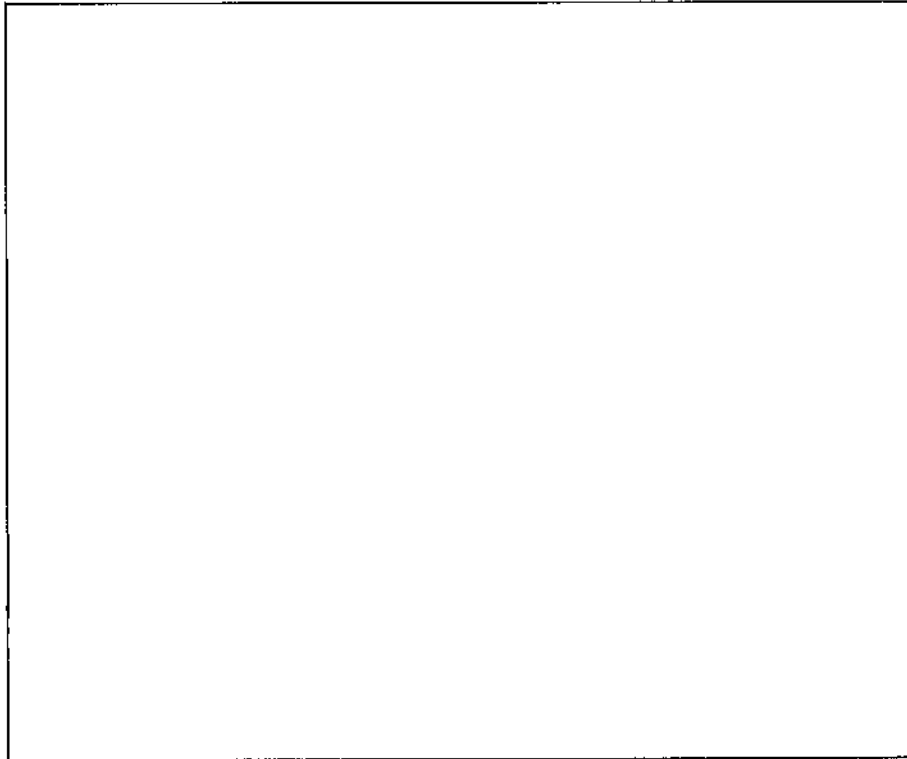


# Professional Paper



**MARCHETTI-077**

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KILLER STORIES  
A System Exploration in Mortal Diseases

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## FOREWORD

The power of Darwin-Volterra methodology to describe the dynamics of competing structures is being tested through exploratory checks in various fields. After energy markets, invention and innovation, transportation, it is now the time of causes of death in a certain human population, basically that of the United States.

The result of this first exploration is reported in the paper, and shows that this could be another fertile area. At first sight the major consequences of such an approach would be at the institutional level, where the perception of institutional power and the optimal use of medical tools can be drastically influenced by the new conceptual map emerging from the analysis.

Properly developed, this could become a valuable contribution to the "Applied" in the IIASA logo.

## KILLER STORIES

### A System Exploration in Mortal Diseases

Some years ago, I started a research on the dynamics of energy markets that led me to discover, in a tortuous way, the power of Volterra equations as descriptors of human affairs [1]. Because these equations really describe the dynamics of competition between structures capable of multiplication and expansion, I tried heