is a similar effect

for death rates (instead of suicide rates); the rates are higher for widowed people but with smaller ratios than for suicide.

According to our previous argument one would infer from these data that the link between husband and wife is strongest in the first years of marriage and becomes weaker in subsequent years.

Escapes from groups

A link with a group or an organization can also be broken by the agents themselves when they decide to leave the organization. The ability of an organization to retain its members can be considered as a estimate of its degree of cohesion. Thus, divorce rates, desertion rates, drop-out rates from school, or turn-over in businesses can provide estimates for the cohesion of these organizations.
Suicide can also be seen as a special form of dropout.

Before ending this brief survey of measurement methods, I would like to draw some conclusions from the previous examples.

Mixing of two groups

Observing the mixing (or non-mixing) of two groups often provides a quick and easy method for estimating the level of interaction. It will tell us if the interaction is gas-like, liquid-like or solid-like. More details will be given in the next lecture.

Measuring the strength of marital bonds

Can we use statistical data about divorce rates in order to estimate the strength of the marital tie between husbands and wives? It can be seen easily that the information provided by divorce data is not sufficient. Indeed, consider a society[31] in which the marriage rate is low; as there are few married couples there will be only few divorces in proportion to the total population (which is the standard definition of the crude divorce rate). A more adequate indicator would be the number of divorces with respect to the number of married couples. Yet such an indicator would still be fairly rough because it does not allow any insight into what happens at different ages. As is well known, the divorce rate is strongly dependent upon the duration of marriage, therefore a parameter which would be able to reflect what happens at different ages would be more significant. In what follows we will be able to define such a parameter.

[31] Such as for instance the Scandinavian countries in the period 1970-1990.

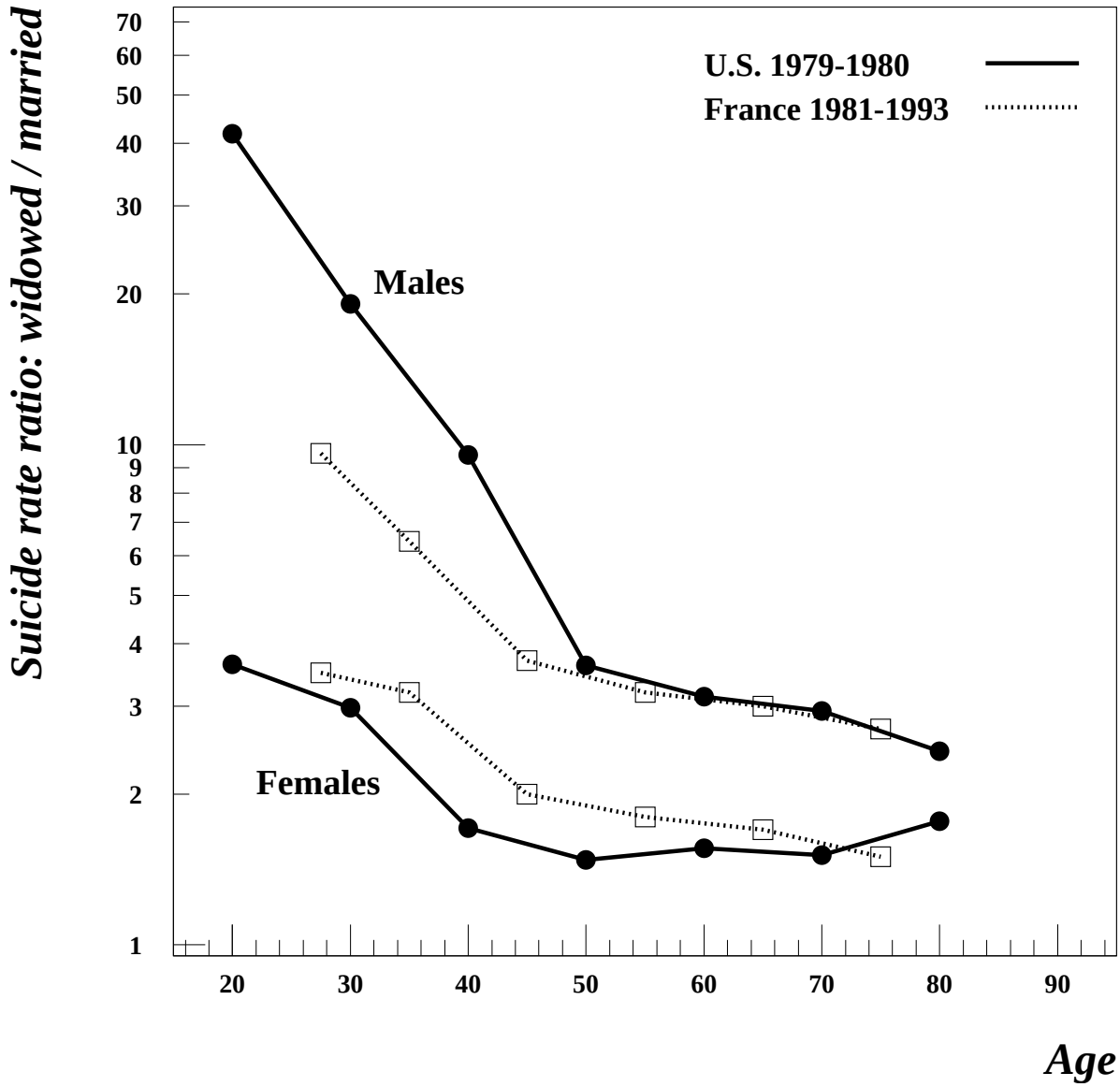


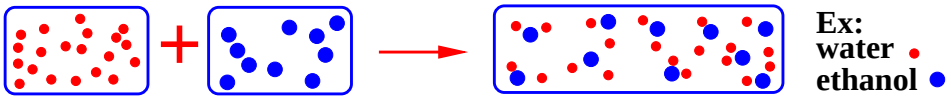
Fig. 4.3 Ratio of suicide rates of widowed and married people. The age groups are 15-24, 25-34, 35-44, etc. in the U.S. and 25-29, 30-39, 40-49, etc. in France. Young widowers have a very high suicide rate, of the order of 1,000 per 100,000. This rate is higher than the rate of married people but it is also higher than the rate of unmarried people. As the number of young widowers is small, the numbers of suicides in the youngest age groups is not large; in the U.S. over 1979-1980 there are 34 suicides in the 15-24 age group and 112 in the 25-34 age group. Consequently, these points have fairly large error bars due to statistical fluctuations. The fact that young widowers have very large suicide rates is confirmed by several studies, e.g. Smith et al. (1988), Luoma and Pearson (2002). *Sources: U.S., suicides: Vital Statistics of the United States, 1979,1980, Vol. II, Part A, p. 323; U.S., population of age groups by marital status: Statistical Abstract of the United States (1981, p. 38); France: Besnard (1997).*

In this section[32] I show how it is possible to estimate fairly accurately both the at-

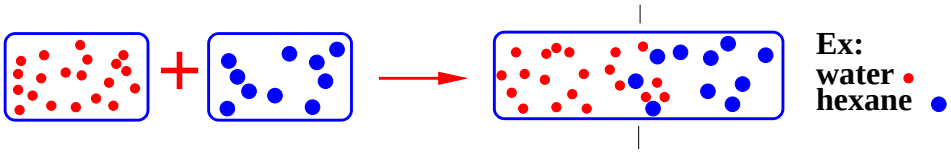
[32]This section was not included in the lecture given on 22 October. It is included here because it provides an illustration of how the previous ideas can be concretely implemented in a specific case.

Method 2: Mixing of two populations

Principle: Systems with strong interactions and cohesion (e.g. two cells) do not mix. On the contrary, systems with weak interactions (e.g. argon + helium) are miscible in all proportions. Thus the degree of miscibility provides an estimate of the interaction strength.
In social systems the degree of miscibility can be estimated, for instance, by the percentage of mixed marriages.



The new red/blue interaction is larger than the loss of interaction in each species



The new red/blue interaction is smaller than the loss of interaction in each species

Fig. 4.4 A second proposal for measuring the interaction strength in biological and social systems.

Method 3: Escape rates

Principle: Intuitively, it is natural to estimate the cohesion of an organization through its ability to retain its members. Thus, the drop−out rate in a school, the desertion rate in an army, the turn−over in a company, the immigration rate in a country provide estimates of the cohesion of these organizations.

The motivation for this approach is strengthened by the fact that in physics it can be verified quantitatively that there is a high correlation between interaction strength in a liquid and the pressure of saturated vapor (that is to say the probability of escape of individual molecules) above the liquid.

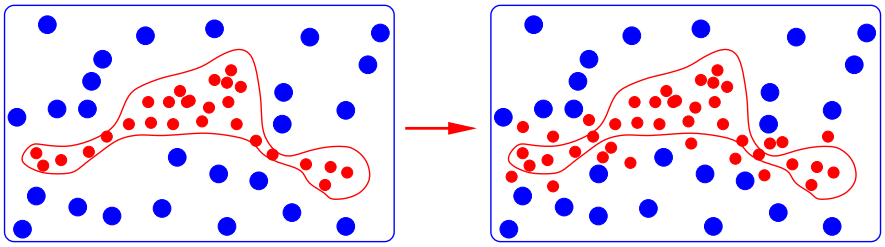


Fig. 4.5 A third proposal for measuring the interaction strength in biological and social systems.

tractiveness of marriage (considered as a specific social state) and the strength of the marital bond by using a systems theory approach which relies on many ideas borrowed from our understanding of the kinetics of chemical reactions.

At the end of the section it will be seen that the same line of reasoning can also be used to characterize other forms of associations, for instance the association between people and nations (citizenship), between people and organizations (members of associations or clubs), or between people and firms (employees of companies or corporations).

Formation of married couples

The formation of married couples can be seen as a reaction of the form:

$$\text{Male + Female} \longleftrightarrow \text{Married couple} \tag{4.1}$$

where the arrow to the right corresponds to marriage and the arrow to the left to divorce and separation[33]. The previous reaction is analogous to a chemical reaction of the form:

$$\text{A+B} \longleftrightarrow \text{AB}$$

In chemistry there are many important reactions which are of this type, for instance the reaction between hydrogen and iodine

$$\mathrm{H_2 + I_2} \underset{\longleftarrow}{\longrightarrow} 2\mathrm{HI}$$

or the Haber process reaction for the synthesis of ammonia (which is of great economic importance)

$$\mathrm{N_2 + 3H_2} \underset{\longleftarrow}{\longrightarrow} 2\mathrm{NH_3}$$

Ideas and concepts of chemical kinetics

Chemists have studied the dynamic of chemical reactions in great detail and it is natural to take inspiration from their findings. What can we learn from them?

- One important idea is to consider the two reactions (forward and backward) separately; this leads to the introduction of *two* different transition constants k_+ and k_-:

$$\text{A+B} \underset{k_-}{\overset{k_+}{\rightleftarrows}} \text{AB}$$

[33]The death of one of the spouses (i.e. widowhood) results in the disappearance due to exogenous factors (accident, illness) of one of the persons; it is therefore a different phenomenon than the disintegration into male + female.

k_+ is the association or binding constant and k_- the dissociation constant. They are defined as [34] :

$$k_+ = \frac{\text{Number of binding events per unit of time}}{[\text{A}][\text{B}]} = \left(\frac{1}{[\text{A}][\text{B}]}\right)\frac{d[\text{AB}]}{dt} \tag{4.2a}$$

$$k_- = \frac{\text{Number of dissociation events per unit of time}}{[\text{AB}]} = \left(\frac{1}{[\text{AB}]}\right)\frac{d[\text{A}]}{dt} \tag{4.2b}$$

- **How can one isolate the forward and backward reactions?** The previous distinction between k_+ and k_- would be fairly useless unless these rate constants can be measured separately. Fortunately, by resorting to adequate experimental conditions these rates can indeed be measured.

For instance, to measure k_+ one must suppress the dissociation reaction. To this aim one will start with a mixture of A and B molecules (without any AB molecules) and remove all AB molecules from the reaction container as soon as they are formed. Under such conditions a measurement of the number of A molecules which disappear will provide an estimate of k_+ that is unaffected by the dissociation process.
Similarly, by starting with only AB molecules and by removing the A molecules as soon as they are formed one can get an estimate of the dissociation rate k_-.

How can we adapt this procedure to the study of marital links? If one adds up all marriages one will count the marriages of bachelors as well as those of people who are divorced or widowed and who get married for a second time. In other words this procedure does not isolate the forward reaction. On the contrary, changes in the number of bachelors will be due only to first marriages[35]. Similarly, in order to isolate the backward reaction one should focus on (first) divorces and separations.

- **Intermediate stages** In chemistry it is often useful to consider intermediate steps; thus the previous reaction can be decomposed into:

$$\text{A+B} \underset{k_-^a}{\overset{k_+^a}{\rightleftharpoons}} (\text{AB}) \underset{k_-^b}{\overset{k_+^b}{\rightleftharpoons}} \text{AB}$$

In the context of chemistry (AB) may designate a collision between A and B which may (or may not) eventually lead to AB. The collisions which indeed lead to AB are called *effective collisions*; thus, the reaction rate may be defined as the number

[34] The main role of $k_+,\ k_-$ is to serve as coefficients in the differential equations which govern the concentration per unit of volume [A], [B] and [AB]. The definitions which follow derive from these equations (see below the equations (4.7a) and (4.8a).

[35] and of course to death but this effect is eliminated by the fact that we normalize these changes by dividing them by the size of age groups.

of effective collisions per unit of time. In the context of marriage, (AB) may be a meeting between a man and a woman that may (or may not) eventually lead to a marriage.

From collision theory, one learns that the collision frequency can be written in the form:

$$\text{Number of collisions per unit of time} \sim \sigma_{\text{AB}} n V$$

where σ_{AB} is the A-B cross-section, a factor which depends on the size and shape of the molecules[36]; n is the number of molecules per unit of volume; V is the relative velocity of the two molecules.
In contrast the transition from (AB) to AB may depend upon more subtle aspects such as the relative orientation of the molecules or their interaction strength.
In short, the previous decomposition separates purely mechanical conditions (those which lead to a collision) from more qualitative factors which define effective collisions. In the context of marriage, the frequency of meetings between men and women is determined by social conditions such as the average "velocity" of people: if everybody stays at home all the time there will be no meeting opportunities whatsoever
The transformation of a meeting into a marriage will depend upon the "compatibility" of the partners in terms of age, language, religion and so on.

Thus, if a population P of size N is composed of two subpopulations R and S (both of size $N/2$) who do not intermarry (e.g. for religious reasons) but mix freely and are not segregated in other aspects of life, then one should observe in P a marriage rate which is one half the rate in a homogeneous (and otherwise similar) population H for the simple reason that all $R - S$ meetings will be ineffective[37].

- **Temperature dependence** In chemistry an important issue is how the speed of reactions changes when temperature is increased. The basic result is that the speed always increases with temperature; in terms of rate constants, this means that they increase with temperature. From physical chemistry we learn that this increase is governed by an equation which is usually called the Arrhenius equation after the name of the Swedish chemist Svante Arrhenius[38]. This equation shows that the temperature dependence of the rate constants is determined by a positive parameter E_a

[36] In the case of two hard spheres of radius r, $\sigma_{\text{AB}} = \pi(r+r)^2 = 4\pi r^2$.

[37] In practice such regularities are not easy to detect because marriage data include a great amount of noise. For instance, it is well known that the marriage rate in Nevada is very high (about 100 per 1,000 residents) because many people come to Las Vegas to get married. A similar effect also exists in other states. Thus in 1950 there were 61,751 marriages in Mississippi but for 61% neither the bride nor the groom were residents of Mississippi. The same observation also applies (albeit to a smaller extent) to Georgia, Idaho, Maryland, South Carolina. One way to overcome this difficulty is to consider changes in the marital state of residents rather numbers of marriages.

[38] Although in its empirical form the equation was first proposed in 1884 by the Dutch chemist Jacobus Van't Hoff.

which is called the activation energy.

Arrhenius equation
$$\ln k = \frac{-E_a}{RT} + A \tag{4.3}$$

where A is a constant term.

It results from equation (4.3) that $k \sim \exp(-E_a/RT)$. The exponential dependence of k can be seen qualitatively. Consider an exothermic reaction characterized by a substantial heat of reaction, i.e. $E_a \gg RT$. For such a reaction when the temperature is raised, say, 10 degrees from $T_1 = 298\ ^\circ$K to $T_2 = 308\ ^\circ$K (i.e. 3.3%) k typically may increase by over 100%.
For instance in the Haber process, $E_a \sim 100$ kJ/mol (E_a is always greater than the heat of reaction which is here equal to 92 kJ/mol), the exponential changes from 2.7×10^{-18} for T_1 to 10.2×10^{-18} for T_2, a change of 270%. In contrast the average velocity of the molecules is increased by a much smaller factor namely $(T_2/T_1)^{1/2} = 1.03$ which shows that it is not the average velocity which is the relevant variable. The factor $\exp(-E_a/RT)$ represents the proportion of the molecules which have an energy greater than E_a. When E_a is substantially larger than the average energy RT, this proportion is fairly small and changes rapidly with temperature.

Equation (4.3) is often used to estimate the activation energy. Thus, when $\ln k$ is plotted as a function of $1/T$ (a graph known as an Arrhenius plot) E_a is the slope of the descending straight line[39].

So far we do not know how to define a notion of temperature for a reaction such as (4.1). However if we could find a set of situations characterized by gradually increasing binding constants, that would help us to identify social parameters which are connected with a kind of "marriage temperature".

Reaction equilibrium

In chemical reactions the concept of equilibrium plays a key role. Equilibrium is reached when the forward reaction is exactly compensated by the backward reaction that is to say when:

$$\text{Number of binding events per unit of time} = \text{Number of dissociation events per unit of time} \tag{4.4a}$$

In terms of the constants k_+ and k_- this will be expressed by the following relation:

$$[\text{A}][\text{B}]k_+ = [\text{AB}]k_- \tag{4.4b}$$

When equilibrium is reached it becomes possible to define an equilibrium constant K:

$$K = \frac{k_+}{k_-} = \frac{[\text{AB}]}{[\text{A}][\text{B}]} \tag{4.4c}$$

[39] In some cases the Arrhenius plot is not a straight line; this means that E_a is not constant but temperature dependent. The nature of the physical mechanism which leads to such a dependence may not be easy to determine.

Needless to say, it is quite possible that in some experimental conditions equilibrium is never reached; for instance if the AB molecules are removed as soon as formed, there will never be an equilibrium. The relations (4.4abc) provide a criterion (expressed in different ways) for determining whether or not equilibrium is reached.

In the case considered here binding events are marriages, dissociation events are divorces + separations. Naturally these numbers must be normalized by the size of age groups, otherwise the data for ages over 60 or 70 would not be comparable with data for younger ages. Once this normalization is done it turns out that condition (4.1a) is approximately realized between the ages of 35 and 60. Under 35, the binding events dominate, between 35 and 60, binding events are approximately in same number as dissociation events, and after 60 binding events dominate again.

The reaction equilibrium constant K is important for at least two reasons.

- The equilibrium constant provides a combined characterization of the attractiveness of marriage (large k_+) and of the strength of the binding provided by marriage (small k_-).
- A formula from physical chemistry gives the behavior of K under temperature changes.

$$\textbf{Van't Hoff equation:} \quad \frac{d\ln K}{dt} = \frac{\Delta H}{RT^2} \qquad ((4.5))$$

where T is the Kelvin temperature, $R = 8.31$ J/ °K is the gas constant and ΔH is the enthalpy change, that is to say (if the contribution $p\Delta v$ due to volume changes can be neglected) the heat which is released (or absorbed) during the reaction. Thus, this equation tells us that if the reaction is exothermic (i.e. $\Delta H < 0$) the equilibrium constant will decrease with temperature, which implies that the backward reaction will be favored. Such is for instance the case in the Haber process ($\Delta H = -92$ kJ/mol). The Van't Hoff equation provides a quantitative statement of the Le Chatelier principle according to which the reaction is shifted in a way which tends to diminish the changing factor. Thus, when temperature is increased in the Haber process, the reverse (endothermic) reaction is favored which tends to decrease the temperature.

Application to marriages in the United States

This section illustrates the notions introduced previously on a real example. The case of the United States has been chosen because detailed census data are available on line.

First we show how the rate constants k_+ and k_- can be determined. The reaction: A+B $\longrightarrow$ AB is a second order reaction. Such a reaction is governed by the following differential equation:

$$\frac{d[\mathrm{AB}]}{dt} = -\frac{d[\mathrm{A}]}{dt} = -\frac{d[\mathrm{B}]}{dt} = k_+[\mathrm{A}][\mathrm{B}] \qquad (4.7a)$$

If we assume that initially $[\mathrm{A}]_0 = [\mathrm{B}]_0$ this equality will hold at all times because [A] and [B] are governed by the same differential equation. Thus the differential equation simplifies to[40]:

$$\frac{dx}{dt} = -k_+ x^2; \quad x = [\mathrm{A}]$$

By integrating this differential equation one obtains:

$$\frac{1}{x} - \frac{1}{x_0} = k_+ t$$

or after rearrangement:

$$[\mathrm{A}](t) = \frac{[\mathrm{A}]_0}{1 + [\mathrm{A}]_0 kt} \tag{4.7b}$$

Fig. 4.6 shows that this equation describes reasonably well the marriage of single males (naturally there is a similar result for females). On the contrary, if we try to describe this process as a first order equation which is governed by an exponential decay it is not possible to find a rate constant which describes all ages (thin blue solid line in Fig. 4.6).

The fact that the data points are above the theoretical curve after the age of 50 suggests that the rate constant in fact decreases for persons over 50. This can indeed be confirmed by plotting the rate constant k_+ as a function of age (Fig. 4.8).

The reverse reaction AB $\longrightarrow$ A + B is a first order reaction because only one AB molecule is needed to bring about the reaction. For such a reaction the concentration is ruled by the equation:

$$\frac{d[\mathrm{A}]}{dt} = k_-[\mathrm{A}] \tag{4.8a}$$

whose solution is:

$$[\mathrm{A}](t) = [\mathrm{A}]_0 \exp(-k_- t) \tag{4.8b}$$

Fig. 4.7 shows that this equation describes reasonably well the dissociation process. Actually the constant k_- is so small that (4.9) coincides with a solution of the form defined by (4.7). Indeed, it can readily be seen that the two expressions become identical when developed to first order in $k_- t$.

The fact that the data points are above the theoretical curve after the age of 50 reveals that the rate constant is smaller for persons over 50. This can indeed be confirmed by plotting the number of first marriages per single male and single female as a function of age (Fig. 4.8). Similarly, the fact that in Fig. 4.7 the data points are above the

[40] The condition $[\mathrm{A}]_0 = [\mathrm{B}]_0$ is approximately verified in the case of males and females. Without this condition one must define a variable $x = [\mathrm{A}]_0 - [\mathrm{A}] = [\mathrm{B}]_0 - [\mathrm{B}]$ and in term of x the differential equation becomes:

$$\frac{dx}{dt} = k_+ \left([\mathrm{A}]_0 - x\right)\left([\mathrm{B}]_0 - x\right)$$

The solution has a slightly more complicated form.

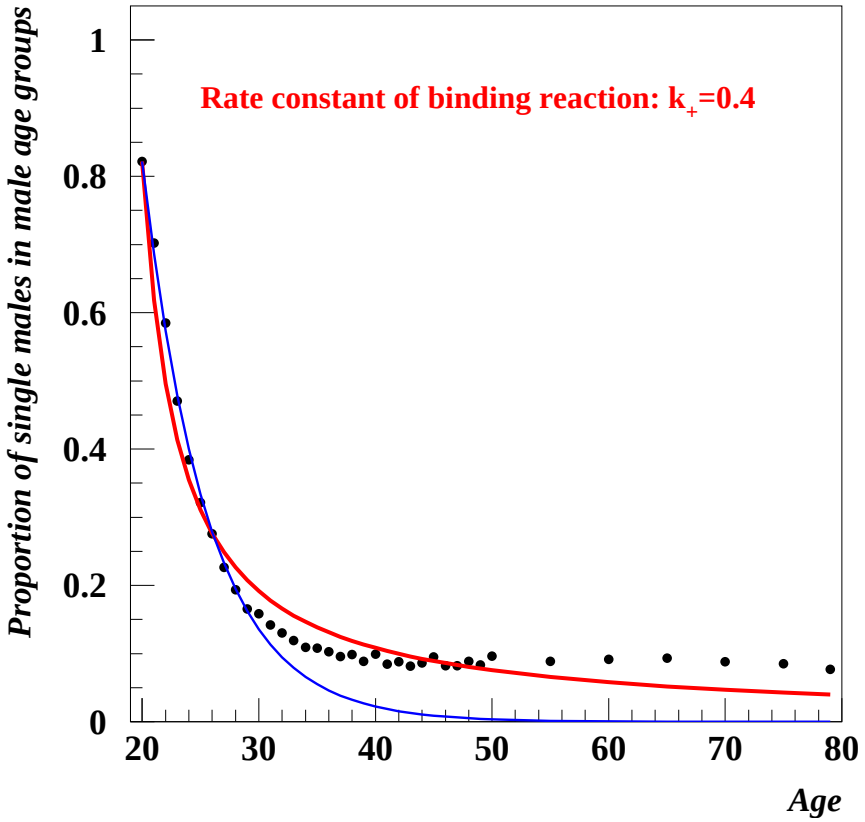


Fig. 4.6 Interpretation of (first) marriages as a second order reaction. The black dots give for each age group the proportion of bachelors with respect to the total population of the male age group; in the parallel with the reaction M+F $\longrightarrow$ MF, this is the variable denoted as M(t). The solid line shows the evolution in the course of time of M(t) when k_+ is supposed constant. The lower line (in blue) shows an exponential decrease for the purpose of comparison.
It should be noted that the exponential fit can be much improved if we assume that a proportion of the bachelors will never marry. This would correspond to a function: of the form [A]$(t) = \exp(-kt) + C$; however it is not obvious how this kernel of non-marriageable bachelors can be defined in an objective way. I'm most grateful to my colleague Didier Sornette for bringing this point to my attention.
The data come from a table for 1950 giving the distribution of the population by age groups of single years of age. In principle, rather than using a population pyramid one should follow a single cohort in the course of time. However, the age-group procedure has the advantage of being simpler to implement. Of course, it remains to show that the two procedures are indeed equivalent. *Source: Census 1950, Volume IV, Part II, Section 6, Special Reports: Family, p. 2D-41*

theoretical curve over the age of 50 suggests that the dissociation rate is smaller for persons over 50.
Next it can be checked that the equilibrium conditions (4.4b) and (4.4c) are fulfilled between the ages of 35 and 60. This equilibrium property provides an additional argument in favor of a parallel with a chemical reaction.

Other social phenomena which can be described as reactions

Marriages are not the only social phenomenon which can be described as chemical

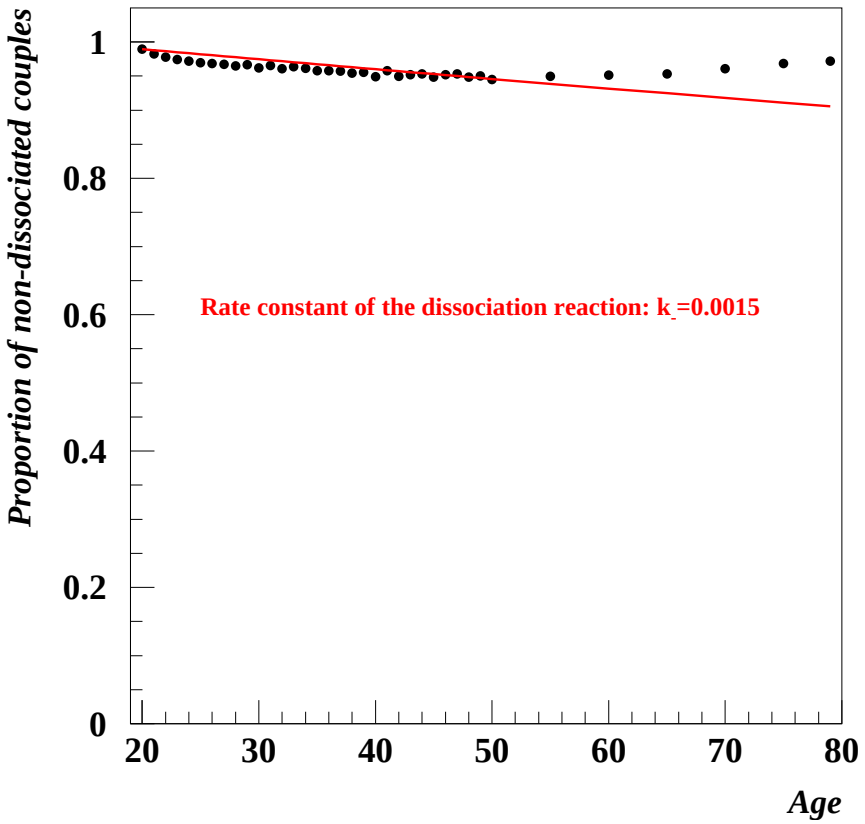


Fig. 4.7 Interpretation of dissociation (divorces and separations) as a first order reaction. The black dots give for each age group the proportion of the males who are divorced or separated with respect to the total population of the male age group. The solid line shows the evolution in the course of time of the number of MF "molecules" under a reaction of the form: MF $\longrightarrow$ M+F, where MF represents a married couple. It can be noted that if the same graph is drawn for African-American people, it is found that k_- is substantially smaller; this comes especially from a higher percentage of separations (it is about 10% of the age group at the age of 40 as compared to 3% for the whole population. *Source: Census 1950, Volume IV, Part II, Section 6, Special Reports: Family, p. 2D-41*

reactions.

As a specific example we can consider a university in which an orchestra is created which will be open to staff members who are able to play music. The transition through which a person becomes a member of the orchestra can be described as a reaction of the form:

$$\mathrm{A} \underset{k_2}{\overset{k_1}{\rightleftharpoons}} \mathrm{B}$$

where k_1 denotes a rate constant which describes the action of joining the orchestra and k_2 the action of leaving the orchestra. If the process starts with $B = 0$ the membership will increase and at the same time the pool of musicians who are not members will shrink. After a while B will become greater than A but the flow

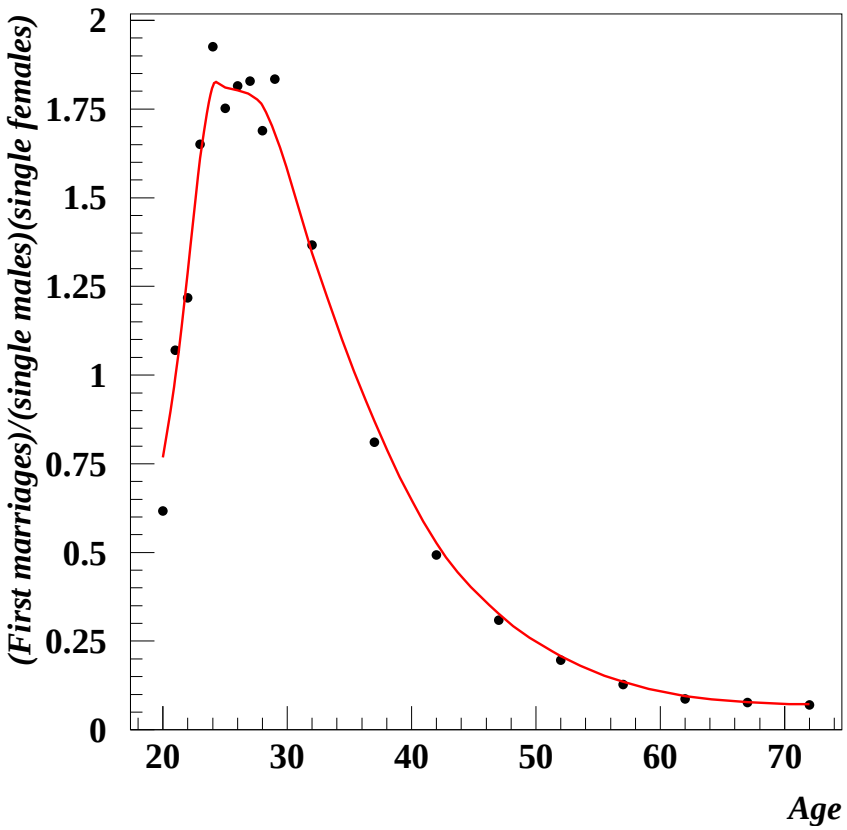


Fig. 4.8 Variation with respect to age of the rate constant for first marriages. The black dots give for each age group the rate constant for the reaction: M+F $\longrightarrow$ MF whose expression is: $k_+ =$ (Number of first marriages)/[(Number of single males)(Number of single females)]. After the age of of 30, k_+ decreases rapidly. The present graph explains the discrepancies between the theoretical curve and the data in Fig. 4.6. It can be noted that the order of magnitude of k_+ has little significance because it depends upon the size of the population: when the population is multiplied by 10, k_+ is divided by 10. *Sources: Census 1950, Volume IV, Part II, Section 6, Special Reports: Family, p. 2D-51; Vital Statistics of the United States 1953, Part 1, Table 3, p. 51.*

of people who leave the orchestra will grow simultaneously until an equilibrium is reached. The equilibrium state will tells us something about the attractiveness of the orchestra and the strength of the links which hold its members together.

- $k_1 \gg k_2$ means that the orchestra attracts many people and develops strong links between them.
- $k_1 \ll k_2$ means that the orchestra has a low potential of attraction and develops only weak links between its members.
- $k_1 \simeq k_2$ means that the orchestra has a good potential of attraction but is not able to develop the strong links that would enable it to retain its members.

This discussion shows that the strength of the links within the orchestra are described by the constant k_2. This is true here because the state A (i.e. not belonging to the orchestra) is a kind of neutral state. If state A has a specific attractiveness in its

own way (for instance if the persons who do not belong to the orchestra can attend theater representations on the evenings on which the orchestra has its rehearsals) then k_2 would reflect a balance between the attractiveness of the orchestra and the attractiveness of the alternative activity. In such a case k_2 would not simply reflect the interaction between orchestra members but rather the competition between the two activities.

For the sake of simplicity, let us assume that the state A is indeed neutral so that the interactions between orchestra members are indeed determined by k_2; then the main issue is: how can we estimate k_2? In the case of marriages we were able to estimate k_- from the number of dissociations (divorces and separations); similarly k_2 can be estimated from the rate at which people leave the orchestra because this rate is governed only by the constant k_2:

$$\text{Number of people who leave} = B(0)\exp(-k_2 t)$$

k_2 is what we called earlier a dropout rate; we already pointed out that dropout rates can be seen as providing estimates for the interaction strength within an organization. In contrast, A and B are ruled by equations[41] which contain *both* k_1 and k_2; thus if we know only the size of the orchestra in the course of time (i.e. $B(t)$) it is much more difficult to determine k_2.

Conclusions

The most striking fact in the previous survey is the lack of a common framework. We have estimated the strength of interaction through the volume of trade, or through the decrease in the life expectancy of agents who are separated from their respective organizations, or through dropout or desertion rates. In still other cases we used inter-marriage rates to estimate the affinity between two groups. The variety of these indicators is in sharp contrast with the unified framework used in physics. It is clear that in order to make comparisons it would be useful to also have a unified framework in the social sciences.

Yet, it must also be realized that different indicators may be necessary for interactions of very different strength. For instance, teenagers who drop out of school probably do not have death or suicide rates substantially higher than those who do not drop-out. In short, escape rates seem to be a more sensitive indicator than decreases in life expectancy. Unfortunately, few data are available for escape rates and those who

[41] Namely:

$$A(t) = (A_0 - A_e)\exp[-(k_1 + k_2)t] + A_e$$
$$B(t) = (B_0 - B_e)\exp[-(k_1 + k_2)t] + B_e$$

where A_0, B_0 denote the initial populations and A_e, B_e the populations at equilibrium.

are available may not necessarily be reliable (e.g. in time of war desertion data are subject to censorship)

What makes interaction strength data important in physics is the fact that they explain not only one but *many* different physical phenomena, e.g. boiling temperature, heat of vaporization, pressure of vapor above a liquid, viscosity, etc. In the social sciences can we also think of *various* variables and phenomena which may be explained by interaction strength? Apart from reductions in life expectancy due to a separation and dropout rates that we already mentioned, there are other data which may possibly be explained in terms of interaction strength; one can mention:

- The ability of a group to mix with another group
- The ability of a group to withstand external shocks without losing its cohesion.

It is by bringing all such data together that one will be able to prove the key-role of interaction strengths.

Appendix A: Further discussion of economic interaction

This Appendix provides precisions on three points:
(i) Firstly, I come back to the calculation proposed earlier for the impact of changes in exports. I point out that in its principle it is not really correct even though the more rigorous argument is difficult to implement due to a lack of adequate data.
(ii) Secondly, I briefly discuss how our prediction is changed when one includes indirect effects and government intervention in the form of a stimulation package.
(iii) Thirdly, I describe the effect of a specific factor namely the impact of importing cheap labor on the average level of wages in the United States.

Impact of export changes on GDP

Basically, I derived this impact from the fact that Chinese exports represent about 30% of the GDP of China.
What makes this argument incorrect is the fact that exports and GDP are two quantities of a different nature. As we know, exports sum up the prices of everything which goes through customs whereas GDP sums up incomes of individuals and companies that are generated in the course of production.

As an example, one may consider the manufacturing of computers in China. The problem comes from the fact that a computer which is exported from China may contain parts which have been built elsewhere for instance in Taiwan.
Let’s assume that the price of the computer is 100 of which 40 represents the price of the parts manufactured in Taiwan. Thus, only 60 will go to Chinese companies. In other words, each exported computer will increase Chinese exports by 100 but will

increase Chinese GDP only by 60.

By not making this distinction, I overestimated the impact of a reduction in exports on Chinese GDP. However, in order to make more precise estimates one would need to know which part (on average) of the price of exported products really contributes to the Chinese GDP.

In conclusion, the figures that I gave provide upper bounds which may nevertheless be useful until more detailed data become available.

Taking into account multiplier effects

The main question seems to be: "Will the 4 trillion yuan injected in the economy by the Chinese government in November 2008 be sufficient to offset the fall in exports and in real estate activity?".
One can propose the following rough calculation.

- Let us assume that the (positive) multiplier of this injection and the (negative) multiplier of the contraction have the same (absolute) values.
- Let us assume that the fall in exports will be about 20% in 2009, a figure which is based on the 2% monthly fall that occurred between September and October 2008.
- Let us assume that the real estate sector (residential construction + marketing) is about 10% of GDP; this figure is based on data provided by the following website: http://www.ier.hit-u.ac.jp/COE/Japanese/online_data/china/tablea8.htm

Let us further assume that this sector comes to a complete standstill that is to say that its contribution to GDP vanishes. Although this may seem a fairly drastic assumption it has two advantages. The first is its simplicity in the absence of more precise data. The second is the fact that it may cover the effect of bankruptcies of construction and real estate companies[42].

With these assumptions one gets the following negative amounts (in billions of dollars):
Chinese exports in 2007 were 1218; -20% $\longrightarrow$ -243
Chinese GDP in 2007 was 3430; -10% $\longrightarrow$ -343
Total: -586

The injection was so far (that is to say until the end of 2008) 4,000 bn yuan that is approximately $ 400 bn In other words the injection covers about 70% of the negative amounts which means that it should be almost sufficient to offset the negative impact. In addition there can be a second injection in a few months if the situation deteriorates further.

[42]This is an important point which was brought to my attention by Prof. Zhangang Han. The argument is that when a company stops its activity, it is true that it does no longer contribute to the growth of GDP but in reality the closure results in a *destruction* of national wealth for instance through the dismantling of production machinery which in a sense should be represented by a negative change in GDP.

In conclusion it seems that the Chinese economy should weather the storm unless there are unexpected events (for instance social unrest and disruption).

Effect of a recession on foreign trade

The previous calculation relies in a critical way on the figure of -20% that we accepted for the fall in Chinese exports. Suppose for a moment that instead the fall is as high as 75% (that is to say a division by 4), then the negative amounts become $-913 - 343 = -1256$, in other words there is now a sizable gap between the drop and the injection. Thus, it is highly important to estimate correctly the fall in foreign trade.

The mechanism under consideration can be represented by the following diagram.

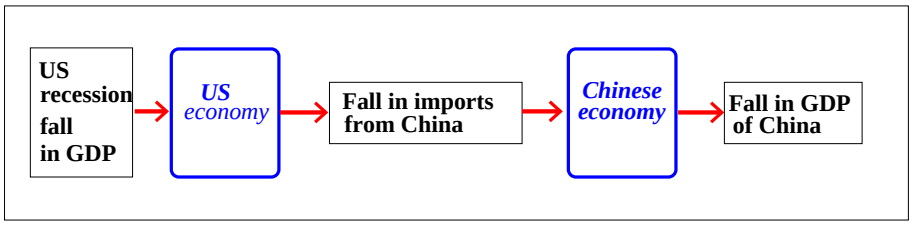


Fig. 4.? Transmission of a recession from one country to another In this mechanism the main unknowns are the response functions of the two economies. They can be determined by analyzing former episodes either for the same countries or, if there are not enough episodes available, for other (fairly similar) countries.

The two blue boxes represent the US and Chinese economies. We want to know the relationship between the intensity of a recession and the magnitude of the fall in US imports and more specifically imports from China.

The main practical difficulty is the following. There have been many small recessions but only few important ones. The effect of a small recession (say with a contraction of GDP of less than 3%) on imports may be too small to be observable because it will be smaller than the background noise that is to say the fluctuations of imports that can be observed even in normal times. In other words small recessions probably have some effect on the level of imports from China but this effect cannot be observed. This distinction between effects which are known to exist on the basis of theoretical arguments but are too small to be observable and those which are clearly observable is not often made by economists.

In order to get clear-cut results we must consider *major* recessions such as the depressions of 1873-1879 (unemployment reached about 20%) or of 1929-1933 (unemployment reached 30%). Of course in such periods it does not make sense to consider imports from China because this country was in a very different situation. As a substitute we can consider imports from Britain, Germany or Japan in the hope that these cases may give at least a rough estimate of what should be expected for imports from China.

Effect of importing cheap labor

Basically exchange of manpower means "importing" immigrants from countries where salaries are low into countries where salaries are higher. This phenomenon is by no means special to the United States (whose case is illustrated by Fig. 7.3 that we will comment in a moment), it is observed in almost all industrialized countries with the notable exception of Japan. If there is a difference, it is only in terms of timing in the implementation of this neo-liberal agenda in the sense that the US and UK were among the first countries to start such policies.
It should be noted that the substitution of cheap foreign labor to more expensive domestic labor also concerns sectors, such as health care, in which international economic competition does not play any role. However, domestic competition ensures that once such a process has been started, all hospitals have to follow suit. In the 1930s it was the same for child labor in US cotton fields in the sense that the employers who did not use it were at a disadvantage. It is only by a federal law that it could be suppressed because it put all employers on an equal footing.

Let us give a closer look at the health care sector. Because medical doctors who work in emergency care services of hospitals have a difficult job which is not well remunerated, such positions have more and more been filled with doctors from emerging countries[43]. Similarly, it is well known that nurses from the Philippines are recruited by American hospitals. The financial support that they send back to their families improves the balance of payments of the Philippines but it is not certain that this short term benefit is sufficient to compensate for the drain on precious human resources. The fact that the operation offers a short-term advantage to all concerned parties (the nurses themselves, the Filipino government, the US employers, the US government) explains its rapid development in recent years.

In a general way such transfers of workforce have three consequences.

(1) They depress wages in the countries which receive the immigrants. Indeed, like all commodities, labor is ruled by the law of supply and demand. The arrival of immigrants increases the supply and thus reduces the price of labor. An illustration is provided in the case of the United States by the graph in Fig. 7.3. From around 1975 up to present time the US "imported" big amounts of cheap labor mostly from Latin America, the Philippines and Vietnam. As a result American wages reached a peak level around 1975 and have been decreasing ever since.

(2) Over-supply of cheap labor undermines the bargaining power of the unions. Needless to say, if labor is plentiful unions are in a weak position in bargaining with management. The effect can be seen in the fact that after 1975 the number of strikes

[43] Such a transfer of highly educated people is of course detrimental (at least in the long-run) to the welfare and economic development of the countries from which they come.

fell in a dramatic way.

(3) Moreover the inflow of labor is not a purely economic phenomena. Indeed, by affecting social interactions the arrival of a great number of foreign workers erodes social cohesion at least until they are better integrated, a process which may take one or two generations.

Lecture 5
Experiments for measuring interaction strength

Lecture given at Beijing Normal University, Department of Systems Science, on 29 October 2008, 14:00.

I will devote the present lecture to two aspects that I have little discussed so far, namely: (i) How to use the mixing-criterion? (ii) How to carry out micro-social experiments?

How to use the mixing criterion

As has already been explained, this criterion allows a rough (but quick) classification of social systems into three categories:

- Systems which are miscible will be called gas-like systems; they have weak interactions.
- Systems which are not miscible will be called solid-like systems; they have strong interactions.
- Systems which are partially miscible will be called liquid-like systems; they have medium strength interactions.

In order to show how this criterion works, let us try to answer the following questions:
(i) To which category belong married couples?
(ii) To which category belong groups of people who speak the same language. The examples of British immigrants in the United States or Australia or of French people in Quebec (the French-speaking province of Canada) suggests that the integration of group into countries where the same language is spoken is fairly rapid.
(iii) The situation is completely different if we consider groups of people who speak a different language than the main language of the country where they have settled. In this case the integration is much slower. An illustration is provided by the example of the Amish in the United States. This is a group of German immigrants (belonging to a specific protestant confession) who settled in the state of Pennsylvania in the second half of the 19th century. Although they can speak English most of them have a heavy German accent because German is still widely used in their community. The

net result is that the Amish remain a group which is still poorly integrated in the American society.
A similar example would be the Hispanic community in Los Angeles or the Russian-speaking community in Ukraine.

How to carry out micro-social experiments

Milgram's methodology

The experiments carried out by the American psycho-sociologist Stanley Milgram (1933-1984) have the specific feature that the people who took part did not know that they were participating in an experiment in socio-psychology. This is obvious for the people who took part in the lost letter experiments [44] because they were not paid and had no contact with the researchers. But it is also true for the obedience experiment that will be described here. In this case participants were paid and told that they were taking part in a scientific experiment but they were not told the truth about their participation which means that their reactions can be labeled as being fairly genuine. They reacted as if in real life situations. This makes of course a big difference with experiments in which nothing is at stake except perhaps the small amount of money that participants can earn in the game.

Description of the obedience experiment

Carried out in the early 1960s, the obedience experiments raised great interest in the general public because they seemed to "explain" the obedience attitudes that had been observed in Nazi concentration camps. However, this interpretation does not do justice to the deep significance of Milgram's experiments. In fact, he has shown that the weaker the interaction between two persons, the easier it is for one to harm the other. Through his experiments Milgram was able to give to this proposition a precise quantitative meaning. To understand how he formulated this result we need to know more about the experimental procedure.

The experiments involved three individuals:

(1) The experimenter E who was, so to say, the supervisor
(2) The instructor I
(3) The subject S

Both the supervisor and the subject were members of the experiment team whereas

[44] As an illustration consider the following experiment which was performed in Hong Kong in order to assess the feelings of the residents with respect to the People's Republic of China. Many envelopes bearing the address of a (fictitious) association promoting friendship with the PRC were left (as if as lost or forgotten) in many places such as street cars, waiting rooms, benches in public parks. The percentage of letters which reached their destination (instead of being thrown away) was taken as an indicator of the people's sympathy for the PRC.

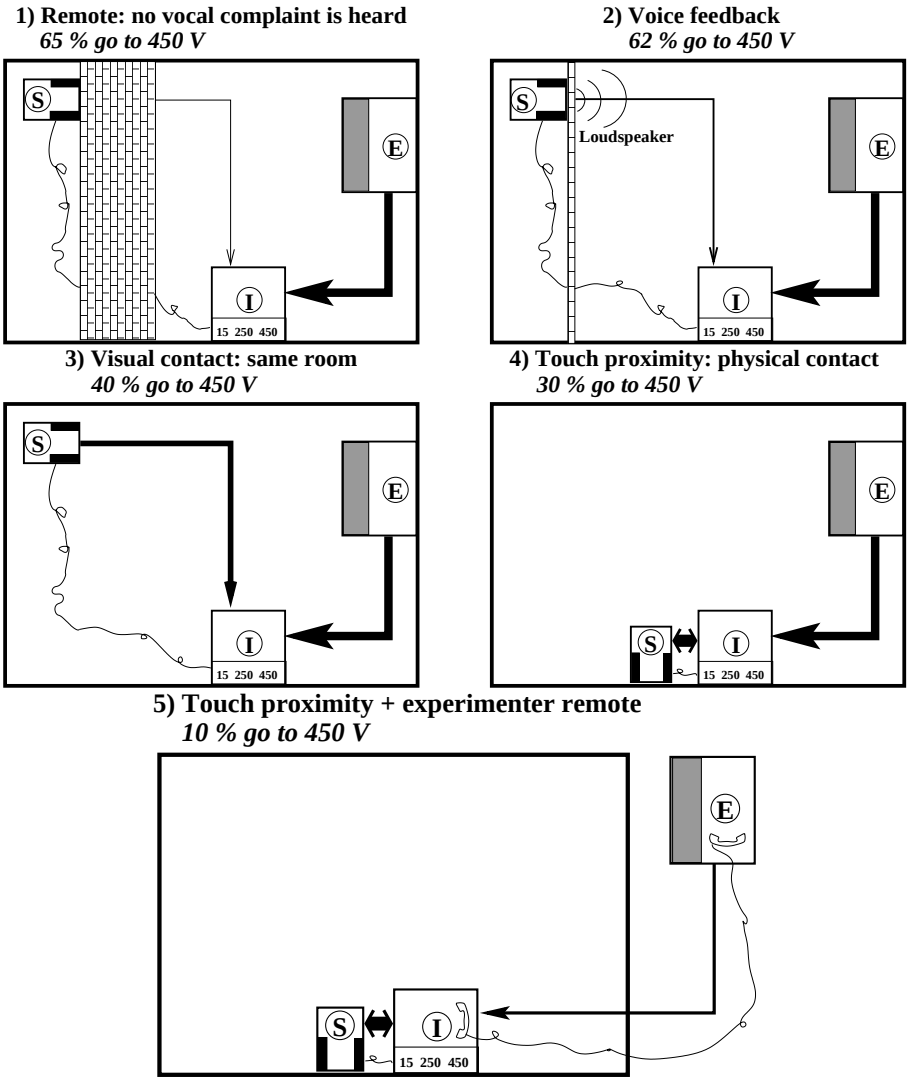


Fig. 5.1 Milgram's obedience experiment The figure shows different settings of the experiment which feature increasing interaction between the instructor (who inflicts the electrical shocks) and the subject (who receives the shocks when his answers are incorrect). *Milgram (1974)*

the instructor had been recruited through a newspaper advertisement and was paid an hourly wage of $ 4.50. At the beginning the supervisor explains to the instructor that the experiment is a scientific study about the role of punishment in learning. The instructor asks a number of questions and if the answer of the subject is incorrect, he delivers him an electrical shock. The generator has 30 switches in 15 volt increments ranging from 15 up to 450 volts. The instructor is supposed to increase the voltage each time a wrong answer is given. In fact, there are no electrical shocks; the subject is an actor who, although never actually harmed, shows increasing manifestations of pain as the voltage is increased.

Just to show how dramatic the situation became at some moments I give below an example of a dialog between the three participants. This dialog is reproduced in the report that Milgram has given of this experiment in 1974. It occurs after a shock of

190 volt had been delivered.
S (yelling, i.e. shouting): Let me out here. My heart is bothering me.
E: The shocks may be painful but they are not dangerous. Continue please.
I: You see he is hollering (i.e. shouting). No Sir, I'm not going to kill that man.
E: The experiment requires that you go on.
S: I absolutely refuse to answer anymore. Get me out.
E: If the subject does not answer in a reasonable time, about 4 or 5 seconds, consider the answer wrong. Continue, please.

This excerpt shows the great involvement of the instructor. It would be difficult to reach that level of involvement in an experiment in which people are told the truth about their role. If the instructor knows that the subject is an actor and that in fact he does not feel any pain the experiment would lose all its significance.

The experiment has been repeated in five different settings with respect to the closeness between the instructor and the subject (Milgram 1974).

(1) In the "remote" setting, the subject is in another room and no vocal complaint is heard from him. However, at 300 volts, the laboratory walls resound as if pounded by S. After 315 volts the pounding ceases and no further answers are given by S (situation 1).

(2) In the "voice feedback" setting, S is again in an adjacent room but his complaints can be heard by the teacher (situation 2).

(3) In this setting S is in the same room as the instructor which gives the possibility of visual contact (situation 3).

(4) In this situation the subject and the instructor sit side by side. At the 150 volt level, the subject refuses to place his hands on the shock plates (schematized by the black rectangles, situation 4). The experimenter then orders the instructor to force the subject's hand on the plate. In this way, the experiment leads to a physical contact between the instructor and the subject.

(5) This setting is similar to the previous one except that the supervisor is no longer in the same room and gives his instructions by telephone (situation 5).

Results

The graph shows that the percentage of people who accepted to carry the experiment to its termination (i.e. 450 volts) decreases when the "proximity" between the instructor and the subject increases.

As often in the social sciences the main problem is to minimize the "noise". In this respect one must recall that the same instructor could not be used twice for after the experiment he (or she) was told about the real meaning of the experiment. As different instructors do not have the same reactions, the experiment must be repeated

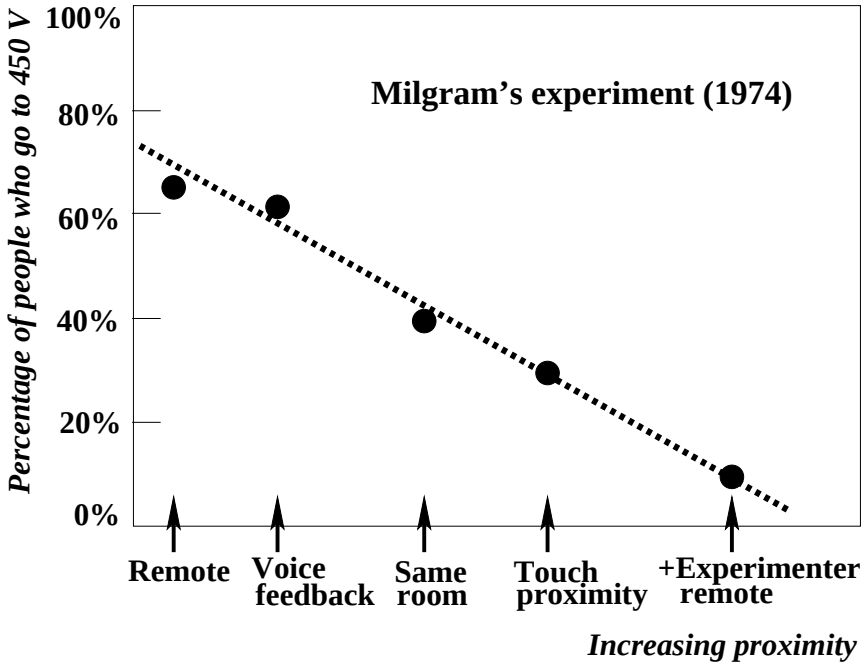


Fig. 5.2 Percentage of instructors who inflicted 450 V shocks. The 5 data points correspond to the 5 experimental settings described in the previous figure. Each percentage is an average over a set of 40 experiments carried out with 40 different instructors which means that 200 experiments were performed altogether. Expressed in words, the main result is that the capability of I to inflict harsh treatment on S decreases when the strength of the $I--S$ interaction increases. *Milgram (1974)*

several times so that these differences cancel out on average. Milgram indicates that 40 adults were studied in each of the settings. This means that (at least) $5 \times 40 = 200$ experiments were carried out. If each experiment took about 3 hours (one hour for the experiment itself, one hour for the debriefing of the instructor and one hour to record the results) this represents about 30 weeks of experiments. At that time Milgram was an assistant professor at Yale; it is remarkable that he got the funding to carry out such an ambitious project.

It is because it is based on a large sample of experiments that the graph is not completely obscured by variability and noise. If there had been only 5 experiments in each situation, the noise due to individual variations, would be too large to show any definite pattern.

There is one point which remains somewhat unclear, namely the exact signification of the horizontal scale in the graph. In his book of 1974, Milgram labels this axis as showing "increasing proximity". But how should the term "proximity" be understood exactly? The simplest interpretation would be spatial proximity. It is true that between situations 1 and 4 the distance between the instructor and the subject decreases, but this is clearly not the main factor. The real difference is the fact that the interaction becomes stronger because it is channeled through more and more means of communication:

(i) almost no audio contact
(ii) audio contact
(iii) audio and visual contact
(iv) audio, visual and physical contact.

Implications and applications

The fact that this experiment is able to record the reactions that people have in real life (as opposed to simulations in virtual worlds) is attested by the fact that its results are used in the training of US Marines. It has been observed repeatedly that in the mind of people there is a strong resistance against killing other persons. For instance soldiers do not fire even when under attack or they fire over the heads of their enemies. This resistance is in line with what is observed in other species: for instance tigers do not kill other tigers (yet, ants are known to kill ants of the same species). In short, soldiers must be trained to overcome this resistance.
This can be done in several ways, but one of the techniques is clearly based on results of the Milgram experiment as attested by the following excerpt (website of Lt. Col. Dave Grossman: http://www.killology.org).

> While physical distance is achieved with bombs, rocket launchers and even night-vision goggles, which reduce humans to ghostly green silhouettes, emotional distance often is achieved by categorizing targets as different because of their race, ethnicity or religion. The military does whatever it can to deny any humanity of enemy soldiers.

Asch's experiments on social conformity

In the experiments conducted by Solomon Asch in the 1950s students were asked to participate in a vision test. In reality, all but one of the participants were confederates of the experimenter, and the study was really about how the remaining student would react to the confederates' behavior. Asch describes his main result in the following way: "We have found the tendency to conformity in our society so strong that reasonably intelligent and well-meaning young people are willing to call white black". This result has became known as Asch's conformity paradigm.

More specifically, the experiments lead to the following observations (Asch 1955).

- When the subject was confronted with false answers of more than 5 confederates its rate of error increased from nearly 0% to about 35%. With only 2 confederates the error rate was 15%, with 3 it was 30%, with 5 it was 35% and it remained at that level even when the number of confederates was increased to up to 15.
- When there was at least one "dissenter" among the confederates the error rate of the subject was only 10%. This result did not depend on whether or not the dissenter

gave the right answer. In other words, what mattered was merely the existence of a dissenter.

- In a few cases [45] the subject suspected that there was a collusion between the other participants. In those cases the game was stopped and the results not counted. As a consequence of this methodological choice the end results over-estimate the level of conformity.

There were three major differences with Milgram's experiments.
(i) In Asch's experiment nothing was really at stake for the subject. It would be interesting to see how the results are changed when the subjects are remunerated on the basis of the number of their right answers.
(ii) Milgram's experiment investigated the interaction between 3 agents and it is in this way that its results were presented. In contrast, Asch's experiment was presented as an investigation of "social pressure" (this expression is used in the title of his article of 1955) but a group of 15 persons is only a fairly remote model of a society[46]. It would be more correct to see this experiment as describing what can happen in other small groups such as the board of directors of a corporation or cabinet meetings of ministers.
(iii) Asch carried out less experiments than Milgram. He used only 123 subjects as compared to over 200 for Milgram.

Apparently, Solomon Asch had few (if any) followers. This fact again illustrates the great difference between experiments in physics and psychology. In physics all major experiments are "repeated" [47] by many researchers in various countries in order to check their validity and improve their accuracy. In the present case it would have been very interesting to check whether or not the conformity effect is culture dependent.

Stanley Milgram showed convincingly that it is possible to carry out *real* experiments in socio-psychology where the term "real" is meant to stress the contrast with class-room experiments whose conditions are most often fairly different from those of real life. Unfortunately the example that he set was not followed by many researchers. In contrast there is a technique which is used very frequently by social researchers namely investigations based on surveys. In this respect one should probably make a difference between fact finding surveys and those which are about the opinions of the

[45] Unfortunately, Asch does not say how many cases of this kind there have been.

[46] The level of conformity with wrong assessments that can be achieved in modern societies is certainly much higher (probably around 95% instead of 35% in this experiment) for the simple reason that in order to form an independent opinion the information on which to base that opinion must be available. Even in our supposedly democratic societies it often happens that crucial information is withheld by governments or mass-media. The example of the weapons of mass destruction that were supposed to exist in Iraq before 2003 was a case in point but one could mention many others.

[47] The quotes are meant to emphasize that the experiment is never repeated exactly in the same conditions; for instance because of the use of different technical devices.

respondents. The census is a typical example of the first sort whereas political polls (such as those pioneered by the Gallup Institute) are an example of opinion surveys. In the next section we give an example of how fact finding surveys can be used to investigate social interactions.

David Laitin's measurement of (economic) integration

Description of the research project

The study that we describe here was undertaken in mid-2007 by David Laitin from Stanford University and it is still currently in progress. The purpose of the study is to investigate the influence of religion on the way immigrants become integrated in a host country. This is a nice experiment in the sense that it focuses on a simple and well-defined issue. It will certainly appeal to econophysicists.

A crucial feature in the design of the experiment is to make sure that apart from religion all other characteristics of the two groups are the same[48]. For this purpose the project considers immigrants from two ethnic groups in Senegal, a country in western Africa: one is composed of Christians, the other of Muslims. Islam is the religion of 90% of the population of Senegal. Their destination country is France.

Naturally, in order to ensure that all other conditions are identical, one must make sure that there are no marked differences between the two groups in terms of:

- level of education
- ability to speak or write French.

Such differences would not be surprising because Christians may have a closer association with French missionaries. It will be one of the aims of the survey to check whether such differences exist or not.

Other factors of importance for the process of integration concern the region of destination. Is it Paris or a provincial city? Is there already a community from the same group established in this area and, if so, what is its size?

Finally, an important point is what criterion is selected to gauge the level of integration. Mixed marriages is a possible criterion but there may be others. Economic integration which is another important facet can be estimated from data about income and job status. Income progression gives a measure of the progress in (economic) integration in the course of time. But this raises the question of whether or not there is a correlation between social and economic integration.

For more details one can read Laitin (2008).

[48] A presentation of the project can be found at the following address: http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0819625

Social versus economic integration

Let us define social integration by the fact that for all major socio-economic indicators the average is the same for the group of immigrants under consideration as in the rest of the population. Thus, this criterion requires in particular the equalization of average (or median) income. If we assume that the immigrants started from fairly low level jobs, such an equalization requires that progressively they get access to medium-level jobs. In short, social integration implies economic integration. However, it can be argued that the converse is not necessarily true. Let us examine this point more closely.

Whenever there is a substantial community of nationals from the same country a new immigrant can develop an economic activity within this community. This was for instance the case in Hawaii in the 1930s; at this time many first generation Japanese immigrants succeeded fairly well economically without being able to speak English fluently. It is true that the first immigrants were recruited to work in the sugar cane fields but that was in the late 19th century. Subsequently, a broad set of activities developed within the Japanese community: priests, fishermen, teachers in Japanese language schools, employees in the banking branches set up by Japanese banks and so on. For all these jobs, almost no knowledge of English was required. Moreover, for those who sent their children back to Japan to attend school, even Nisei (i.e. second generation Japanese) were more fluent in Japanese than in English. In other words, the possibility of joining a large community of fellow country people certainly accelerated economic integration but at the same time delayed social integration. For instance, there were very few mixed marriages.
A similar example is provided by the community of Chinese immigrants in Indonesia. One knows that this community enjoys a privileged economic status in the sense that it controls a substantial part of Indonesian business companies[49]. In spite of the fact that this community has been present in Indonesia even before the country became independent, it is still not well accepted and integrated as was shown by a series of very serious anti-Chinese riots in 1965-1966, 1975 and 1998[50].

The “ceteris paribus” condition

In order to draw clear conclusions from Laitin’s “experiment” it is crucial to ensure that the two groups are indeed identical in all aspects except religion. This is a difficulty which is inherent in all comparative social studies. As already pointed out, through its very design this experiment provides comparability conditions which are better those usually achieved in standard social studies.

[49] Although only approximate data are available they live no doubt about the reality of the concentration of power in the sense that a community which represents a few percents of the population controls about 60% of the companies.

[50] According to Amy Chua (1995) the number of Chinese fatalities was of the order of several hundred thousands.

Often social scientists think that they are able to focus on a specific variable Z and to "control for all other variables" that is to say make sure that these variables do not affect the response of the system to Z. But to be able to do this one must know in advance *all* relevant variables, an assumption which is equivalent to the claim that one has a perfect knowledge and understanding of the phenomenon. In order to emphasize how tricky this requirement can be I will illustrate it by the following example.

In a study presented at a conference at Harvard in May 2002 the authors analyzed the factors that had an impact on the rate of desertion in the army of the Union during the American Civil War. They considered a long list of variables, e.g. age, level of income, state of origin, and so on. which could plausibly influence desertion rates but they did *not* mention one variable of crucial importance, namely the amount of the premium payed by states to recruits who signed into the army. States which experienced the most difficulties in fulfilling their quotas of recruits tried to solve the problem by paying a higher premium. But at the same time such payments generated a process by which recruits got the premium, deserted, offered their service in another state, got a second premium and so on. That kind of scam would of course be impossible nowadays; it was the lack of centralized files which made it possible in 1861-1864.

The important point in this example is that no plausibility argument can possibly make us discover such a factor. Can it be revealed in some other way? The surest way to check if no variable has been overlooked is to carry out similar studies in other countries. Unexpected divergences in results may be related to factors which have not been clearly identified[51].

The empty seat experiment

How can we estimate the barriers which, to some degree, exist between people? Here is a proposal for an experiment which is based on an observation made in the subway of Tokyo by Michael Hasset and was published in the Japan Times (25 November 2008).

> "After nearly two decades in Japan I, like many non-Japanese, have repeatedly experienced the empty-seat phenomenon when the only empty seat on the train happens to be the one next to me".

To explain the point made by Hasset one must realize that in 2008 there were very few Westerners (that is to say persons who visibly were non-Japanese) in the sub-

[51] It is true that such a test will not reveal unexpected factors that are common to *all* countries in the sample, but it is probably the best one can do. Even in physics there is no other way around this difficulty than to try out different sets of experimental conditions.

way. The fact that he is the only foreigner in the train (or at least in the carriage) is implicitly assumed in his account.

Based on this observation the design of a possible experiment would be as follows. Let us assume that there are 3 seats on each side of the carriage.
(i) One would employ a group of 3 Japanese and one Westerner (e.g. students who take part in the experiment).
(ii) Two Japanese will occupy 2 of the seats on side A while the third Japanese and the Westerner will occupy two of the seats on side B:

$$\text{side } A: \quad J \quad \text{empty} \quad J$$

$$\text{side } B: \quad J \quad \text{empty} \quad W$$

(iii) One will count the number of times n that the empty seat A is occupied before the empty seat B. (iv) If N is the total number of persons who occupied one of the seats, can the ratio $b = n/N$ provide an estimate for the "barrier" between Japanese and Westerners? If $b = 1$ (which means that the empty seat next to the Westerner has never been occupied it would indicate a high barrier. If $b = 0.5$ (which means that the two seats had the same occupation rate) it would mean that there is no barrier. If $b = 0$ (the empty seat between the two Japanese was never occupied) it would mean that the empty seat next to the Westerner in fact exerted a special attraction.

Theoretically at least, the experiment appears fairly clear and should lead to estimates of barrier height or levels of attractiveness. So far, this experiment has not been tried[52]. However it is fairly likely that, as in most social experiments, there will be a high level of "noise". The only way to get significant results in spite of this noise is to repeat the observations many, many times[53]. The interesting point is that once a procedure has been set up which gives reliable and reproducible results it can be used to test other similar effects. Thus the westerner can be replaced by an attractive lady, a priest (or a monk), a tramp or any other character whose effect one may wish to study.

Just to show that many experiments of this kind can be designed, let us describe another version of Milgram's lost letters experiment.

The lost CV experiment

[52] My own observations in the metro of Tokyo in fact would suggest that there is no barrier effect. On some occasions the seat occupancy pattern described above sometimes occurred just by chance and a number of times I observed that the seat next to me became occupied while the empty seat on side A remained empty. This remark is based on a small number of observations and is therefore hardly significant. I spent only one month in Tokyo whereas Hasset spent 20 years, so one should probably trust his testimony.

[53] Let us recall that Stanley Milgram repeated each experiment 40 times. In the present case the experiment requires relatively little time and preparation so that one may probably repeat it one hundred times within one week.

At the beginning of this chapter I described the experiment performed in Hong Kong in order to assess the level of sympathy for the People's Republic of China. Milgram performed a similar experiment in southern states of the United States in order to assess the level of sympathy for the Civil Rights movement and in a more general way for the African American minority. The idea of the lost job application experiment[54] is derived from this experiment.
First the research team writes a fictitious job application which includes a CV (with photograph), a letter of motivation and a stamped envelope bearing the address of the applicant which is supposedly for the response of the company. The fictitious identity of the applicant can be selected at will as belonging to a group A. For instance, A can be a population of minority workers such a Polish workers in the United Kingdom, Turkish workers in Germany or Tunisian workers in France. – The next step is to leave a large number of job applications [55] in an area inhabited by a group B. The number of applications sent back to the applicant will be an indicator I of the sympathy between the groups A and B. If A is a minority group and B the majority population the experiment will tell us how well the minority A is integrated and accepted in the population. Naturally, as for any measurement device it must be calibrated by which I mean that a number of tests must be done in order to check if I indeed measures what we would like it to measure[56].

In recent years experiments about discrimination in the job market have been performed by the International Labor Office in Geneva in several countries: Belgium, France, Germany, Spain, Sweden, United States. These reports are published in a publication of the ILO entitled: "International Migration Papers" and they are available on the website of the ILO. These experiments consisted in sending (fictitious) job applications in response to job offerings. The applications were designed by pairs so that to be fairly equivalent (though of course not identical which would immediately arise the suspicion of the company) in terms of education, previous experience, age and so on. They differed only by the ethnic origin of the applicant: one was from the majority population, the other from a minority population.

The first steps in the applications process can be made by mail or by telephone, but subsequent steps will involve personal contacts with the employer and therefore require that comedians play the role of applicants. Needless to say, such experiments require a great amount of work and a large research team. For the F For the experiment performed in France about 2,400 applications were sent in initially; 26 actors played the role of applicants in job interviews.

[54] For the sake of brevity, I will often call it the "lost CV experiment".

[55] As in Milgram's experiment they would be left in street cars, subway cars, waiting rooms of railroad stations, etc.

[56] For instance it must be checked that the same job applications left in the same area in successive weeks give approximately the same return rate in other words that the effect is reproducible.

The lost CV experiment is much simpler to implement. Although it does not measure exactly the same effect there may be a substantial correlation between the two experiments. Indeed, one may argue that in the reaction of employers there is an "overall component" which reflects their general opinion about the minority B and a component which is specific to their sector of activity or profession.

At this point it may be of interest to explain why many studies are concerned with measuring social interaction even if they do not explicitly mention this objective. In order to make that discussion more concrete I will consider the example of the studies that I have done in former years. In other words, I will briefly explain how I became interested in the measurement of social interactions.

Other research topics centered on social interactions

At first sight my topics of interest (as judged by the book titles that are cited below) seem to span a broad range of issues. Yet, as will be explained in the following lines, in most of these studies the key objective was to define and measure some kind of social interaction.

- The purpose of "Theory of Markets (1995)" is explained by its subtitle: "Trade and space-time patterns of price fluctuations"[57]. During the 19th century there were grain markets in all cities and towns. At that time in a fairly large country such as France there was no unified market for wheat or other commodities in the sense that at a given moment the prices were not the same at different locations. For instance, the price of wheat may have been $p_A = 17$ franc/hectoliter in a city A, say the city of Orléans, 100 km south of Paris and $p_B = 20$ franc/hectoliter in a city B, say the city of Rouen, 100 km West of Paris. If the transport cost $C(A, B)$ of wheat from A to B was at that time smaller than the price differential $\Delta p = |p_B - p_A| = 3$ francs and provided this price differential lasted long enough (basically longer than the time required for the shipment) this situation would have generated a trade flow from A to B. This is the normal mechanism by which an exchange of goods is generated by spatial differences in prices.

The higher the price difference Δp the greater the propensity to ship goods from one place to another. If Δp is barely equal to $C(A, B)$ few traders will care to organize shipments. On the contrary if Δp is much larger than $C(A, B)$ the incentive will be greater. More precisely, for a trader in city B the potential yield will be of the order of: $Y(A, B) = (\Delta p - C(A, B))/p_B$. If $Y(A, B)$ is notably higher than the yield for other trading destinations, the shipment from B to A is likely to materialize.

[57] Some specific points were developed in subsequent papers. In Roehner (1999) the space-time structure was investigated; in Roehner (2000 a,b) the objective is to define and measure the correlation length of commodity markets.

There are two different effects which are at work in this phenomenon: local conditions create spatial differences whereas traders provide connections which reduce these differences to a level which is determined by the effectiveness of the transportation system. The fact that a diversification force is checked by a unification force is a fairly common mechanism.

- In "Separatism and Integration (2002)" we investigate a similar mechanism but this time for languages and cultural characteristics. Local conditions give rise to linguistic differences[58] whereas contacts between people tend to produce a common language. This common language can be a national language or a lingua franca that is used as a means of international communication. In Europe during the Middle Age among learned people it was Latin, then at least among the aristocracy it was French and in more recent times it has become English. In short, local idiosyncrasies tend to develop during periods of time marked by a low level of exchanges and communication, whereas social interaction favors the emergence of universal means of communication.

The main parallel between the case of prices and the case of languages is the role played by communication networks. Poor communication leads to a segmented market in terms of prices or to a fragmented society in terms of languages. On the contrary, easy communications bring about unified markets and languages.

- In "Cohésion Sociale (2004)" (a book written in French) I tried to measure social cohesion by observing the response of societies to various forms of exogenous shocks: military victories, or defeats, assassinations of political leaders, attacks on religious or national symbols, etc. Any of these events tends to trigger a uniform reaction in a homogeneous population, but diversified reactions in a culturally segmented population.

In other words the reactions to shocks provide a kind of radiography of the society which shows the level of heterogeneity.

- In a series of studies of occupation episodes[59] I explore what happens when a large group of young men is brought in contact with the population of a foreign country. These episodes provide a kind of "natural experiments" about social interaction. The fact that the group of young men is the same in all cases makes it a controlled experiment in which the number of parameters is reduced as much as possible.

[58] Often languages spoken in neighboring countries are not very different: French is not very different from Italian, Portuguese is not very different from Spanish, Czech is not very different from Slovakian, Swedish is not very different from Danish. In each case one would of course have to explain the exact meaning of the expression "not very different". In the case of French and Italian for instance it means that a Frenchman can (more or less) read and understand a simple text written in Italian. In the case of Czech and Slovakian it means that a Czech can understand a Slovak who speaks slowly and in fairly simple terms.

[59] For the sake of uniformity these studies focus on post-World War II occupation episodes by American, Australian and British troops taking place in different countries such as Japan, Germany, Iceland, Australia, China, Hawaii.

- In "Patterns of Speculation (2002)" I have studied real estate speculative bubbles, that is to say episodes during which the price of houses and apartments increases much faster (about 10 times faster) than either the consumer price index or the national income[60]. Do such episodes have an explanation in terms of interaction? I think so. For instance, I have shown that the number of newspaper articles on real estate topics increases during the phase of ascending housing prices and decreases during the phase of falling prices. Newspaper articles are only one manifestation of a frenzy that engulfs the whole society. In the course of a few years people who had never before given a thought to real estate speculation all of a sudden take an active part in such operations.

The number of newspaper articles is a fairly indirect indicator of the jump in interaction which seems to occur during such episodes. It would be useful to have an indicator reflecting medium-range social interaction[61].

Usually it is difficult to follow the spread of a speculative frenzy because the social network has just too big. In the case of the Madoff scheme which surfaced in December 2008 the relevant network was restricted to a select group of wealthy people. This gives a better chance to observe how it spread. In an article published in the New York Times which documents the way the scheme had spread one finds the following description[62]:

> Country clubs, golf courses, locker rooms, recommendations, word-of-mouth. That's how it was done. A lawyer would call a client, saying: "I'm setting up a fund for Bernie Madoff. Do you want in?" Or an accountant at a golf club might tell his partner for the day: "I can make an introduction. Let me know". [In addition to such casual recruiters there were also a few institutional recruiters; thus, the article emphasizes that Madoff] could not have had a more effective recruiter than Jacob Ezra Merkin, a lion of Wall Street who was also president of the Fifth Avenue Synagogue in New York.

- In "Driving Forces" I developed a parallel between social interactions and intermolecular interactions (a topic developed in the second lecture in this series). Then I used these ideas to come up with a clearer understanding of the influence of close social links (e.g. family links) on suicide rates. Actually, the relationship is actually so close that suicide rates can in a sense be considered as a measure of the strength of family links.

[60] There are similar episodes for stock prices but for stocks there is a greater variability; thus, stock prices may double in one year which is 50 times faster than the increase of the consumer price index.

[61] Short-range social interaction consists mainly in family bonds; its strength is reflected in the level of suicide rate. Medium-range interaction consists mainly in interactions with friends, colleagues and neighbors.

[62] Article entitled "The world wasn't big enough for this Ponzi scheme" by Diana Henriques; published in the New York Times on 20 December 2008.

Apart from the investigations which found their way in books or journal articles I must confess that I also made a number of attempts which lead no where. One of the most frequent reasons of such failures was the lack of adequate data. For instance, the speed of propagation of a rumor would provide excellent insight into the interaction between social agents but so far I was mot able to find data which were accurate enough for this purpose.

Lecture 6
Toward a scientific approach in historical analysis

Lecture given at Beijing Normal University, Department of History, on the invitation of Professor Xueqin Mei on Friday 24 October 2008, 10:00.

CONTENT

A word about the title

I will try to convince you that a scientific approach can only be achieved through comparative analysis. Of course, we know that there have been studies in comparative history for a long time. What I will propose is an approach which focuses on sharply defined mechanisms. One of the main points of this talk will be to explain what is meant by "sharply defined mechanisms".

A word about myself

- I got a PhD in theoretical physics from the university of Paris in 1972
- During the 1970s I was a researcher in particle physics while at the same time teaching physics at the University of Paris.

- In 1981-1982 I visited a Russian American mathematician in Chicago and this marked the beginning of my shift from physics to systems science.
- During 1989-1990 I conducted an investigation about wheat prices in the 19th century at the French National Archives: this was my first historical research. Eventually it resulted in the writing of two books which were published in 1991 and 1995 respectively.
- During the following years I continued to work in comparative history and this led to the publications of two books in 2002.

In the course of time I have had some contacts with individual historians but I am glad to say that this is one of the first times that I am able to give a talk in a department of history.

What is scientific and what is not

At the beginning of this talk I used the expression "scientific approach". At first sight one may think that it has a clearly defined meaning but through many discussions I became convinced that there is often a serious misunderstanding about what is scientific and what is not. A belief which is fairly common nowadays is that what is mathematical is scientific and what is not mathematical is not scientific. As you have a deep understanding of the role of science in history you know of course that such an idea is completely wrong. We know that the bases of physics were laid by Galileo and that he used only very elementary calculus. Yet, the idea that a mathematical model is necessarily scientific is commonly accepted particularly by economists. You know of course that what matters is not that the model is mathematical but whether or not it has been successfully tested on statistical data. Yet, at least 10 Nobel prizes in economics have been awarded to economists whose models had *not* been tested in any way. This had never occurred in physics. To my best knowledge, *all* Nobel prizes given to theoretical physicists were awarded only after the theory had been successfully tested by experience. By the way, the recent financial crisis can well be seen as the consequence of the fact that too much confidence was put in the (mostly untested) mathematical models that banks had been using to price their financial products. When real sales took place it turned out that these theoretical prices were highly overvalued.

Why do I visit the department of systems science at BNU

Last year I already visited the Department of Systems Science but only for a few days, so I was quite glad this year to come back for a 2-month stay. You may wonder what is the connection between physics, systems science and comparative history.

In order to understand this point, one must recall the meaning of the expression "systems science". Well, this expression can be defined in different ways, but one of its most basic meanings is that it is an attempt to provide a unified view of phenomena which at first sight appear to be different. Let me illustrate this definition by an example.

Consider the phenomenon of economic speculation.

- There can be speculation in stocks.
- There can be real estate speculation in houses or apartments.
- There can be speculation in commodities such as oil, wheat, cotton or gold.
- There can even be speculation in more exotic items such as rare stamps, that is to say stamps collected by collectors.

For all these items, there are what can be called "speculative price peaks" by which I mean a succession of two phases: first a period of time, usually lasting several years, during which prices go up, then a period also of several years during which prices go down. The important point is that by studying such price peaks for stocks, houses, commodities one finds out that they are basically similar. In other words, the mechanism which is at work in these different phenomena seems to be the same.

It is precisely the purpose of systems science to establish a link between these different phenomena and to provide a unified description.

What has systems science to do with physics

As I mentioned at the beginning I am basically a physicist. Now you may wonder why a physicist should be attracted by the comparative approach of systems science. Well, the answer is very simple. Physicists use a comparative approach all the time. As an example I will consider the phenomenon of free fall, that is to say what occurs when one drops an object. We all know that this object will fall, but this fall may occur in several forms.

(1) the fall of an apple
(2) the fall of a feather
(3) the fall of a drop of red liquid in water
(4) the "fall" of the moon on the earth
(5) the "fall" of the earth on the sun.

We now know that all these phenomena are ruled by the same mechanism namely the force of gravitation and the resistance of the air, but this was not always obvious. It was Newton who showed that the astronomical phenomena 4 and 5 are ruled by the same laws as the fall of objects such as 1 and 2. This was a major breakthrough. In short, when Newton established a link between these phenomena he was using the

approach of systems science.

Nowadays physics has become a very mathematical field which is why many persons tend to identify physics with the fact of using mathematics. This is a misinterpretation however. In fact, the most important step is to realize that behind the five previous observations there is a *common mechanism*. Once this mechanism has been clearly identified, it is a fairly easy matter to describe it in mathematical terms.

How can comparative history be made more scientific

The previous examples suggest that in order to make comparisons meaningful one should follow the following rules.

(1) The comparison should focus on a sharply defined mechanism
(2) The comparison should as far as possible be expressed in quantitative terms.

The main difficulty in the first rule is to define what is meant by a "sharply defined mechanism". The rest of the talk will mostly be devoted to this question.

First let me ask you a question? Do you think that comparing the American, French, Russian and Chinese revolutions can be seen as focusing on a sharply defined mechanism? These revolutions had many, many facets which makes their comparison very difficult. If we want to focus on a sharply defined mechanism we need to focus on only one of these facets.

For instance you may remember that during the French Revolution the estates of the Church were nationalized and subsequently sold. This process is more precisely defined than the whole revolution. Did it happen also in other revolutions? It happened during the American Revolution but in that case the estates which were appropriated by the government were the estates of the so-called loyalists, that is to say the Americans who were opposed to independence and who sided with the British army. As you know, about 200,000 definitively left the United States after the victory of General Washington. A process of nationalization of the estates of the Church similar to what happened in France also occurred in many countries during the Reformation, e.g. in Britain, Denmark, Sweden, Germany.

Of course, for historians who are not familiar with these episodes such an example will not be very meaningful. That is why in the following sections I will consider cases with which all of us are familiar. The first case is the melamine problem that occurred recently in China; there has been much news on this question in recent times on TV. The second example will be the episodes of military occupation which occurred during and after World War II. Finally, the last example which is taken from the recent history of the United States will illustrate the fact that if we do not use quantitative data we may miss important changes.

Defining historical *mechanisms*: first example

The information given by CCTV9 suggested that this was an isolated problem. The New York Time provided some additional information by mentioning a case of tainted food for pets which was apparently imported from China in the spring of 2007. When I read all these reports I was wondering if they did not take a too narrow view. As an European I had of course in my memory the so-called mad-cow disease which originated in Britain and then spread to many other countries including Japan. You may also remember that, according to many scientists, this disease was due to the fact that the cows were fed with left-overs of the slaughtering process and cadavers of sick animals such as sheep or chickens which could not be sold for human consumption.

Starting from this observation I had a closer look at this question in particular by using the online archives of the New York Times. First, let us try to understand the rationale of such practices. Let us assume that I am a farmer. As in all market-oriented activities, I am supposed to produce as cheaply as possible. Of course as a farmer I know that cows are herbivores and are not supposed to eat other animals. But I also know that by feeding them with food containing a high proportion of proteins my cows will take weight much more rapidly than if they were fed with grass. What source of proteins will I use? Naturally, the cheaper the better.

There are many sources of proteins that I can get almost for free because they are residues from other production processes. I already mentioned the cadavers of sick animals; one can also mention the feathers or other trash from the mass production of chickens. Unless used in feeding cows, all this garbage would be thrown away which explains why farmers can get it at a very small cost. In other words, the cows will be fed almost for nothing, an ideal situation. Apart from the trash already mentioned what are other cheap sources of proteins?

- Breweries which produce beer and distilleries which produce whiskey use grain, but only a part of the grain is used. What remains would have to be thrown away unless one can use it to feed cows. This was indeed done in New York during the second half of the 19th century. It was the so-called *swill-milk scandal*. The word “swill” refers to a mixture of water and garbage food. This scandal was denounced in articles published in the New York Times as early as 1858 but the practice nevertheless continued for over 60 years. According to one estimate published in the same journal about 8,000 children died each year as a result of drinking this tainted milk.
- In 1986, 100 dairy farms were closed in Arkansas, Missouri and Oklahoma because they were feeding their cows with pesticide treated grains which in addition contained harmful microscopic mushrooms due to the fact that the grains were stored in a humid environment. This was not an accident. The company which produced

this food had been warned repeatedly by the FDA (Food and Drug Administration) not to use such grains. Nevertheless such questionable practices continued during 5 years.

- Then, there is melamine. As you know melamine contains protein-like molecules.

Its big advantage is that these proteins are about 5 times cheaper than proteins from soya, wheat or corn. You may also remember that the harmful effects of melamine have been discovered only recently. In an article published in the New York Times on 30 April 2007, I read: "Melamine is not believed to be particularly toxic. Scientists are now trying to determine whether melamine could be harmful to humans".

I will not continue this discussion further but I hope you will agree that the picture which emerges from these episodes is very different from the presentation of the melamine issue as being an isolated event. In fact, it is a side-effect of the procedure by which farmers try to minimize their cost of production. Such problems have and will occur repeatedly in all market-oriented countries because of the pressure to lower production costs. The only way to prevent them is by public regulation. Governments and local authorities (at state, county or city level) must edict precise rules and have them enforced by frequent inspections.

If you wish more information on this question an interesting source is:
Wilson (B.) 2008: Swindled. The dark history of food fraud from poisoned candy to counterfeit coffee. Princeton University Press. Princeton.

Defining historical *mechanisms*: second example

Military occupation of a country A by the troops of a country B (or sometimes by the army of country A itself) is a process which occurred many, many times in history. During and after World War II there were many episodes of this kind. I mention this case because I have studied several such episodes. Of course, military occupation cannot be described as a single mechanism. There are many facets: black market, prostitution, traffic accidents, assaults on soldiers dating local girls, etc. So we have not one but several mechanisms, but due to the fact that we have so many occupation episodes we are in a good position to make comparisons.
In short, this seems to be a good laboratory for studying many social effects from a comparative perspective. If you wish more details about some early results of this ongoing investigation, you can have a look at my website where all studies are available on line.

Importance of quantitative data

Quantitative history was popular in the 1960s but has fallen out of favor. Yet, is it not

an essential step? If we wish to make comparative history more scientific should we not follow the advice of Lord Kelvin who once declared that without measurement all knowledge is “meager and unsatisfactory” whereas “when you can measure what you are speaking about, and express it in numbers, you know something about it”.

So in my last example I would like to show that even some crucial changes may go completely unnoticed unless we use numbers. I will show you several graphs[63] which all suggest that something important happened in the United States around 1975. As a physicist I’m tempted to call this change a phase transition, but you may use any other term.

(1) The first graph (Fig. 7.7) shows the evolution of infant mortality in the United States and in the UK relative to a sample of three other industrialized countries chosen more or less randomly. Here, in contrast to the next graphs, the sharp turn occurred in the early 1950s.

(2) The graph (Fig. 7.6) shows the evolution of the rate of incarceration that is to say the number of people who are in prison in proportion to the total population. There is a sharp up-turn around 1974. The curve of homicides is shown only for the purpose of comparison. In 1974 the homicide rate was at a high level, but so was it in 1930. After 1930 it decreased although there was no increase in the incarceration rate.

(3) The third graph (Fig. 7.5) shows that there was a sudden change in the trend of two important education statistics: the rate of high school graduates and the rate of PhD degrees. These changes occurred between 1968 and 1973.

(4) The fourth graph (Fig. 7.1) refers to the distribution of income. It shows that there was a dramatic change between the period 1947-1979 on the one hand and the two following decades on the other hand. The growth of income which was fairly uniformly distributed over all income groups became tilted in favor of the more wealthiest segments.

(5) Finally the last graph (Fig. 7.3) shows also a dramatic change in the pattern of strikes and wages.

Of course, one would like, (i) to know if such changes also occurred in other industrialized countries (ii) to understand if such changes were connected. Although we do not have enough time to investigate these questions more closely, I guess you understand the main point I wish to make, namely that without these quantitative data we would be completely unaware that such dramatic changes took place.

Conclusions

[63] These graphs will be found in lecture 7.

My wish is not that all historians suddenly get engaged into comparative studies of the kind that I have tried to advocate here. But presently the ranks of the quantitative comparative historians are really very thin. As I am convinced that this approach can be quite rewarding by allowing a better understanding, I would welcome a revival of this field.

In France there is currently a big crisis in the teaching of history in high school. I am fairly ignorant about the situation in China. However I am convinced that by adopting a comparative perspective, by both sharpening our questions and broadening our field of observation, we will make the teaching of history more exciting in high school as well as in college.

Lecture 7
Was there a phase transition in the U.S. around 1975?

Lecture given at Hokkaido University, Faculty of Economics, Sapporo on Saturday 22 November 2008, 14:00. and at the International Christian University, Tokyo on Monday 8 December 2008, 10:00.
This seminar provides an illustration and application of the notions and rules about segmentation outlined in the previous lectures.

Outline

In the post World War II era the American society was amazingly successful in many respects. In terms of number of Nobel prizes won, industrial innovation, military power and in many other fields the United states is far ahead of all other countries. Yet, empirical observation shows an abrupt change that took place around 1975 in the trend of several social and economic variables.

- Whereas over the three decades 1945-1975 there was a fairly uniform increase in incomes for all income groups, after 1975 only the highest income groups experienced a substantial income growth. In contrast, the lowest income groups experienced a *fall* in real income.
- Whereas in previous decades the marginal federal tax rate for the highest bracket was 70%, after 1980 it was lowered to 35%. There were similar reductions for the tax rates on the earnings of businesses.
- Whereas the number of strikes had been more or less constant between 1935 and 1975, it experienced a dramatic decline after 1975.
- Whereas the number of PhD degrees delivered between 1900 and 1975 had been increasing steadily (in proportion to population), after 1975 it leveled off.
- Whereas the incarceration rate had remained fairly stable between 1930 and 1975, after 1975 it began to increase at a rapid rate.

Because other developed countries did not simultaneously experience similar changes, it is hardly possible to attribute them to the sharp increase in the price of oil which occurred in the mid-1970s. This raises the question of how such a turning point can

be explained.

The previous observations suggest that after 1975 the gulf between the super-rich (top 1% of the households) and the rest of the population has widened rapidly in terms of income and wealth. Moreover other forms of social segmentation occurred at the same time.

- Holding companies and other "absentee landlord" structures such as hedge funds, investment funds or private buyout companies control an ever increasing percentage of firms and corporations [64] .
- Infant mortality rate data suggest that in spite of the success of the Civil Rights movement of the 1960s the divide between the African-American minority and the rest of the population was not substantially reduced.
- The so-called "white flight" of the middle-class population toward suburban areas and the rapid development of gated communities brought about a new kind of spatial segregation.
- The development of communication infrastructures (electrical power grid, interstate railways and highways, suburban subways) has lagged behind in the last decades. In addition air travel is hampered by congestion at many large hubs and by the segmentation of the airline industry (in spite of a consolidation process that occurred in recent years). Such factors may have reduced the forces of spatial integration.

A highly successful nation

- In the decade 1901-1910 the United States won only 2 Nobel prizes (including one for Peace to President Theodor Roosevelt) which represented 3.2% of the prizes awarded. In the decade 1919-1928 the American share doubled to 7.8% but remained modest with respect to other industrialized countries (e.g. Germany: 22%, France: 12%, UK: 12%). If we now move up to the decade 1981-1990 we see a situation where the United States completely outranks all other countries; its share of Nobel awards has jumped to 49% while the share of Germany which comes in second position is only 8.2%. The situation is almost the same in the decade 1999-2008 with a share of 52% for the United States and only 8.0% for the UK which comes in second position.

Moreover, in all academic ranking of world universities (whatever the criterion) there is an overwhelming proportion of American universities in the top 50.

[64] Due to the financial crisis which started in mid-2007 there may be a temporary change in this trend; whether or not this shift will be permanent depends on the duration of the crisis.

- With corporations such as Microsoft, Google, eBay or Wikipedia [65] the United States is in a monopolistic situation for the computer and Internet industry. There is a similar situation in agribusiness and biotechnology where firms such as Monsanto enjoy a near monopoly.
- The American film industry and TV channels are present worldwide[66].
- The American industry has more world class brands than any other country, e.g. Coca-Cola, Disney recreation parks, MacDonald fast food restaurants, Starbuck coffehouses, Nike and so on. General Motors and Ford are present through their subsidiaries in many countries worldwide[67].
- In terms of military capability the United States enjoys an overwhelming domination. In 2007 the military spending of the United States which reached $ 500 billions represented 45% of the world total and was about 10 times the spending of China which came in second position. With the advances made in Eastern and Central Europe during the past 20 years the network of American military bases (over 700 worldwide) is more extensive than ever.
- During the whole period of the Cold War the United States was able to suppress Communist movements worldwide. It is true that the Vietnam War marked a setback but it remained isolated (there was no domino effect) and in the end a clever policy was able to outmaneuver the Soviet Union.

In short, here is a country that is highly successful in what can be called its high end achievements but reveals symptoms of neglect and fracture at grass-root level: top research is thriving but high school education is struggling, American corporations are highly successful but the real wages of their employees are declining, the worldwide extension of US armed forces is unparalleled but at the same time it has become a separate, closed-off and self-sufficient entity within the American society. The US foreign policy is highly successful at worldwide level but the relations between the Federal government and many of the 50 states are becoming more strained.

Such a picture would not be surprising in the case of a dwindling colonial empire when falling income from colonial possessions brings about a fiscal and social crisis. Such was more or less the case of the UK after World War II. In the present case, however, we are facing a completely different (and, to my best knowledge, unique) situation.

[65] The founders of Wikipedia make the claim that their foundation is based on international cooperation which is probably true; nevertheless, close to 100% of its donors are American, at least for those who are not anonymous as is the case of over 50%.

[66] For instance in the cafeterias or meeting places of many Japanese universities there is a wide TV screen which is exclusively broadcasting CNN programs.

[67] The non-military aircraft division of Boeing has tried a similar operation by sharing the manufacturing of the 787 Dreamliner among half a dozen countries. This policy in which the core company provides only the design has made the success of Coca-Cola for decades; it is obviously more difficult to implement for more complex products such as cars, ships or aircraft.

Greater income inequality

First we consider four graphs which document a major change in the income pattern.

- The first graph shows that there was a drastic change around 1979. In the 3 decades before 1979 the growth of earnings was shared fairly uniformly by all income groups. As a matter of fact, the lowest income group benefited the most and the highest income group the less. It can be recalled that prior to 1980 the marginal tax rate in the highest tax bracket was 70%; subsequently it was lowered to 35%.

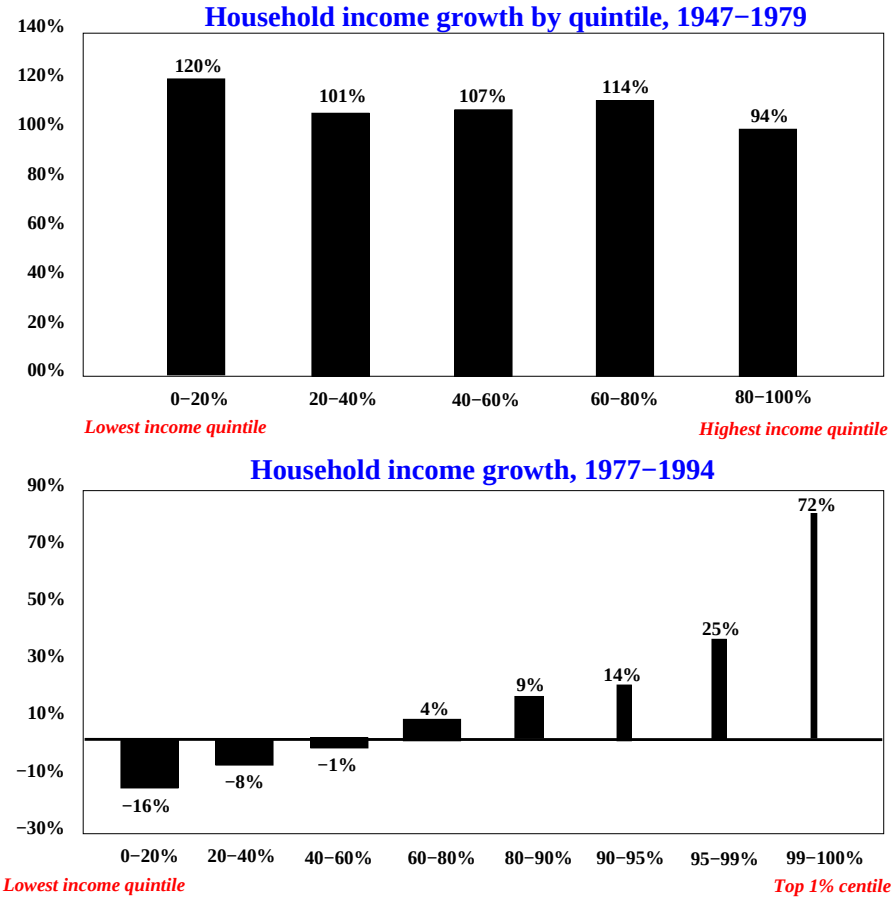


Fig. 7.1 Change in the income pattern in the United States After 1979 substantial income increases were confined to the highest income groups and particularly to the top 1% component. *Source:"Wealth and Democracy" by Kevin Phillips (2002, p. 138); primary sources: Economic Policy Institute, Congressional Budget Office.*

- The second graph presents basically the same evidence. We see that between 1965 and 1978 the income of workers and chief executives progressed at the same pace but after that the two lines separated: the (current) earnings of executives increased by 180% while those of workers increased only by 60%. Note that in the following 20 years the growth of executive pay was even faster. As an illustration, in 2007 Barclays paid its president more than $ 40 million (The Independent 9 November 2008). In relative terms such levels of earnings are similar to the income of dukes and prices in former times. Moreover executives are prepared to go at great length to

keep such privileges even to the point of putting their company at risk. The article of the Independent cited above mentions that Barclays shunned aid by the British government to avoid being forced to curb bonuses. Instead the bank preferred to solicit the (hypothetical) aid of Middle Eastern investors.

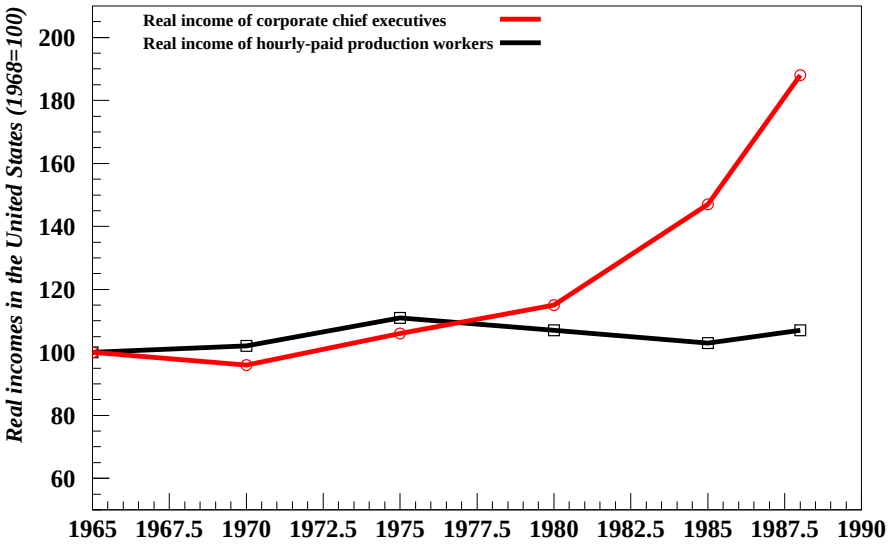


Fig. 7.2 Change in the income pattern in US corporations A growing gap developed after 1979. *Source: "Wealth and Democracy" by Kevin Phillips (2002, chart 3.22); primary source: "The Economist" June 1989.*

The two previous graphs were taken from a book by Kevin Phillips entitled "Wealth and Democracy". It is interesting to note that Phillips was a close adviser of President Nixon.

- The third graph compares wage level and strike frequency. We see that after 1975 real wages decreased while at the same time the number of strikes fell dramatically.

- The fourth graph provides a comparison between the United States and three other industrialized countries. It shows that with the possible exception of the UK which presents a similar (but less marked) trend the other countries do not show the same evolution.

Leveling off in education trends

The next graph highlights abrupt changes in educational trends. The lowest line refers to the percentage of high school graduates, the other to the percentages of PhD degrees conferred annually. How can we interpret this graph? The stagnation in PhDs may have several causes but a fairly obvious factor is the inability of middle-class families to pay such long studies. The decrease in high-school graduates may

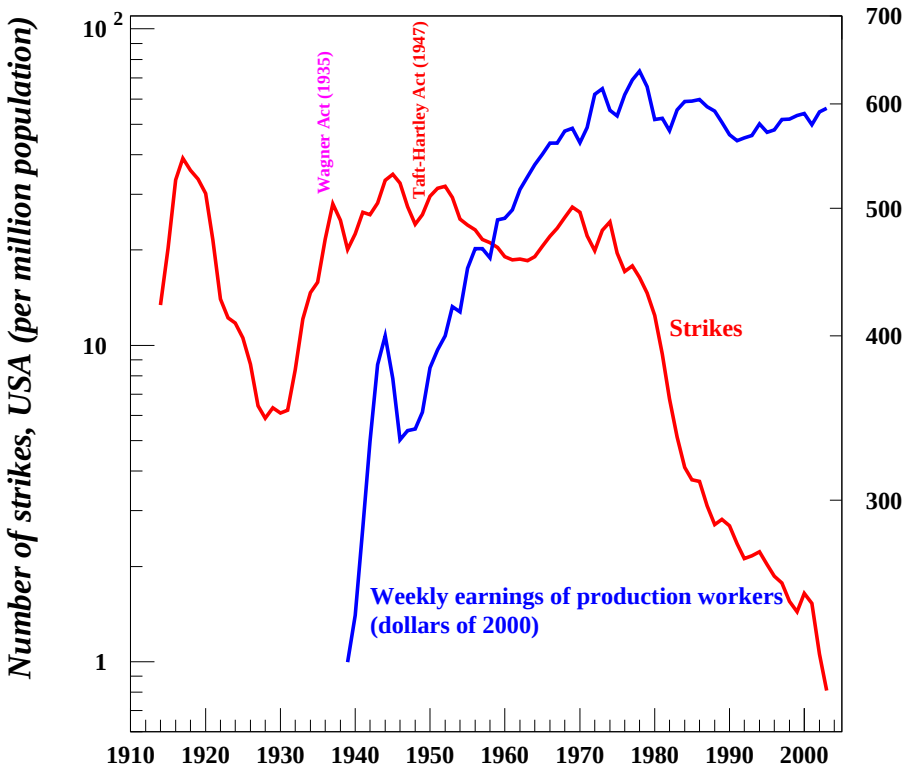


Fig. 7.3 Consequence in terms of earnings of the loss of influence of American labor unions. There has been a dramatic decline in the number of strikes after 1970. Real wages reached their maximum in 1973. After this date the largest part of GDP was absorbed by the growth of non-salary earnings (e.g. income from financial assets, real estate profits, etc.) the share of which increased from 35% in 1950 to 55% in 2004. *Sources: Statistical Abstract of the United States; Website of the US Department of Labor.*

be related to another effect namely the high inflow of uneducated immigrants.

Abrupt increase in the trend of incarceration rate

The next graph documents a rapid increase in the incarceration rate after 1975, an effect which at first sight seems unrelated to the previous changes. The homicide rate is showed mainly for the purpose of comparison. It is true that this rate was high in 1972 when incarceration began to pick up but it was also high in 1932. It is probably a general rule that crime tends to increase when economic conditions become difficult. In the years after 1932 the homicide rate decreased by itself (without a jump in incarcerations) as economic conditions became better. In recent years incarceration rates continued to increase even after homicides had fallen back to their level of the 1960s.

Change in the trend of infant mortality

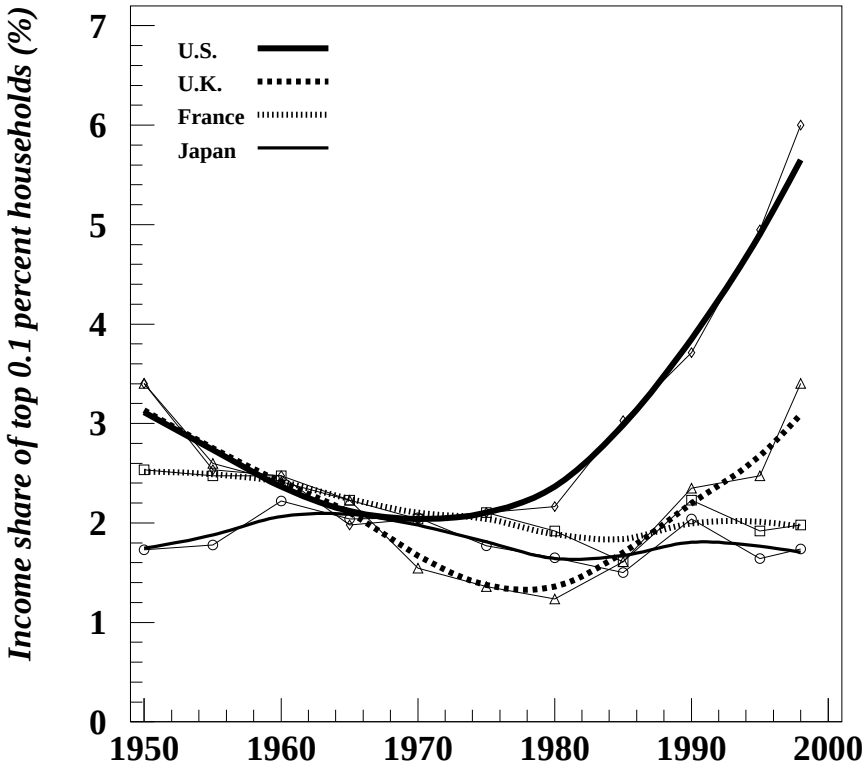


Fig. 7.4 Income inequality in several countries. Vertical scale: share of national income earned by the 0.1% of the households with highest income. The data are based on incomes reported to the fiscal administration; they represent incomes before the payment of income taxes and exclude capital gains. Under an egalitarian distribution of income the top 0.1% would earn 0.1% of national income. According to the present graph their share is in fact 20 larger in 1970 and 60 times larger in 1998. *Sources: US, UK, France: Piketty and Saez (2003); Japan: Moriguchi and Saez (2004).*

The last graph also seems fairly unrelated to the previous ones. It shows the evolution of infant mortality that is to say mortality between birth and one year of age. Infant mortality is a kind of synthetic indicator of various social conditions such as the health of the mother, her working conditions, the healthiness of the home and so on. This graph shows the US rate relative to a sample of three other industrialized countries chosen fairly randomly. Surprisingly, in the present case the change in the trend occurred as early as 1950. It is in the 1960s that the rate became higher than in the reference countries. In 1975 the ratio was equal to 1.45 but there is no change of trend as in the previous graphs.

Increasing segmentation of the American society

Why should one focus on social segmentation?

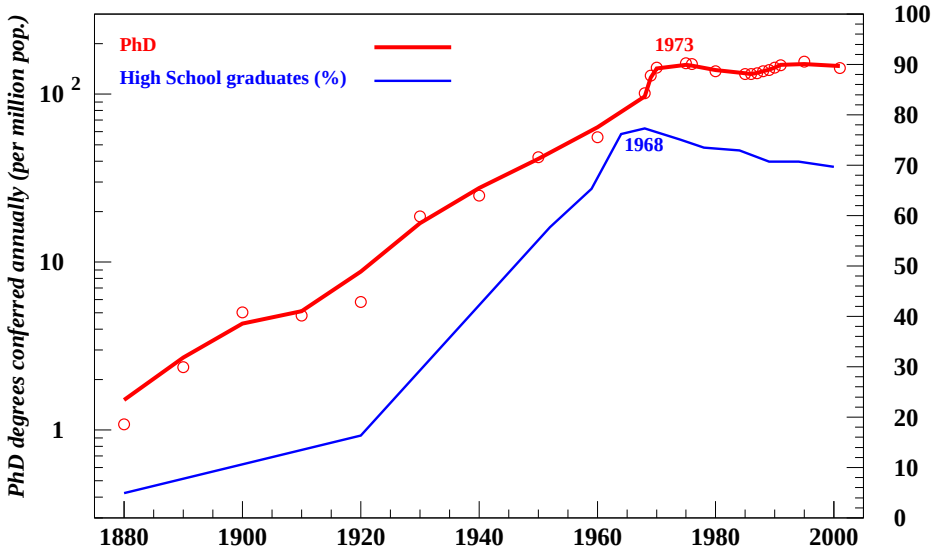


Fig. 7.5 Number of high school graduates and PhD in the United States A marked change in the trend of both curves occurred around 1968-1975. These changes suggest that two transformations took place simultaneously: (i) A contraction (at least relative to total population) of the upper middle class who previously had furnished a large part of PhD graduates. (ii) A widening of the poorest segment whose children leave school without graduating. It can be observed that in contrast with high school and doctorates, the proportion of Bachelors has continued to increase albeit at a rate that is smaller than during the decades before 1970. *Sources: PhD: Statistical Abstract of the United States; high school graduates: Barton (P.E.) 2005: One-third of a nation. Policy Information Center Educational Testing Service.*

I have already mentioned that the federal tax rate was greatly reduced for rich people in the late 1970s that is to say approximately at the time when the phase transition happened. The increase in income inequality is a clear sign of greater social segmentation. In this respect, the changing attitude of the federal government was certainly an important factor. During the New Deal it can be said that the Federal Government sided with the workers and the middle class. It is in his famous address of 7 April 1932 (that is to say at the beginning of his first electoral campaign) that Franklin Roosevelt introduced the notion of the "Forgotten Man":

> "These unhappy times call for the building of plans that rest upon the forgotten man at the bottom of the economic pyramid."

This was not only rhetoric but was matched by sweeping reforms. Many of them were blocked by the Supreme Court especially during Roosevelt's first presidency. For years the Wagner Act which gave so many new rights to workers and unions was not accepted as law by the employers because they expected it to be nullified by the Supreme Court.

However, such an explanation would suggest that the whole matter depended upon the personality and political choices of American presidents. In short Roosevelt

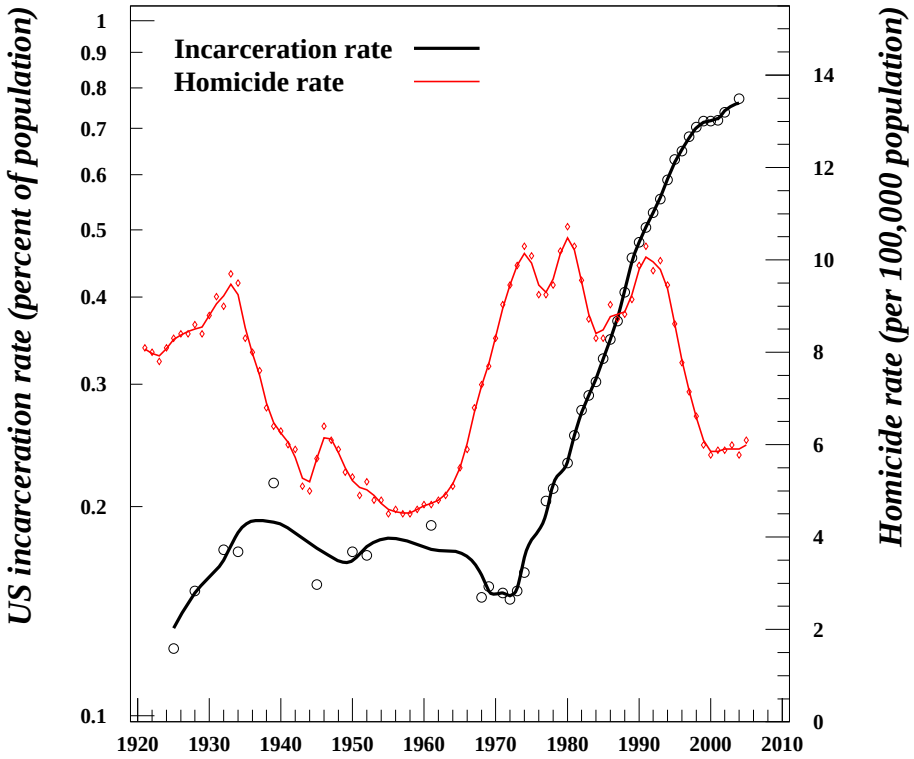


Fig. 7.6 Rate of incarceration and homicide rate. The marked increase in the rate of incarceration after 1975 resulted in a reduction in the homicide rate which began around 1990. Between 1930 and 1955 the homicide rate fell fairly steadily; this fall seems to have little or no connection with the (small) increase in the incarceration rate that occurred between 1925 and 1935. It should probably be attributed to the improvement of living conditions during the New Deal era. In 2008 the average cost of housing a single prisoner was $ 46,000 a year (i.e. $ 3,800 a month, a figure which is higher than the median personal income of full time workers in the United States (The Independent, 15 February 2009). *Sources: Statistical Abstract of the United States.*

versus Reagan. It would be a very anthropomorphic explanation.

It might be tempting to attribute some of the changes that we listed above (i.e. lower educational achievements, higher infant mortality) to the increase in income inequality. Strictly speaking that would be a mistake however. Indeed, it is rather the fact that real wages stagnated or decreased which made living conditions more difficult for low income people. If all incomes had been increasing (even if at different rates) that would have made the greater inequality almost bearable.

A closer inspection shows that the segmentation due to income inequality is only one (albeit a major one) of many symptoms of segmentation in the American society. From the perspective of physics it makes sense to examine the degree of segmentation for we know that (at least in physical systems) the collective properties of a system are determined by its interactions at molecular or atomic level. Segmenta-

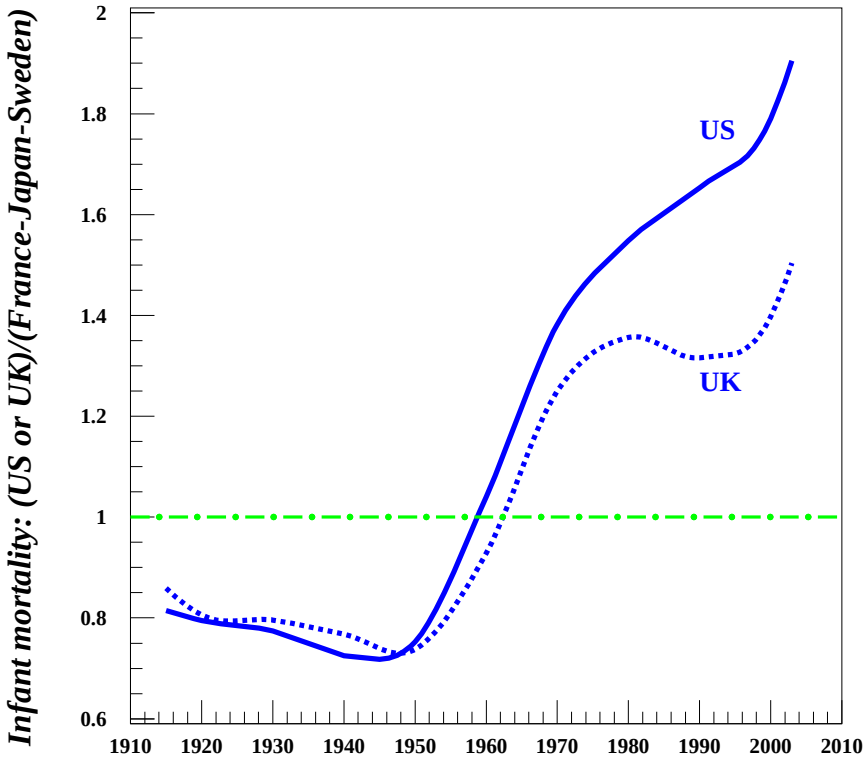


Fig. 7.7 Ratio of infant mortality rate in the US (or UK) to the rate in three other countries. Infant mortality refers to the mortality of babies between birth and one year of age. Because this variable reflects health care and living conditions in all social strata, it is considered a significant indicator of social welfare. The graph shows that in the 1950s there was a change in the trend. The new trend displays a growing gulf between the US (and similarly for the UK although to a smaller extent) and other developed countries. *Sources: Statistical Yearbooks of the respective countries.*

tion basically means less interaction. Listing segmentation factors is a fairly indirect method for assessing interaction strength but so far no better method seems available.

Persistence of the Black-White divide

One might think that in the wake of the Civil Rights movements the divide between African-Americans and the rest of the country progressively narrowed. Complete integration can be considered to be achieved when the statistical indicators of the minority population become the same as those of the total population, that is to say same average income, same infant mortality, same percentage of college graduates and so on. Here we examine one of these indicators, namely infant mortality. Fig. 7.8 shows that instead of decreasing the gap rather increased. This is really a surprising result because for other aspects (e.g. higher education) the gap narrowed.

Perhaps is this result in some way connected with the factor that we examine in the next section

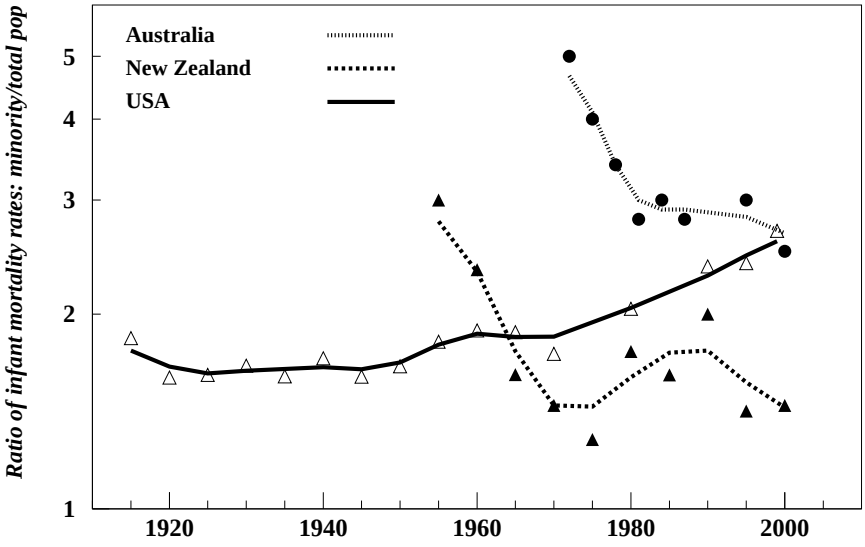


Fig. 7.8 Ratio of infant mortality rate of the minority to the total population for three countries. The purpose of the graph is to assess the progress in the degree of integration of the minority. Somewhat surprisingly, in spite of the success of the Civil Rights movement, there was little progress in the United States (at least in terms of infant mortality). *Sources: Statistical Yearbooks of respective countries.*

"White flight"

For over 3 decades a phenomenon commonly referred to as "white flight" has lead middle-class people to move from city centers to distant suburban areas. In fact the phenomenon is more a move away from poverty: indeed it concerns all middle class groups whether White, Hispanic or Black. This point is explained in the following article: Jego (C.), Roehner (B.M.) 2006: White flight or flight from poverty. Journal of Economic Interaction and Coordination 1,75-87. This flight has transformed many city centers (e.g. Atlanta, Cincinnati, Detroit) into distressed areas.

Gated communities

Simultaneously, the development of so-called "gated communities" has provided a new form of self-chosen segregation. Gated communities are private areas in which new owners are accepted only if they fulfill certain conditions. In large-scale gated areas like retirement communities, there may be local stores, restaurants and businesses all within the secured area of the complex. As this notion is fairly difficult to define precisely the statistics provided by the American Housing Survey are uncertain. However, an Internet key-word search shows that this term is used quite commonly as a commercial argument by property developers (mid-November 2008):

- "gated community": 3,870,000 websites found by Google
- "exclusive gated community":137,000 websites
- "upscale gated community": 25,300

- "charming gated community": 4,600

The self-sufficient world of US Armed forces

Since the end of World War II military and veterans live in a world where many services are provided by the army: stores, schools, hospitals, sport installations, funeral services, vacation resorts. In short, the personnel of the US armed forces lives in a kind of huge gated community.

Dwindling role of social organizations

In "Bowling alone" Harvard Professor Robert D. Putnam documents the loss in membership of many civic organizations. Putnam uses bowling as an example. Although the number of people who bowl has increased in the last 20 years, the number of people who bowl in leagues has decreased. More generally, he uses the data of the annual "General Social Surveys" to show an overall decline in organization membership.

Gap between employers and employees

As noted earlier, the role of the unions has declined *in spite of* a fall (or stagnation) of real wages. In other words the quasi-disappearance of strikes can hardly be interpreted as an expression of satisfaction. The point is rather that unions provided a bridge and means of communication between employees and employers so that their quasi-disparition has cut off this link. In a sense the present trend can be seen as a return to the situation which prevailed during the 19th century. We do not yet see the high level of confrontation between workers and employers which marked this century but it is probably in the making.

Aging and underfunded transportation infrastructures

The Penn Central's bankruptcy in 1970 was the final blow to long-haul private-sector passenger train service in the United States. The troubled line abandoned most of its remaining passenger rail service, causing a chain reaction among other railroads. The federal government stepped in and, in 1971, created Amtrak, a virtual government agency, which began to operate a skeleton service on the tracks of Penn Central and other US railroads. After private-sector reorganization efforts failed, Congress nationalized the Penn Central under the terms of the Railroad Revitalization and Regulatory Reform Act of 1976. A subsequent attempt to create Comrail in 1987 lead to failure in 1999. In short, there remain only few (fairly obsolete) lines for passenger transportation by train in the United States. As a result, transportation by car (including buses) and by air became the two most common forms of transportation. More details about the process which lead to the neglect of transit transportation can be found in Jones (2008).

The bus system operated by the Greyhound company is efficient but for some reason it is little used by middle-class people.
A good part of the road infrastructure is aging and deficient: 13% of bridges in the United States (i.e. about 80,000) share the same "structurally deficient" rating as the bridge that collapsed in Minneapolis in August 2007. In addition, an equal number are "functionally obsolete". Of course, to make sense of such data one would need to compare them with similar data in other countries.

Ownership by "absentee landlords"

Between 1947 and 2000 the assets of American mutual funds as a proportion of GDP has been multiplied by a factor of the order of one hundred[68]. Mutual fund giants such as Fidelity Management and Research (FMR), Vanguard Group, Capital Research and Management or State Street, are the major shareholders (with percentages over 5% and up to 15%) of many large American corporations.

The term "absentee landlord" became widely used in the 19th century in relation with English owners of large Irish estates. The term "absentee" refers to the fact that these owners spent most of their time in London or in vacation resorts of the French and Italian Riviera. More fundamentally it refers to the fact that they were only interested in short-term financial returns. Because they had no knowledge of and no interest in the problems of their estates, they were reluctant to spend money on investments that would have brought a return only in the long-term. The stewards who managed the estates had of course a better knowledge but they were powerless as far as investment decisions were concerned.

The situation is similar for holding companies, mutual funds or private buyout companies. Their interest in the companies that they own is restricted to immediate financial returns[69]. Moreover, because of their lack of empathy they are in the same position as Stanley Milgram's instructors (see lecture 6) who inflicted painful shocks on their subjects without much hesitation.
This can be illustrated by the attitude of employers with respect to fatal accidents in the workplace. According to an investigation performed by journalists of the New York Times (Barstow 2003) it appears that over the period 1982-2002 there were 2,197 cases in which fatal accidents were due to *deliberate* violations of safety laws

[68] More details can be found in Roehner (2006, p. 270).

[69] This situation is plainly apparent in economic and financial newspapers. Very little attention is given to the technical issues faced by companies. Ninety percent of the content is devoted to questions about mergers, acquisitions, changes of top executives, stock prices, bond issuance and other financial issues. Moreover all these topics are considered in a highly compartmentalized way. Thus, until recently it was not realized that problems in the real estate sector can have an impact on financial markets. Even nowadays it is hardly ever realized that the main engine of an economy is the income earned by employees. If this income is depressed through large scale imports of cheap labor there can be no sustainable domestic demand. This point was discussed in more details in chapter 4.

by employers[70]. Even more revealing of the *Zeitgeist* which prevailed during this period is the attitude of the federal government.

- Only 1,242 of these 2,197 deaths were ever investigated by the federal "Occupational Safety and Health Administration"; moreover, in 93% of the cases that were investigated OSHA declined to seek prosecution.
- Former OSHA officials say that those who were pushing for prosecution were hardly ever rewarded and in some cases they were penalized.
- When Congress established OSHA in 1970, it made it a misdemeanor[71] to cause the death of a worker by willfully violating safety laws. The maximum sentence, six months in jail, is half the maximum for harassing a wild burro (small donkey) on federal lands.As a result, the average prison term per worker's death was only 5 days.

The fracture between management and workforce is not only harmful for employees, it also results (as suggested in the third lecture) in poor global efficiency. This means that in the long term such a system can hardly survive if competitors are allowed to emerge.

Even though the previous observations point to a deepening of the divide between employees and employers in recent decades this should not be interpreted as a steady and linear trend. There was already a broad divide in the 19th century which to some extent narrowed in the first half of the 20th century. As an illustration of the turn of mind which prevailed in the early 20th century one can cite the following excerpt from a Federal report on industrial relations[72]:

> The lives of millions of wage earners are subject to the dictation of a relatively small number of men who are totally ignorant of every aspect of the industries which they control, except the finances, and are totally unconcerned with regard to the working and living conditions of the employees in those industries.

Reduction in national solidarity

One of the main roles of government wether at federal or state level is to facilitate and improve the life of the citizens at the collective level. This can take various aspects: (i) providing free facilities such as schools, roads, bridges, police, and so on (ii) ensuring a decent life even to the poorest citizens by a redistribution of income.

In the last two decades two factors contributed to reducing this role.
The first factor was the neoliberal ideology itself which proclaimed that the role of

[70] The total annual number of fatal workplace accidents is about 5,000.

[71] As opposed to felony, a more serious criminal act. Petty theft, prostitution, vandalism, public intoxication are misdemeanors.

[72] The excerpt is from the "Final Report of the Commission on Industrial Relations" and is cited in Boyer and Morris (1955). As a case in point the report includes the copy of a cable addressed by J.P. Morgan from his castle at Aix Les Bains (France) as to the necessity of a low wage scale.

governmemt should be limited to its most basic functions (e.g. army, diplomacy, police) and that the poor should help themselves[73].
The second factor is the erosion in tax-income at both federal and state level. This erosion should be attributed to the change in tax rules that we already mentioned but also to the development of tax havens.

In a report issued in 2005 the "Tax Justice Network" estimated that global tax revenue lost to tax havens exceeded $ 255 billion per year [74]. Actually, when compared with the budget of the United States which is of the order of 2,000 billions, 225 billions is not a big amount. The main point is that there has been a rapid development of tax havens during the past 20 years and that this evolution will continue unless the government of the United States changes its stance on this topic.

Conclusion

We have listed gaps and segmentation effects at different levels (spatial, social, economic) and between various social agents (rich-poor, Black-White, employers-employees). It can be expected that these cracks will result in different effects and consequences depending on the sector where they arise. Unfortunately, we are not yet in a position to predict such effects. It can be hoped that by giving closer attention to such issues we will be able progressively to improve our understanding of such effects.

The real estate lending spree was a direct (but not necessary) consequence of the trends that we outlined. As shown in the section about "White flight" the move to suburban areas continued but in recent decades stagnating (or declining) real wages made it difficult to buy new houses unless affordable loans were provided. As one knows such loans became available in the period 2000-2007 but many had adjustable interest rates which means that they were affordable only during the first years of the loan. They would have been manageable if in subsequent years wages had experienced a substantial increase. On account of the sluggish increase (or even decrease) observed in the previous decades this was a bold and fairly unrealistic assumption.

It is quite possible that it will be feasible to ease and bring under control the US debt through an inflationary process. Inflation is a powerful tool for erasing debt. It has been used with great success in Germany (a process which culminated in the

[73]Such a narrow conception of social solidarity was already prevalent in 19th century England. Revealing of this orientation was the institution of the workhouses. In order to get shelter and meals, poor people had to carry out absurdly useless tasks such as beaking stones. Similarly in India during periods of famine men,women and children had to break stones in order to get relief. For more details see Nash (1900) and Longmate (1974).

[74]The source is: "The price of offshore", Briefing paper (March 2005). It is true that this figure was contested by the "Center for Freedom and Prosperity". However, the fact that this organisation was created to lobby legislators in favour of market liberalisation and offshore financial centers suggests that it cannot really be trusted.

hyperinflation of 1923) as well as during the New Deal when it allowed many farmers facing bankruptcy to reimburse their loans.

However, inflation alone will not fix the cracks that we listed in this study. As an illustration consider the following example. In late 2008 many states were facing large tax shortfalls. In marked contrast with the federal government, states have balanced-budget requirements. In such a situation there can be two policies.

- One may increase taxes especially for rich people who can afford to pay them. This is what was done during the New Deal[75].
- One may increase the price of public services.

As shown by the following excerpts it seems that most states have chosen the second policy.

According to the Center on Budget and Policy Priorities, about 41 states face budget shortfalls this fiscal year (i.e. April 2008 – March 2009) or next. Many took the steps of cutting services and raising fees. Around the country, state-supported colleges, universities and community colleges have already increased tuition or announced plans to do so next year. Tuition has increased as much as 15% for undergraduates in Florida's university system, 14% in Rhode Island, 13% in Alabama, 9% in Kentucky. California's two public university systems warned that tuition could go up 10 percent next year. This comes at a time when families can least afford increased tuition. As a result many young people may have to renounce going to college.

Needless to say, the effect of such a policy will be to widen the cracks. This stands in stark contrast with the massive college funding that was provided to World War II veterans in the late 1940s.

[75] Advocates and mouthpieces of the neoliberal ideology tend to present the income tax as an oppressive institution. However, when seen from the perspective of social interaction is it not a major expression of social solidarity in the same way as Federal aid to the poorest states is an expression of national solidarity at state level.

Lecture 8
Media interactions

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Lecture given at Chuo University, Tokyo, 27 November 2012

Abstract In recent years there have been several theoretical attempts to model consensus formation, notably by Prof. J-P. Bouchaud. In such models all players contribute by spreading their own view and consensus eventually emerges as a kind of collective effect. An alternative model for reaching quasi-unanimity is to assume that one agent has a sufficiently strong voice to make his view prevail.
Which one of these models best describes the current state of world media?

In order to answer this question we will analyze several specific episodes which were especially selected to allow a clear distinction between these contrasting models. Among the evidence that will be considered one can mention the following cases: An incident at a nuclear power plant in California, elections in Russia, events of 8 August 2008 in Georgia, the elections of 1996 and 2012 in Russia, the recall campaigns of Audi and Toyota cars in the United States in 1985 and 2009 respectively.

CONTENT

(1) A case-study of media omissions: Onofre nuclear reactor

(2) US newspaper articles published in non-American newspapers: the examples of China, France and Japan

(3) What happened in Georgia on 8 August 2008?

(4) Election accounts: Japan (1946), South Korea (1948), Russia (1996, 2012)

(5) Events which disappear on historical records: the case of the uprising and crushing of the Russian Parliament.

(6) Quantitative evidence

(7) Discussion

> "Nothing can now be believed which is seen in a newspaper. He who knows nothing is nearer to truth than he whose mind is filled with falsehoods and errors."
>
> Thomas Jefferson, Letter to John Norvell, 11 June 1807.

A case-study in media omissions

Statistical physics versus socio-political systems

Researchers, especially econophysicists who try to extend the methods of physics to the investigation of social phenomena, often wonder what are the major differences between social and physical phenomena. In such discussions there is an important factor that is almost always omitted. It concerns the way phenomena are recorded.

In physics it can happen that the published results of an experiment are not correct, but it is exceedingly rare that researchers deliberately try to doctor, bend or alter their results. This would be considered as extremely serious frauds by the whole community of researchers.

In contrast, news about social events are most often biased in one way or in another. In some cases this bias is very serious. We will see several examples in this lecture. This implies that in the social sciences one should not blindly trust the data. Caution must be exercised. The data must be submitted to a critical examination. If possible, several sources should be used and compared.

An approach in the spirit of statistical physics postulates that all participants play a role but that each of them plays only a *small* role; none is able to decisively influence the whole system. By tracking the distorsions in news accounts it becomes quickly clear that the interaction between media is not of this kind. In the media industry there are *macroplayers* and, as will be seen, their actions have a *global* effect on the whole system.

One of the most common sources of bias, and also one of the most difficult to detect, is the *omission* of specific events. An recent example is described in the next subsection.

Missing information about the Onofre nuclear reactor incident

After the Chernobyl accident back in April 1986 it was said, probably with good reason, that the public was not told the entire truth about the radioactive pollution.

Similarly, after the Fukushima accident it was said that the Japanese government withheld crucial information and did not well inform the public.

In France there has not yet been a serious nuclear reactor accident but the same critic was made about some past incidents, including the Chernobyl accident.

If underreporting of nuclear incidents is observed so frequently, would it not make sense, instead of blaming the Soviet, Japanese or French authorities, to recognize that this kind of reaction is common to *all* countries and governments?
Perhaps there are exceptions, you may think. Well, so far I did not find a single one. Here, the latest example that I found.

Around 30 January 2012 there was a serious problem at the nuclear power plant located at Onofre in Southern California. So serious was the problem that the reactor has been shut ever since and that it will probably not be restarted before one or two years or perhaps will be closed definitely. One would expect such a serious incident to be mentioned on the first page of US newspapers such as the “New York Times” or the “Washington Post” or the “Los Angeles Times”. Was it the case?

Well, not only was the news not on front pages, but in fact it seems that there was no account whatsoever. You can easily check by yourselves by using the search engines for former articles that are available on the websites of these newspapers. The keyword “Onofre” does not give any result in late January and early February 2012. For instance, in the Washington Post there is not a single article about the Onofre nuclear plant between 2 November 2011 and 14 March 2012; even more surprisingly, the article of 14 March does not say anything about the incident of 30 January.

The only newspaper where I found some information about this event was the “Seattle Times” (the city of Seattle is located in the state of Washington on the west coast).

On 31 January 2012 Southern California Edison issued a statement saying “there has been no release in the atmosphere”. However, on the following morning a second statement said that “a small amount of radioactive gas could have escaped” without giving any data about the magnitude of the release.

In a general way, any statement saying that the amount of radioactive pollution was “small” but without providing any data, should be regarded with suspicion. Why? If some underestimated data were given it could later be labelled as being a lie or at least an inaproppriate mistake. When using words such “tiny”, “negligible” or “small” there is no similar risk because such words do not have any objective definition.

Here is a summary of the incident which (eventually) appeared in the “Washington Post” in October 2012.

Excerpt of an article in the Washington Post (9 October 2012).
The problems at San Onofre center on four steam generators that were installed at San Onofre during a $670 million overhaul in 2009 and 2010.
The trouble began on 31 January 2012, when the Unit 3 reactor was shut down as a precaution after a break in a tube carrying radioactive water. Traces of radiation escaped at the time, but officials said there was no danger to workers or neighbors.
Unit 2 had been taken offline earlier that month for maintenance, but investigators later found unexpected wear on hundreds of tubes inside steam generators in both units. Tests found some tubes were so badly corroded that they could fail and possibly release radiation.
The Onofre power plant has 3 reactors that were started in 1968, 1983, 1984 respectively. The unit no 1 was closed in 1992, that is to say after having been in operation for 24 years.

The Onofre incident was not the only one although it was the most serious.
One day before the incident in California the Byron reactor located 150 km north west of Chicagolost electric power from an off-site source. As the circulation of water was stopped, the temperature began to rise. Along with the temperature, the pressure of the steam began to rise. Thus, the operators released some steam in the atmosphere which contained tritium, a radioactive gas. The company said that the tritium was not at “unsafe level”. Once again, no data were given.

Between 1975 and 2000, there were 9 steam generator incidents similar to the one at the Onofre plant in American PWR (Pressurized Water Reactor) reactors. To my best knowledge no data about the amount of radioactive release are available for these incidents.

Worldwide influence of US media

Articles of US newspapers published in foreign countries

The “Japan Times” and the “Yomiuri Shimbun” are two Japanese daily newspapers who publish English editions. Almost every day and particularly during the weekend these newspapers carry articles published previously in US newspapers such as the “New York Times”, the “Washington Post”, the “Los Angeles Times” or others.
“China Daily” does the same in its weekend edition.
Although it is not an English-language newspaper, the French newspaper “Le Monde” [i.e. “The World” does the same in its weekend edition. In this case the articles are of course translated into French.

Two things should attract our attention from the perspective of this investigation.

- There is no reciprocity in this process in the sense that I have never seen an article from “China Daily” or “People’s Daily” published in the New York Times. Nor did I hardly ever see articles from the other newspapers.

- One can of course understand that English language newspapers want to reproduce articles published in English-speaking countries. If so, they could also use articles from Australian, British, Canadian or New Zealand. Why do they limit themselves to US newspapers?

Nowadays, few people read newspapers. TV has become a much more important media. However, the same observations apply to TV programs. The TV programs broadcast in Japan, China or France contain a large number of American series and films. Once again, this is not a symmetrical process in the sense that I have never seen a French, Chinese or Japanese TV program broadcast on US channels.

Of course, cultural infuence is not something new. What is new, however, is the fact that this influence is skillfully used as a political public relation tool. As we will see this has far-reaching implications.

A personal recollection about fog in Beijing

On Friday, December 9, 2011, while being in Beijing, I received the following email from a French friend. She wrote:

> Mardi dernier [6 December 2011], la presse a annoncé une pollution battant tous les records à PEKIN parlant d'un nuage extrêmement toxique ce qui a entrainé l'annulation de vols, etc.
>
> Translation: Last Tuesday, French media announced record-breaking pollution in Beijing due to an extremely toxic cloud which, among other effects, lead indeed to the cancellation of many flights.

Not surprisingly after reading such news my friend was worried about my health!
As I had seen nothing of this supposedly toxic cloud, I began to wonder whether there were two Beijing cities, one in which the journalists were living and another where I was staying.

What did we see in Beijing?
We saw fog. As one knows, fog is nothing else than small dropplets of water. As a matter of fact, at ground level the relative humidity of the air reached 75%-80% which means that water droplets can be formed above the ground. A confirmation of the fact that this supposedly toxic cloud was just fog was the extension of the phenomenon. The fog was not limited to the city of Beijing and Tianjin but extended to the whole area between Beijing and Shanghai including the country side. This widespread fog lead to the cancellation of many flights.

What were the titles in US newspapers about this incident?
In the 5 days between 5 and 9 December 2012 there were 6 articles (one by day) with the key-words pollution+Beijing and 44 with the key-words pollution+China. Here are some excerpts.

- Smog grounds flights in Beijing (New York Times 5 December 2011).
- "Anger grows over air pollution in Beijing" (New York Times 6 December 2011).
- "An air monitor atop the United States Embassy building stopped taking new readings for much of Tuesday, with reports of hazardous" levels" (New York Times 6 December 2011).
- Growing public anger at the chronic pollution in Beijing as Chinese take to the Internet to complain (New York Times 7 December 2011).
- Residents are angry about the severity of fine-particle pollution in the capital and the government's lack of transparency (New York Times 6 January 2012).

Having been in Beijing for several 3-month periods between 2008 and 2012 (always in fall) I can hardly understand that I didn't see anything of the "chronic pollution" mentioned in one of these articles. In fact, most of the time the sky is blue. In spite of the fact that the campus of Beijing Normal University where I stay is not far from the city center, I have never seen as many butterflies as there. Sometimes there were one or two hundreds butterflies (belonging to different species) on a single flower bed of a few square meters.

There is no doubt that in March-April winds coming from the desertic areas in the north west of Beijing can bring sand particles but I never saw something of that kind in fall.

Although I have been puzzled by this kind of media frenzy for some time, it is only very recently that I decided to give it a closer look. Two factors contributed to this decision. First there was the feeling that these frenzy media campaigns have become more frequent and widespread than they had been so far.

Next, two recent experiences that I will describe now brought about the idea of writing the present paper.

An exhibition about the history of French newspapers

The spark which lead me to writing this paper was a visit together with Prof. Aruka and a group of German and Japanese social scientists, of an exhibition held at the French National Library in Paris. It was a historical retrospective about French newspapers. Their accounts at some critical moments such as the military occupation by Germany in World War II or the war in Algeria inevitably raised the question of how accurate and trustful newspapers really are.

This was in July 2012. However, this question had already attracted my attention 4 years before, more precisely on 8 August 2008, the opening day of the Olympic games in Beijing.

8 August 2008 in South Ossetia

On that day there was a major event in Georgia. In the following days, the accounts given by French media were particularly unclear. For instance, the media reported that then Prime Minister Vladimir Putin declared: “It is a tragedy. Hundreds of people have been killed”. However, they did not say who were the people who were killed nor who killed them. As the only hard fact reported by these media was a Russian intervention the public could only assume that those people were killed by Russian troops.

How can we learn the truth?

The situation was so unclear that I decided to devote some time to a closer investigation. First, I read the New York Times but it turned out to have the same ambigous account as French media. Of course, the most promising source were Russian media. There are (at least) two media published in Russia that are in English, namely the “Moscow Times” and the English version of a Russian news agency. Although the “Moscow Times” was an opposition newspaper, its account was much different from what I had read in western media. In particular, it explained who were the people who were killed and by whom they were killed. They attributed the fatalities to the attack made by Georgian troops against the city of Tskhinvali in South Ossetia. I will come back to this in a short moment.

Quasi-unanimity of western media

This episode made me realize that the quasi-unanimity of European media was just echoing the position of the US State Department.

The heavy American involvement in Georgia at that time and the strong support it was giving to the Georgian government can of course explain why the accounts given in US media were biased againt Russia. However, France (and the same can be said for that matter of all other European governments) had no special interests to defend in Georgia. Why then did all these media follow the line set by US media?

Beijing media

This was not just true for European media. In early September 2008 I came to Beijing for a 3-month stay at Beijing Normal University. During my stay, I watched CCTV 9 (now called CCTV News[76]) Although in 2008 Russia was a close ally of China, the CCTV accounts of the events of August in Georgia were basically the same as in Europe, that is to say there was much talk about the Russian intervention and almost no mention of the Georgian attack that started the war.

The Tagliavini fact-finding mission for the EU

[76]CCTV means China Central Television; it is an English speaking government channel.

Needless to say, the Georgian and Russian governments gave very different accounts. Very often in such cases it is almost impossible to know which one is correct. However, in this specific case it is fairly easy to find out because the Council of the European Union set up a fact-finding mission headed by Swiss diplomat Heidi Tagliavini[77]to investigate the case.

The report published one year later by the Tagliavini mission (available on the Internet at http://www.ceiig.ch/Index.html) left no doubt in that it blamed Georgia for starting the war with Russia.

Heidi Tagliavini. Excerpt from the Tagliavini report
"Open hostilities began with a large-scale Georgian military operation against the town of Tskhinvali and the surrounding areas, launched in the night of 7 to 8 August 2008.
Georgian claims of a large-scale presence of Russian armed forces in South Ossetia prior to the Georgian offensive could not be substantiated by the mission" the report concluded.

The real story of what happened in South Ossetia

First one must recall that South Ossetians declared independence from Georgia in 1990, calling themselves the Republic of South Ossetia. The Georgian government responded by abolishing South Ossetia's autonomy and trying to retake the region by force. This led to the 1991-1992 South Ossetia War. On January 5, 1991 Georgian troops entered Tskhinvali. As for most civil wars this led to bitter fighting with many atrocities committed by militias on both sides. In 1992, the government of Georgia and South Ossetian separatists reached an agreement which ended the war. However, in June 2004, the Georgian authorities tried to bring the region back under Tbilisi rule by establishing an alternative pro-Georgian government for South Ossetia in Tbilisi.

The events of August 2008 were a replay of the two previous attempts made by the Georgian government to retake control of the province. In the meanwhile, the US State Department had gained an ever increasing influence over the Georgian government and the Pentagon had sent advisers to train the military and the police.

From July to early August 2008 Georgia together with some 1,000 American troops conducted a military exercise named the joint US-Georgian Immediate Response 2008. Russia organized a similar exerecise at about the same time.

On 7 August 2008, Georgia massed some 15,000 troops including 75 tanks on the

[77]Having previously reported on the war in Chechnya (see her book "Zeichen der Zerstörung" [signs of destructions]) Ms. Tagliavini had certainly no reason to be supportive of Russia.

Ossetian border and in the first hours of 8 August 2008 these troops started a massive attack. On the same day, 12 Russian peacekeepers were killed and nearly 150 injured. Heavy fighting was reported in Tskhinvali for most of 8 August, with Georgian forces attempting to push Ossetians slowly from the city. As the Osetian resistance was stronger than what was expected by the Georgians they resorted to heavy shelling of the city which lead to many fatalities among the civilians. These are the "hundreds of people killed" mentioned by Vladimir Putin. We now understand that for western media it was impossible to say how these people were killed unless breaking the whole story.

By the afternoon of 8 August the Georgians had captured most of Tskhinvali, but were unable to take the northern quarters, where they were meeting heavy resistance from Ossetian militia and Russian troops, including regular Russian forces arriving from the Roki Tunnel. The Georgian troops were also unable to take the control of the roads leading from the Roki tunnel to Tskhinvali. Russian special units reportedly prevented Georgian saboteurs from blowing up the Roki Tunnel, which could have hindered the sending of reinforcements to South Ossetia.

The fighting reached a turning point toward the evening of 10 August, when Russian and Ossetian troops were bolstered by Russian reinforcements from the Roki Tunnel, and counterattacked. Georgian forces were cleared out of most of Tskhinvali, and forced to retreat to the south of the city.

At the outbreak of the war 127 US military trainers were present in Georgia. Additionally many of the 1,000 US troops who had participated in the military exercise "Immediate Response 2008" were still in the country but the United States stated that they did not participate in the conflict. However, with 127 advisers present in the Georgian army it is of course difficult to imagine that the Pentagon had not been informed about Georgian reconquest plans. Probably the advisers even offered some helpful suggestions. After all, that was their role.

Reactions to election results

This is an interesting class of cases because it involves not just one or two cases but dozens. All such cases have very similar outcomes:

- Every time a faithful US ally (or party) is elected, the election is deemed by US media to have been "reasonably democratic" no matter what real conditions had been. In some cases, when the evidence of fraud is all too clear, no reports are given and the election is just ignored.
- On the contrary when a candidate (or party) critical of the United States is

elected the election is invariably described by US media as being marred by massive frauds or at least as being suspicious.

The key point here is that in the examples given below the label given by US media is accepted uncritically by the media in other countries.
almost all historical accounts made subsequently, either in the US or *elsewhere* each election was catalogued under the label decerned by US media.

A case in point is provided by the elections of 1996 and 2012 in Russia.
Before the election of 1996, president of Russia Boris Yeltsin had an approval rating of only 3% (see below for more details). On the contrary, in 2012 Vladimir Putin had an approval rating of some 70%. Yet, in the days following these two elections, western media decided that the election of Boris Yeltsin had been honest and fair whereas the election of Vladimir Putin had been marred by massive fraud. More details will be given later on.

In what follows the previous rule will be illustrated by a number of examples. But first of all it must observed that among the many ways through which an election can be made unfair, one of the simplest and most effective is to prevent the opposition from taking part in the electoral process and to authorize instead a straw opposition which poses no real threat whatsoever. This technique has the advantage of attracting little attention because it can be implemented well ahead of the election at a time when foreign media pay little attention.

Election of 1946 in Japan.

Any candidate had to undergo a screening process which examined whether or not he had been a militarist. Needless to say, the borderline between patriots and militarists was not always clear. Although the screening was nominally implemented by a Japanese commission it was controled and supervised by the US occupation authorities.
This process appears with particular clarity in the case of Ichiro Hatoyama.

On May 5, 1946 General MacArthur issued a directive declaring Ichiro Hatoyama, former Minister of Education and leader of Japan's largest party, the Liberals, an "undesirable person" on the eve of his nomination as the next Prime Minister. The order excluded him not only from Premiership but also from holding a seat in the Diet or any public office. The directive came as a surprise because the pre-war activities of Mr Hatoyama had been well publicized in earlier weeks (one should recall that prospective candidates were screened with regard to their former activities). A few days earlier a spokesman from Headquarters even emphasized that General MacArthur would accept any of the elected party leaders for the post of Prime Minister. Former Prime Minister baron Shidehara had already informed Emperor Hiro

Hito that he intended to recommend Mr Hatoyama as the next head of government.

Ichiro Hatoyama was far from being a vocal opponent of the United States. In 1946 this would have been impossible. Why was he discarded? It is difficult to know exactly but one may think that he was found not to be sufficiently cooperative.

Election of 1948 in South Korea.

The slogan used by US and western media to describe this election was that it represented the first free election in the 4,000-year long history of Korea. This slogan was repeated again and again to the point that it became the accepted truth.

As an example, one can mention the following excerpts from an article published in the US magazine “National Geographic” (Chetelat 1950).

- Caption of a picture: May 10, 1948: South Koreans flock to the polls for their first free election in their country’s history (p. 793). The same sentence also appears twice on p. 780: “The American Military Government gave all facilities to permit the Korean people to have a really free election”. “For the first time in Korean history a free election was to take place”.
- In Pyongchang [in the north-east of South Korea, some 80 km south of the 38th parallel] a full 99% of the registrants voted (p. 789).
- The only serious incident in my gun [an administrative subdivision in Korea] was the shooting of a Communist by Korean police at Poll No. 42. During the previous night a band of roving troublemakers had come south from the Russian Zone and clashed with a Korean patrol (p. 789).

Was the author just naive? Probably not. He was not a journalist but a US adviser who had been working in Korea for over a year.

Incidentally, a previous article published in “National Geographic” about Korea was written by Lieutenant General Hodge, the Commander of US troops in Korea. Entitled “With the US Army in Korea”, it appeared in June 1947.

Before closing this section one must shortly explain why this election was not fair. A more detailed account can be found in Roehner (2012).

First, it must be observed that all opponents (and in particular the Communists) were either in prison or in hiding. As a matter of fact, this election is a good illustration of the effectiveness of the candidate pre-selection technique.

Secondly, many Koreans were uneasy about this election because they understood that it would solidify the division of Korea. Yet, they were forced to get registered and to vote under the threat of losing their food card privileges. This is not merely a rumor, it was recognized by the Korean Chief of police in an interview with an US officer.

Elections of 1996 and 2012 in Russia.

Election of 1996:

In the New York Times of 8 July 1996 appeared an article written by Condoleezza Rice. One can remember that she was an academic expert in Soviet history before becoming US National Security Advisor in January 2001 and Secretary of State in January 2005.

She says:
The election saw Mr. Yeltsin's *convincing victory*. The election, both process and outcome, suggests that a nascent democracy is taking root in Russia. Yeltsin had some backstage help from American campaign advisers. A casual observer could be excused for confusing the Russian [electoral] campaign with an American one.

Here is what observers think today of this election. The following excerpt is from Marie Mendras: Russie l'envers du pouvoir (2008, Odile Jacob): "L'élection de juin-juillet 1996 sera la première élection postcommuniste ouvertment malhonnête [The election of July 1996 was the first one in the post-Communist era that was blatanly rigged].

Indeed, it is said (July 14, 2011 on a blog of the Financial Times by Charles Clover) that in 1996, Boris Yeltsin had an approval rating of only 3%. Under Boris Yeltsin, oligarchs were allowed to run TV stations and to fund political parties. They massively supported Yeltsin and have said on the record that their goal was to get Yeltsin a second term by any means necessary.
In February 2012, on the occasion of the publication of the letters of Boris Yeltsin, President Dmitri Medvedev declared that in fact it was not Boris Yeltsin who won the election of 1996 but his opponent, the Communist Gennadi Zyuganov, who promised a return to the stability of the USSR.

Was there really a revision and reversal in the mainstream historica account of the 1996 election? No. The persons that we cited are a small minority. As proof, one can mention that in the Wikipedia article about Gennady Zyuganov there is a section about this election but it does not even suggest that there may have been fraud.
"Yeltsin gained most from the elimination of the many smaller parties and the support of Alexander Lebed and eventually won the two-man showdown by 53.8% against 40.3%". There is also a Wikipedia article specifically devoted to the election of 1996 which does not have a single word about possible fraud[78].

[78]However the article in French mentions the fact that there may have been massive fraud. "Cette élection présidentielle fut la premire démocratique dans l'histoire de la Russie post-soviétique actuelle même si elle fut entachée de fraudes massives, à tel point que l'issue véritable est controversée. [This was the first democratic election in post-Soviet Russia although it was marked by fraud so massive that the real outcome is still in doubt.] Incidentally, it can be observed that in July 2011 over 50% of the Russian GDP was still generated by state-owned companies.

Election of 4 March 2012:
As I was in France at that time, I followed this election through the comments of French media. In spite of the fact that independent opinion polls credited Vladimir Putin with an approval rating of some 70%, there was much talk in French media that the election would be marked by fraud. Then, immediately after the election French TV channels began to show footage of ballot boxes being stuffed with ballots and at the same time there were demonstrations by opponents who claimed that the election had been rigged. This, however, lasted only 2 or 3 days. Thereafter, there were official statements in particular by the US State Department recognizing the election of Vladimir Putin. Simultaneously, the allegations of French media stopped. What had happened? Why did the media campaign not continue as had been the case after the election of June 2009 in Iran? We will probably never know.

In any case, the media's historical account of this election has become rather positive. For instance, Wikipedia says that in spite of some reservations, "Organization for Security and Cooperation" observers assessed the voting on the election day positively overall. However, one should recall that the voting itself is only one part of the electoral process.

Elections in Egypt under President Mubarack.

According to the Wikipedia article entitled "Elections in Egypt" there were 3 main elections during the Mubarack presidency.

(1) The presidential election of 7 September 2005. It was marked by a turnout of 23%.

(2) The parliamentary elections of 15, 26 November and 7 December 2005. According to official records, the average turnout for the 3 rounds was around 23%.
In the New York Times there were almost no reports about this election.

(2) The parliamentary elections of 28 November and 5 December 2010. Official figures of voter turnout in the first round set voter participation at 35%; for the second round, voter participation was reported at 27%. These figures stand in stark contrast to those put forth by independent observers which are between 10% and 15% for the first round, and even lower for the second round. (Ashraf Swelam: Egypt's International Economic Forum, Occasional Papers 2: January 2011.
The New York Times of 12 December 2010 reported that "President Hosni Mubarak hailed the elections as a milestone" but, overall, there were few articles about these elections.

Some events disappear from historical records. Why?

In this section we consider the "disappearance" of specific events in the sense that

they are erased in 95% of the accounts to be found on the Internet. We are talking here about major events which because of their historical significance should not vanish in such a way if the process were really a collective effect in which all voices can be heard. On the contrary, in these cases all voices become mute and the only version available excludes all "inconvenient" events that are at odds with mainstream ideology.

1993: Yeltsin's tanks crush the resistance of opposition law makers

In accounts of the Boris Yeltsine Presidency the failed Army rebellion of August 1991 is usually well documented. On the contrary, the episode of October 1993 in which tanks crushed the resistance of opposition members of the Russian Parliament gets only scant attention. Although hundreds were killed during this repression, US media considered this show of force as necessary.

In order to document the reaction of the "New York Times" we searched the database of its articles with the key-words "Parliament" + "Moscow" and for a time interval covering 20 September 1993 to 20 October 1993. Surprisingly there were only 10 articles. The following table lists the first sentences of some of them.

(1) 22 Sep: Showdown in Moscow. In the past, Mr. Yeltsin and Parliament have backed away from direct clashes.

(2) 23 Sep: US will speed money to bolster Yeltsin.

(3) The lights were on all over the Russian Parliament building tonight. Groups of men, some with guns hung about the lobbies.

(4) 5 Oct: Tanks and troops loyal to President Boris N. Yeltsine today crushed an armed uprising by his opponents.

(5) 16 Oct: Russian papers have not been allowed to appear since Mr. Yeltsin declared martial law in Moscow after the pitched battle around the Parliament.

It can be seen that no regrets were expressed for the loss of lives. In fact, as every-time when something embarassing has to be reported, the New York Times opts to say very little. We have seen the same attitude about the Egyptian elections under President Mubarack.

The last article mentions a "pitched battle". According to an online dictionary, this is supposed to mean a fiercely waged battle fought by troops in opposing formations and orders of battle. Can the struggle of men fighting tanks with light weapons be called a pitched battle?
Clearly, President Yeltsin had to be supported at all cost and the "New York Times" faithfuly followed the political line set by the State Department.
A more detailed account of these events is given in the following box.

Several similar cases of forgotten events could be mentioned. The following list

Brief account of the Moscow massacre as seen by the New York Times

New York Times 5 October 1993

The Parliament building, known as the White House, was shaken by huge explosions from 125-millimeter shells fired from T-72 and T-80 tanks. As crack airborne troops conducted a floor-by-floor assault, hundreds of legislators, defenders and supporters began filing out of the building shortly before 5 pm.

Russian television showed Ruslan I. Khasbulatov, the Parliament chairman, and Aleksandr V. Rutskoi, a former general who is the Vice President, grimly boarding a bus. About 30 prisoners, including Mr. Khasbulatov and Mr. Rutskoi, were taken to Lefortovo Prison in central Moscow where, the Interfax news agency reported, they missed dinner. Mr. Khasbulatov and Mr. Rutskoi were given neighboring cells and granted smoking privileges.

There were no immediate reports on the total number of dead and wounded, but Russian television showed rows of corpses outside the White House. Only three people were killed in the coup attempt in August of 1991 against the President of the Soviet Union, Mikhail S. Gorbachev.

Russians across the nation sat glued to television sets, watching live coverage by CNN relayed on Russian channels. Footage of a huge burst of smoke from the first cannon shell, which demolished Mr. Khasbulatov's fifth-floor office, was repeatedly replayed.

Occasional firefights were reported around the city between pockets of Parliament supporters and special police units, the most intense at the offices of the newspaper Moscow Komsomolets.

Mr. Yeltsin moved quickly today to solidify his power. In addition to ordering the arrests, he banned some opposition parties, including the Communists and nationalist organizations like Pamyat. He also closed many opposition newspapers, including Pravda, the former organ of the Communist Party. Mr. Yeltsin was also reported to be preparing a decree to deal with the Constitutional Court, a panel he created early in his presidency to safeguard citizens' rights. Under its chairman, Valery D. Zorkin, the court turned into a center of political opposition. The measures were likely to spread unease among Western and domestic libertarians.

Box 1: Excerpt of a New York Times article about the assault The article tries its best to give a benign picture of the crackdown. One learns that in their prison the leaders of the movement missed dinner but were given smoking privileges. However, no estimate is given for the number of people killed. The official death toll published subsequently gave 150 killed but non-official estimates go into several hundreds. The New York Times even accepts the severe restrictions on political freedom such as the dissolution of major political parties and of the Supreme Court as well as the closing of major newspapers as being necessary. *Source: Website of the New York Times.*

gives 4 examples.

- South Korea, October 1946. An uprising was followed by the crushing of protestors by US occupation forces. The death toll is not well known but run into the hundreds.
- Thailand, Bangkok, October 1976. Massacre by armed forces and right-wing groups of people protesting against military rule. As the protestors were mostly students the massacre was followed by a sweeping purge in universities.
- South Korea, Gwangju, May 1980. Uprising and subsequent massacre of protestors

by armed forces. Estimates suggest up to 2,000 people may have died.

- Thailand, Bangkok, May 1992. A military crackdown on 200,000 demonstrators resulted in an undetermined number of deaths (the official death toll 0f 52 mentioned in the Wikipedia article being probably an under-estimate), many disappearances and over 3,500 arrests. Many of those arrested were tortured.

With the exception of the Gwangju massacre, there are only brief mentions of the other events in the English Wikipedia articles. The first event is not mentioned at all. The fact that the Gwangju repression is better documented is largely due to the fact that president Kim Dae-jung who was elected in 1997 had been arrested and tried in 1980 which lead him to encourage an investigation of this dark page of South Korean History. Between 1980 and 1997, any mention of the massacre was prohibited.

Response to an objection

In what precedes we emphasized the ability of US media (then followed by other world media) to represent events in a way that is consistent with the wishes of the Department of State. An objection comes to mind however. What about the Abu Ghraib scandal?

- Was it not revealed on 28 April 2004 during a program of the US TV channel CBS?
- As this episode was hardly to the advantage of the United States does this revelation not show how independent and courageous the US media actually are?

This is indeed what can currently be read on most websites.
However, the real story is quite different. As a matter of fact the “revelations” made in the program “60 minutes” of CBS were what the Pentagon calls a “damage control” operation. This expression means that as the torture story was about to be made public anyway (in fact it had already been spread among policy makers and media directors) it was preferable that the announcement be made on an American media rather than by British media or by the International Red Cross. As a matter of fact, CBS (as well as other US media) had been informed about this story several weeks before it was made public.

What allows us to say that the story would have become public anyway? It is the fact that several months before 28 April 2004, statements about torture in US prisons were made by several organizations.

- In November 2003 the Iraqi Minister of Human Rights, Abdel Bassat Turki, alerted US administrator Paul Bremer that serious violations of human rights were committed by US soldiers on Iraqi prisoners. As he got no reply, he eventually gave his demission on 8 April 2004.

- In a report given to President Bush in February 2004, the director of operations of the International Commission of the Red Cross (ICRC), Pierre Kraehenbuehl, described abuse of prisoners (kicking and striking with rifles, keeping naked in complete darkness, and so on) by US Intelligence. The report said that these were not isolated acts and that they were not limited to the prison of Abu Ghraib. It was rather a broad system. In fact, this report was a summary of what the CICR had been saying to US authorities on many occasions between March 2003 and the end of 2003.
- On 19 January 2004 an investigation was opened by the "Combined Joint Task Force" in Iraq. The conclusions of this investigation became known to the British government and to US media by the end of February 2004. From this moment, the main objective of Washington was to convince the American public (including US Congressmen) and the international opinion that Abu Ghraib was an isolated phenomenon due to special circumstances and to a few irresponsable persons.
- In fact in the CBS program of 28 April only a short (and fairly imprecise) account was given. What triggered this "revelation" was the fact that the weekly newspaper "The New Yorker" was about to devote a fairly detailed article to this story.

This article which appeared on 30 April 2004 was written by Seymour Hersch, an investigative journalist who had already played a key-role in the revelation of the My Lai massacre back on 1969.

Hersh was called by Richard Perle, an American defense advisor, the "closest thing American journalism has to a terrorist" but this judgment is not correct. In fact, Hersh was able to get interviews with many intelligence officers who, obviously, would not have been willing to talk to him if they did not expect some good results. Indeed, in his articles Hersh tells the whole story exclusively from an American perspective. By so doing, he comes to find good reasons for using torture. He emphasizes that this harsher methods were (in his own words) a "success story" in the sense that they permitted to win the battle against the Iraqi resistance.
At no moment does he try to estimate how many prisoners were tortured, or how many died while being tortured either in Iraq or in the other places (such as Egypt or Romania) where torture was used by US interrogators [79] .

In his article of 10 May 2004, he expresses much sympathy for the officer who was in charge of the Abu Ghraib prison and reports her statement according to which: "living conditions now are better in prison than at home. At one point we were concerned that they [the prisoners] would not want to leave.", a fairly weird claim.

In short, even when they investigate episodes that the State Department would pre-

[79] In his article of 20 May 2004, Hersh justifies the fact that these interrogations were done abroad by saying that it would have been too dangerous to bring these terrorists to the United States, a rather strange argument.

fer not to come into the media, journalists like Seymour Hersh are tolerated by the system because, in spite of their critics, they remain part of the system and can on occasion be quite useful. Whenever their articles happen to displease the US authorities, their stories are just discarded as being far fetched.

What about the Internet?

It is often said that the Internet provides a means for getting information from different sides and different countries. Although this is basically true, one must observe that in recent times there has been a tendency to make information less available. Let me just mention two facts.

- There used to be total free access to all articles of the New York Times published in the Internet era that is to say since 2002 or so. Recently, the access has been limited to 10 by month.
- Did you ever come across one of the following messages when doing a Google Internet search?

This website has ben deleted by Google due to a legal request

Opening this website may damage your computer

Incidentally, I opened several such websites (after asking permission from our system administrator) and no damage occurred to my computer.

Such limitations may likely increase in the future.

Regarding the Internet one can of course observe that in most of the world it is completely run by US organizations and companies: one needs only to mention Google, Wikipedia, AMAZON, e-Bay, Linkedin, Worldcat and so on. In this respect the only major exception seems to be China.

A quantitative approach

So far, our investigation remained at a purely qualitative level. This was essential for the following reason. If the accounts made in different countries were so to say “neutral” (assuming that neutral accounts are at all possible) it would not really matter whether what we read comes from one country or from another. However, in the previous sections we have seen that most accounts are *not* neutral. Once we know this, it becomes important to know the origin of the news. This is easier for TV and movies than for newspaper articles. Indeed, newspaper articles always rely on information from news agencies but it is difficult to make a clear distinction between the respective contributions of the journalist and the part of information from news agencies.

For music, movies or TV programs it is easier to know where they have been produced. Sometimes, especially in TV programs, the original footage is complemented by interviews carried out in the country where the program is broadcast in order to make it look more indigenous.

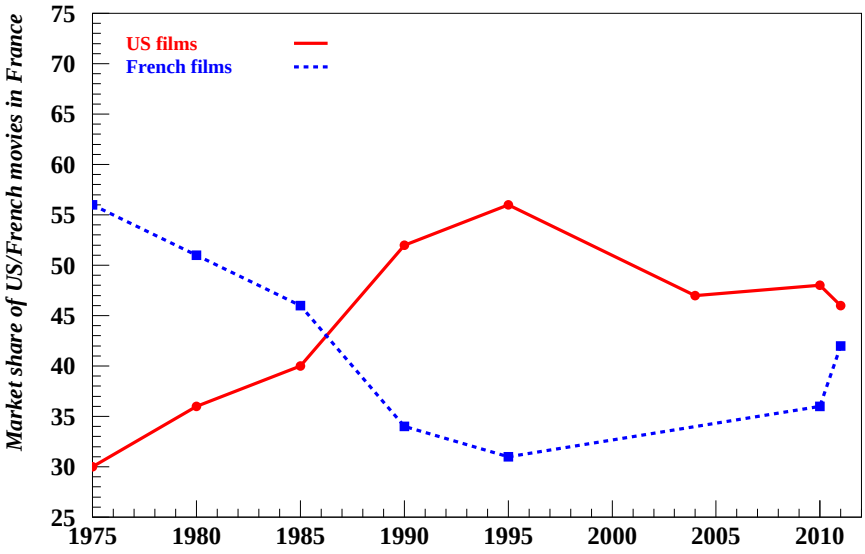

Fig. 8.3 Respective market shares of French and US movies in France. We were not yet able to find detailed data for the 30 years between 1945 and 1975. Here are some indications: between 1945 and 1955, US and French films both had a market share which fluctuated between 40% and 45%. Then, between 1955 and 1975 the share of French films increased to about 55% while the share of US films fell to around 35%, with European films representing a substantial share comprised between 15% and 20%. In 1973, the market share of US films reached its lowest point with 20%.
It can be noted that in 1946 in order to get a loan from the United States, France had to open its market to US films; however, one quarter of the time was still reserved to French movies (for more details see the Wikipedia article about the Blum-Byrnes agreement).
Sources:
http://www.screendaily.com/news/europe/french-cinema-admissions-hit-45-year-215-million-high-in-2011/5036125.article
http://lisa.revues.org/1626
http://www.robert-schuman.eu/question_europe.php?num=sy-58
http://fr.wikipedia.org/wiki/Accord_Blum-Byrnes
http://www.allocine.fr/communaute/forum/voirmessage_gen_refmessage=20341814&nofil=355915.html

In March 2000, 56% of the series shown on French TV channels were produced in the US; only 25% were produced in France. In Germany the proportions were 57% and 35% respectively, and in Italy 64% and 18%. The source for these numbers is: http://www.crtc.gc.ca/fra/publications/reports/drama/drama3.htm.

According to the website http://lisa.revues.org/1626 In 2004, the market share of American films in Europe was 70%. It was 84% in the UK, 78% in Spain, 62% in Italy, 47% in France.

In Japan, the data for the period after World War II were as follows (Seagrave 1996, p. 215, 255):
1950: 40% , 1957: 30%, 1958: 21%, 2001: 51%, 2002: 73%, 2004: 63%.
In India the market share of Indian films is 90% which means that American films have a market share of less than 10%.

In the United States, the market share of all foreign films was 5% in 2000.

Growing concentration in the media industry

In themselves the high degree of concentration and the broad globalization trend cannot explain the uniformization (almost a quasi-unanimity) that we have described in the previous sections. After all, in all major countries there are still national media groups which would be able to develop some independent information channels. The problem is rather that they do not wish to do so.

Similarly, the European Union could introduce a pro-active policy for developing an European movie industry. Some 20 years ago there have been some attempts in this direction, in particular with the realization of animation movies. It seems that instead of going forward in this direction the European Commission has decided to scrap these early attempts. One may wonder why.

Chapter 9
Questions, challenges and prospects

In this chapter I summarize a number of open issues and challenges which arose in the course of the previous lectures. In the last section entitled prospects, I describe three possible directions for future research which may open the way to a cumulative process of exploration.

Questions

(1) In the third lecture we have seen that less than 1% of the species developed colonies in which a large number (say more than 1,000) of individuals live *permanently*[80]together? How can one explain that there are so few? Do the species in which this occurred share some common characteristic?

(2) The previous question can be stated in an alternative form. Constructing nests or cities, supplying them with enough food, eliminating wastes and dead individuals requires a substantial amount of work. What was the initial attraction force which nevertheless brought individuals together and made them accept these additional inputs of labor even before they could benefit from the social innovations that "urban" centers would bring about?

(3) In chapter 4 we have seen that in the case of marriages in the United States (and probably in other countries as well) the association constant (for first marriages) decreases steadily between the age of 30 and 55. It would be interesting to understand why this is so. Is it because single people have less occasions to meet each other when they become older, or is it because the percentage of meetings which result in marriages becomes smaller?

(4) In chapter 4 we have seen that the dissociation constant k_- is notably higher for African-American couples than in the total population. This suggest weaker marital links. Also one knows[81] that there is a close connection between suicide rates and the strength of marital links. This leads one to expect that African-Americans should have a high suicide rate whereas in fact the suicide rate for African-Americans is

[80]This qualification is important to distinguish them from the temporary gatherings of birds or grazing animals during their migrations.

[81]This connection has been shown by Émile Durkheim in his book on suicide. It was confirmed by additional tests in Roehner (2007, Part III).

more than two times smaller than in the general population. How can this paradox be solved?

(5) Some 50 years ago murder and suicide rates in Ireland were at a much lower level than in neighboring countries such as the UK or France. But during this half-century these rates experienced a tremendous increase as can be seen in Fig. 8.1. Can one explain this transformation in terms of a weakening of social interactions?

(6) In addition to the trend at national level shown in Fig 8.1 there has also been a kind of social disaggregation at microsocial level in the sense that in a number of areas vandalism, crime and anti-social behavior greatly expanded. This is for instance the case in some of the suburbs of Limerick (in the west of Ireland), e.g. Moyross, Southhill, St Mary's Park, Ballinacurra-Weston. The following examples illustrate this kind of behavior[82].

- Buses were stoned.
- In 1996 there were more than 2,200 syringue attacks in Dublin, an average of 6 a day. The article of the British journal "The Independent" (6 July 1997) which reported these data was entitled: "Dublin muggers bring terror to the streets with blood-filled syringues". More than 10 police officers have been stabbed with syringues. Among recent victims is also the Lord Mayor of Dublin, Councillor Brendam, who needed hospital treatment for hand injuries after he tackled thieves who threatened him with a syringue. In subsequent years, according to the Annual Reports of the "An Garda Siochana" (Irish Police), the annual number of syringe attacks declined steadily from 1104 in 1996 to 221 in 2002 (it can be noted that the figure of 1,104 is about one half of the figure cited in "The Independent"). This fall can be attributed to an increase in the prison population and improved drug treatment in Dublin.
- Cars, houses, night clubs and hotels were torched with petrol bombs.
- On several occasions in the middle of the night the windows of houses inhabited by peaceful families were shattered by a hail of bullets, seemingly for no obvious reason.
- Workers who came to repair broken water hydrants were battered.
- Between 1997 and 2003 there have been 40 killings in Limerick[83]. Assuming that this figure is for the area including the suburbs which has a population of about 90,000 one gets an annual rate of 6.7 per 100,000 which is about 6 times more than

[82] A list of crimes and incidents which occurred in the Limerick area since May 2006 can be found on the following website: http://newswire99.blogspot.com/2006_12_01_archive.html
One striking characteristic of many of these incidents is the young age of the perpetrators. Here is an example. On 16 September 2008 a 12 year-old girl stole a van at 3 am and drove it to the police station of Henry street where she beeped the horn in an effort to taunt the Gardai [name of Irish Police] into chasing her. The Gardai then gave chase to the girl out of the city center and eventually managed to corner the van in the Garry Owen area. The girl rammed a police car before being pulled from the van and arrested.

[83] Source: The Sunday Business Post Online, 23 November 2003.

the national average. The average annual suicide rate over 1997-2005 was 17 per 100,000, about 1.5 times higher than the national average.

It is known that high crime rate and anti-social behavior also occurred in other countries, for instance in Detroit, Michigan, in Glasgow, Scotland or in suburbs of French cities (e.g. Paris or Lyon). But in those cases factors such as an economic slump or a highly heterogeneous population seem (rightly or wrongly) to provide easy explanations. What makes the case of Ireland particularly puzzling and interesting is the fact that no factor of that sort can be invoked.

- During the period 1990-2007 Ireland has enjoyed a period of great economic prosperity[84]
- At the census of 2006 Limerick's population of non-Irish people was only 12% [85] and the population of people from non-European Union countries was only 1.9%.

So the case of Ireland suggests that the "obvious causes" such as unemployment and highly mixed population, after all are perhaps not the real causes. In any case, for Limerick (and also, albeit to smaller degree, Dublin West) an alternative explanation must be found. Perhaps will this explanation turn out to apply to other places as well.

Challenges

One of the main challenges is to make sure that what we measure, for instance by one of the methods delineated in lectures 4 and 5, is really an estimate of interaction strength.

The previous lectures provided a broad introduction but in a subsequent phase of this research we plan to focus more closely on a few issues. The objective will be to measure interaction strengths by *several* of the methods which were delineated in chapters 4 and 5. Because we cannot see social links we cannot measure their strength in the same way as we would measure the length of a table or the production of wheat in the United States. All measurements that we have proposed rely on indirect observations: one observes an *effect* of the interaction (or of its removal) and then from this effect one tries to derive a numerical indicator for interaction strength. But the fact that this indicator indeed represents the interaction needs confirmation. How can such a confirmation be obtained?

To answer this question it makes sense first to examine how this problem has been solved in physics.

[84] In 2000 the county of Limerick had an unemployment rate of 4.2%. It is true that in suburbs such as Moyross the rate was estimated to be 4 times the national average, but that puts it at only around 15%, way under the 40% or 50% in French or British suburbs.

[85] As compared with over 50% in suburbs of French or British cities who experienced similar problems

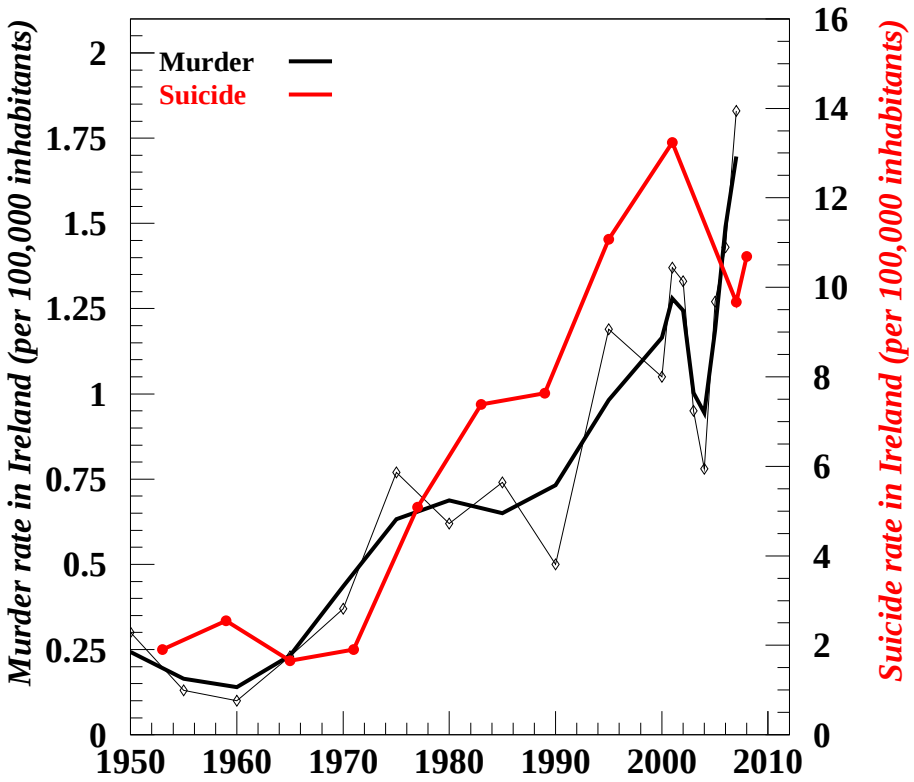

Fig. 8.1 Murder and suicide rates in Ireland. The two rates were multiplied by 6 approximately; the main increase occurred between 1970 and 2000. As a matter of comparison the murder and suicide rates in the UK are 1.4 and 10 respectively. By international standards Irish rates are not particularly high. For instance in the United States around 2000, the murder and suicide rates were equal to 5 and 11 respectively. Will the Irish rates continue to increase in coming decades? In order to be able to answer this question one must first understand what brought about the huge increase shown in this graph. *Source: Statistical Yearbook of Ireland (available online.*

Measurement of intermolecular forces in physics

First let us explain why in physics one faces exactly the same difficulty as in the social sciences. The following excerpt from a book which gives a review of methods for measuring intermolecular forces states this point very clearly (Hirschfelder 1967).

> "It should be noted that no direct way of measuring intermolecular forces is known. What is generally available are measurements of some macroscopically observable quantity having some functional dependence on intermolecular forces. The problem, then, is to extract information about these forces by analysis of the measurements."

Incidentally, it can be observed that interatomic interactions within molecules are easier to measure because molecules have well defined structures which can be identified by various techniques such as X-ray scattering or infrared spectroscopy. For

instance it is known that the molecule of water forms a open angle of 102 degree[86]. In contrast, in gases distances between molecules are not fixed and in liquids the situation is even worse because one molecule can simultaneously interact with many others. For instance in water the molecules form a pattern of cells but these cells in permanence experience large-scale changes and recompositions which make the average structure fairly fuzzy. Ice is more stable which is why physicists have been able to identify several well-defined ice structures. The case of liquids is of particular interest in relation with social sciences because social links are also characterized by a high degree of variability.

There are several ways of characterizing the strength of interaction between molecules in a liquid through macroscopic variables.

(1) The boiling temperature t_b is an estimate of the kinetic energy (remember that the temperature is nothing but a macroscopic indicator of molecular movements) which is required to make the molecular bonds which exist in the liquid susceptible of being broken up. Thus it makes sense to think that the boiling temperature provides a rough estimate of molecular interaction strength in the liquid.

(2) The heat of vaporization H gives an estimate of the energy which is required to transform one mole from liquid state (at a temperature close to the boiling temperature) to gas state. Thus it makes sense to think that the heat of vaporization provides a rough estimate of molecular interaction strength in the liquid.

(3) The equilibrium vapor pressure p_v is basically an expression of the number of molecules of vapor which are present in the air above the liquid when equilibrium is reached that is to say when the molecules leave the water at the same rate as they return from the air into the water. This variable is connected to the interaction strength because the molecules which are very close to the surface of the liquid are attracted downward by the other molecules[87] and thus, the greater the interaction strength the more difficult it is for these molecules to leave the liquid and become gas molecules. In other words, it makes sense to think that the vapor pressure provides a rough estimate of the molecular interaction strength in the liquid.
The vapor pressure has a direct connection with the evaporation rate; from the perspective of social phenomena it can be seen as expressing a kind of dropout rate of molecules from the liquid in the same way as people drop out from organizations.

These three variables are very different in nature which is reflected in the fact that they are expressed in different units: unit of temperature (degree Celsius), unit of energy (Joule), unit of pressure (Pascal). If all three are indeed connected to the molecular interaction strength they must of course be closely related. Are they?

[86]The vibrations of the molecules are so quick that they are averaged out in all measurements.
[87]The upward force that they experience is much smaller because there are only few molecules above them.

As an illustration let us answer this question for the alkanes C_nH_{2n+1}, more specifically I will consider pentane ($n = 5$), hexane ($n = 6$), heptane ($n = 7$), octane ($n = 8$) and pentadecane ($n = 15$) The data for t_b and H are given in Fig. 8.2. There is not only a clear relationship between the two variables but also a high linear correlation: the correlation is 0.999 and the regression line is: $H = 0.1t_b + 21$. Thus this result comes as a confirmation of our assumption that both variables are related to the interaction strength.

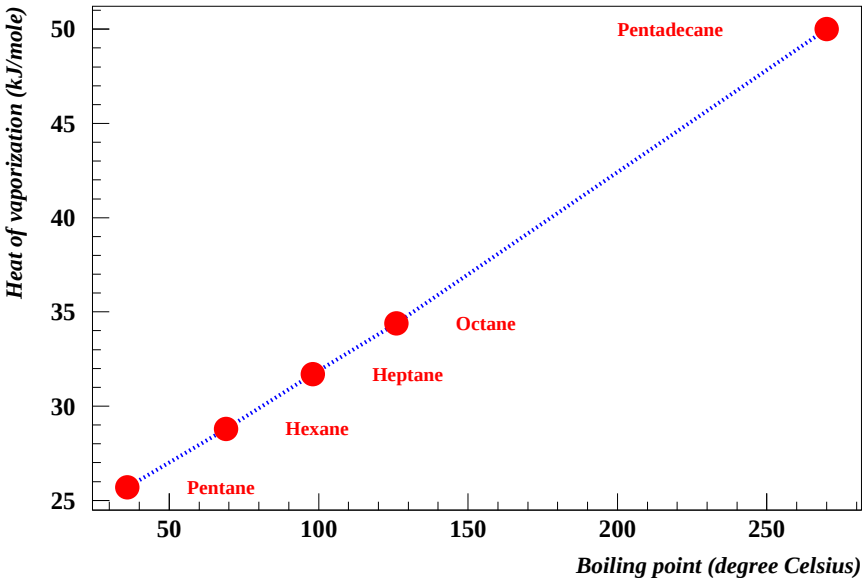

Fig. 8.2 Relationship between boiling temperature and heat of vaporization. All 5 alkanes are liquid at room temperature. The close relationship between the two variables confirms that they both express the molecular interaction strength. *Source: Lide (2001).*

Remark How can one derive the bond energy between two molecules from the heat of vaporization? Heat of vaporization is easy to measure. For water it is equal to 41 kJ/mole, but what does it represent in terms of molecular interaction? It is the energy corresponding to *all* the links that a water molecule has with other molecules that surround it. This can be checked by the following calculation.

- From the permanent dipole moment of water molecules which is 1.8 Debye one can derive the energy associated with the dipole-dipole interaction: 36 kJ/mole.
- In addition there is a London interaction i.e. through (non-permanent) induced dipoles which represents 11 kJ/mole. The total is 47 kJ/mole which is reasonably close to the 41 kJ/mole of the heat of vaporization[88].

The next step consists in determining the interaction between *two* molecules[89]. This

[88]The same observation holds for other substances. Thus in liquid argon the molecules have an interaction energy of 8.5 kJ/mole (solely due to London interaction) whereas the heat of vaporization is 6.7 kJ/mole. In liquid chlorhydric acid the molecules have an interaction energy of 21 kJ/mole (3.3 kJ/mole due to dipole-dipole + 17.7 kJ/mole due to London interaction) whereas the heat of vaporization is 16 kJ/mole.

[89]This will lead to the determination of the potential of interaction for a pair of molecules. The great advantage of this

is a much more difficult step for we need to know how many links each water molecule has with neighboring molecules. Such information can be obtained from X-ray scattering experiments but, as emphasized above, these measurements are tricky because of the great variability of the bonding patterns in the course of time. Such experiments lead to the conclusion that each water molecule participates in 4 bonds; since each bond links two molecules there are 4/2=2 bonds per molecule. Apart from the energy required for breaking the bonds, a part of the heat of vaporization is required to vaporize (that is to say increase the volume) of the water sample. This part is small however: 2.8 kJ/mole. Another part of the heat of vaporization goes into cutting the medium range interactions (that we do not represent by bonds); this part is small also and we will ignore it here.
Thus, one is lead to a bond energy of $(41 - 2.8)/2 = 19$ kJ/mole.

If the previous arguments are correct, there should be a fairly high correlation between heat of vaporization and equilibrium vapor pressure for different liquids. Is this the case? A first difficulty is the fact that to define a vapor pressure one must select a specific temperature. Which temperature should one select? It is fairly natural to try room temperature (i.e. 25 degree Celsius); the relation between boiling temperature and vapor pressure at 25 degree is represented by the curve in blue on Fig. 8.3. There is a non-linear dependence between the two variables but no significant linear correlation (by which we mean that the confidence interval for the correlation includes 0)[90].
One may reason that the vapor pressure is highly dependent on how far one is from the boiling point. Of course if we take as reference temperature the boiling point all the vapor pressures will be equal to one atmosphere which means that this is not a good solution either. As an intermediate solution we try a temperature of 35% of the boiling point. This leads to the magenta curve in Fig. 8.3; yet there is still no significant correlation. The present difficulty comes from the fact that it is the *logarithm* of

potential function is the fact that it is valid no matter in what state (gas, liquid or solid) the molecules are. This is why the interaction potential is often derived from the virial coefficient B which is defined for gases as:

$$B(T) = 2\pi N \int_0^\infty [1 - \exp(\phi(r)/kT)] r^2 dr$$

($N =$ Avogadro number, $k =$ Boltzmann constant, $T =$ Kelvin temperature).
B can be derived from the Van der Waals parameters a, b of the gas: $B = b - a/(R - T)$, where R is the ideal gas constant. a, b are defined by the state equation:

$$\left(p + \frac{n^2 a}{V^2}\right)(V - nb) = nRT, \quad p: \text{ pressure}, \quad V: \text{ Volume}, \quad n: \text{ number of moles}$$

a expresses the attraction between molecules; it is equal to 0.03 for helium, 1.4 for nitrogen and 15 for butane.

[90] What makes the linear correlation important is the fact that in the social sciences due to the high level of background noise it is often the only possible observation. For the alkanes it is the quasi-absence of noise which enables us to determine that there is a nonlinear dependence.

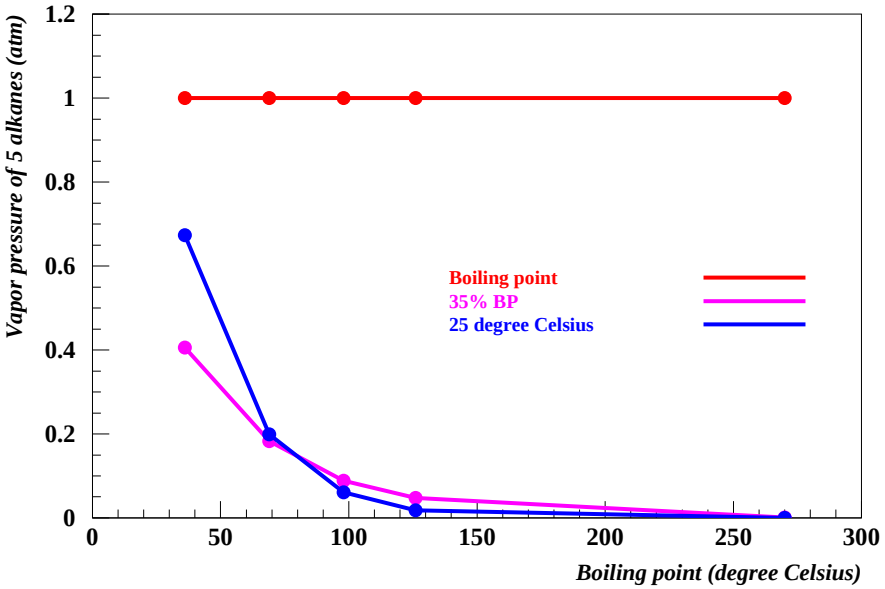

Fig. 8.3 Relationship between boiling temperature and vapor pressure. Each of the 5 points corresponds to an alkane; from left to right: pentane ($n = 5$), hexane ($n = 6$), heptane ($n = 7$), octane ($n = 8$), pentadecane ($n = 15$). The horizontal scale represents the boiling temperature of these 5 alkanes. The vertical scale represents the vapor pressure for each alkane at different temperatures (i) at the respective boiling points (in which case the pressure is of course simply the atmospheric pressure) (ii) at 35% of the respective boiling temperatures (iii) at room temperature (i.e. 25 degree Celsius).
Both the boiling points and the vapor pressures are an expression of the interaction strength but it can be seen that the relationship between them is no longer as clear as in Fig. 8.2: there is no significant (linear) correlation between boiling temperatures and vapor pressures for the three sets of points. *Lide (2001), http://www.s-ohe.com/Octane_cal.html*

the vapor pressure which is a linear function of the interaction strength whereas the boiling point is (almost) a linear function of the interaction strength.

We have explained this case in some detail because it shows that even in physics it is not easy to establish a connection between different indicators of interaction strength. So we should not be surprised to face similar difficulties with different social indicators of interaction strength.
How can this approach be transposed to the social sciences? This issue is discussed in the next section?

Comparing several indicators of social interactions

The main idea is to measure a given type of interaction by *several* indicators and to check to what extent these measurements are correlated. Fig. 8.4 provides an illustration of this approach that is based on a *Gedanken* experiment which means that although plausible, these data are not real data. The graph provides a comparison between two possible interaction indicators, the dropout rate and the time spent together. These indicators have been selected because it should be possible to obtain them fairly easily by contacting clubs and associations.

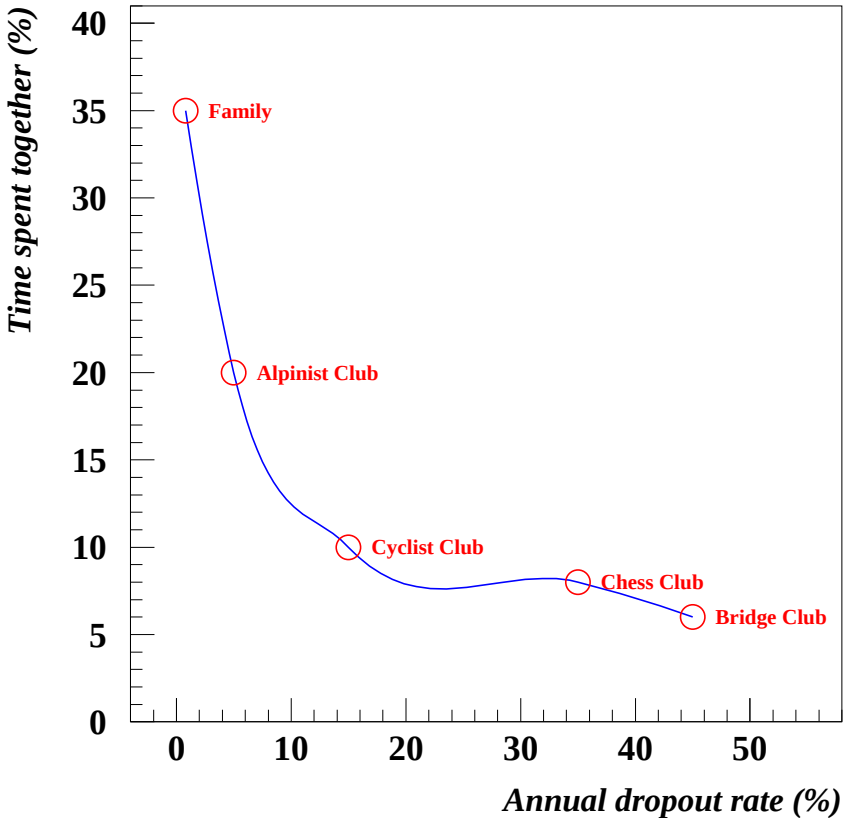

Fig. 8.4 Relationship between two indicators of social interactions. One would expect that the two indicators reflect the interactions between the members of these organizations. If the indicators were found to be fairly closely related as in this graph this would come as a confirmation. This graph which is based on hypothetical (not real) data was drawn in parallel with the graph in Fig. 8.2.

Prospects

In this section we propose three directions for future research.

- The first one relies on field research in the world of clubs and associations.
- The second one is a proposal for a series of field experiments.
- The third one is a study about marriage, divorce and separation, a topic for which many data are available online in different countries on the websites of national statistical offices.

Interaction strength in clubs and associations

Let us come back to the graph in Fig. 8.4. How can one collect the data needed to build such a graph? The time that members spend together can be estimated from interviews with a sample of members. In order to estimate dropout rates one needs membership numbers[91] and data giving the numbers of new members $\Delta n_1(t)$

[91] One must beware of the fact that if there is no subscription, members who leave the association will not unsubscribe which means that membership data are likely to be inflated and completely unrealistic. In that cases it may be more effective to record the average number of those who actually take part in the activity of the association. Such information

in a given time interval (for instance a year). If membership implies a (substantial) subscription then to get the number $\Delta n_2(t)$ of those who withdrew one can just count the persons who stopped paying their subscription. Whether one measures n_1 or n_2, the dropout rate

$$d(t) = \frac{N(t+1) - N(t) - n_1(t)}{N(t)} = \frac{n_2(t)}{N(t)}$$

will be correct only if $N(t)$ is a realistic estimate of actual membership by which we mean that only those who take an effective part in the activities should be counted.

Naturally, as in all social phenomena one should expect a substantial level of "noise"[92]. This noise can be reduced in two ways:

(1) By performing observations on *several* clubs of each kind. For instance, instead of investigating only one chess club the same observations will be performed on 3 or 4 chess clubs. The data point in Fig. 8.4 will then represent the averages for all chess clubs that have been studied. In big cities like Beijing, New York, Paris or Shanghai there are probably more than half a dozen active chess clubs which means that this averaging process can be performed even in studies done at the level of a single city[93].

(2) By pre-selecting the clubs to be investigated so that they are as similar as possible. For instance, alpinism is a broad term which includes many different activities, e.g. indoor wall climbing, outdoor wall climbing, rock climbing, ice climbing, ascension of high altitude peaks in the Alps or in the Himalayas. These activities will produce different types of links between members and should therefore be distinguished. As shown by this example the pre-selection process requires some knowledge and understanding of the activity involved.

The nice feature of the graph in Fig. 8.4 is that it can be drawn for many different places and countries. As most cities have plenty of clubs and associations of all kinds it will be possible to repeat this experiment a great number of times in each country. The ability to perform many experiments is the key factor which will allow us to produce robust results.

Influence of conflicts between states on mixed couples

In a novel entitled "The Patriot" which was published in 1940 Pearl Buck tells the story of a young Japanese who fled Shanghai in 1927 to avoid being executed as a Communist; his father sent him to Japan where he spent about 10 years. Around

will again be obtained from interviews with members.

[92] This term refers to all the features and circumstances by which two chess club may differ even within the same country or within the same city.

[93] These comments about the reduction of background noise will also apply to the other projects. In any new physical experiment the reduction of noise is an important challenge. This is true to an even greater degree for social observations. A more detailed discussion of the issue of noise reduction can be found in Roehner (2007, chapters 2 and 3)

1933 he got married with a Japanese girl. As the military confrontation between the two countries escalated he experienced a growing ostracism in the Japanese society and at a personal level he found himself subject to two opposed forces: his love for his wife and his attachment to China. Around 1938 he leaves his wife and two sons and goes back to China to join the Chinese Army in its fight against Japanese forces.

All mixed (bi-national) couples may experience a similar conflict when a war breaks out between the respective countries of origin of the partners. This is an interesting situation because it allows us to draw conclusions about the relative strength of two forces: the marital bond on the one hand and patriotism on the other hand. If 90% of the mixed couples ask for a divorce, it would mean that patriotism is stronger than the marital bond. On the contrary, if only 10% of such couples ask for a divorce, it would imply that it is the marital bond which is the strongest. The great interest of such an observation is to connect two different forces of cohesion.

The statistics which are needed for this quasi-experiment are data about rates of divorce or separation in mixed couples by respective nationality of the partners.

Field experiments (in Stanley Milgram's style)

For the second example we return to the empty seat experiment described in the 5th lecture. Initially, we considered the case of subway cars but the same experiment can be made as well in other places: waiting rooms in railroad stations, benches in public parks or commercial centers, etc. Any situation in which there are more people than seats will provide an opportunity to carry out such experiments.

As in the previous experiment, it will be possible to repeat this experiment in many different places, countries and conditions. Thus, it will again be possible to average out the background noise.

In the two previous experiments the important point will be to show that the measurements are robust and reproducible because this will open the way to other experiments designed in a similar way. I am convinced that once several experiments of this kind have been conducted we will see more clearly the route that leads to a better understanding of social interactions.

Marriage and separation seen from the perspective of chemical kinetics

Marriage, that is to say the association between men and women, is well documented through vital statistics data and such data are available for almost all countries. In chapter 4 we have introduced a simple "model" for this association. Basically, we have shown that this social phenomenon can be investigated from the perspective of chemical kinetics. This parallel enabled us to define and estimate association and dissociation rate constants as well as equilibrium constants. Such a perspective can be developed in different ways, such as the following ones.

(1) First it is important to check to what extent the association, dissociation and equilibrium constants are equal in different areas or countries.

(2) It would be interesting to find historical episodes during which these rates took on extreme values, either very small or very high. Tthis would provide an insight into main social determinants.

(3) Through comparative analysis on data from different countries it should be possible to understand how these rate constants are determined by prevailing social conditions in terms of contact frequency and "effectiveness" of such contacts.

As in the two previous cases, the investigation of marriages can be carried out in various countries. This will enable us to explore the effects of a broad range of social conditions. Thus, we are on solid ground for thorough comparative analysis.

First objective and beyond

What should be our first objective?
As in all scientific observations the first requirement is to show that the experiments are *reproducible*. So, the first (and crucial) challenge will be to establish that social interactions are sufficiently robust, stable and (in some way) "universal" to be measured in a meaningful way.

Once this has been established, it is our hope that similar studies will be carried out by other groups of researchers. This would lead to a *cumulative* body of data and knowledge on which a real understanding of social phenomena may progressively build up. Can the "theory" developed in these lectures help us to better understand how this process my develop?

As emphasized at the beginning of these lecture notes, measuring social interactions must rely on a long-term program covering several decades. Experiments like the one described here will prove that such a program is indeed feasible.

In the first lecture we described the process which lead to the emergence of quantum mechanics in the 1920s. The process comprised three stages.

(1) The accumulation during the previous decades of many experimental results which could not be explained in the framework of classical physics.

(2) The emergence of the main concepts of quantum mechanics between 1925 and 1928.

(3) The applications of the ideas of quantum mechanics to many other fields such as chemistry, astrophysics, solid state physics and so on.

If one tries to apply this "model" to the topic considered in these notes one must be lucid enough to recognize that even the first phase has not yet really begun. There are currently a number of pioneers in this field many of whom were mentioned in

these lectures[94]. However we are not yet in a phase in which empirical knowledge develops in a cumulative way. This is because of two main reasons.

- Empirical investigations represent a tiny percentage of current publications in this field. About 90% of the papers are devoted to mathematical models and theoretical simulations often with little empirical basis.
- Empirical studies are done from different perspectives which bars any cumulative process. For instance, while some studies will investigate the (non weighted[95]) network structure of a system, others will propose criterions for distinguishing between endogenous and exogenous factors. Of course, such studies contribute to the same final objective, namely to understand how people interact, but they are still too segmented. We are not yet in the coalescence phase in which the results become connected enough to be confronted and compared. In short, the interaction between various studies is still too weak.

When can we expect the coalescence phase to start? Once a topic emerges which is simple and promising enough to attract many studies, the "density of results" will become high enough to allow consistency checks and comparisons. This will mark the beginning of an accumulation process.

[94] E.g. Yuji Aruka, Jean-Philippe Bouchaud, Zengru Di, David Laitin, Menghui Li, Sergei Maslov, Jürgen Minkes, Makoto Nishibe, Didier Sornette, Dahui Wang.

[95] In contrast, a *weighted* network would represent the strength of interactions between agents and would therefore be much closer to the objective pursued in these lectures.

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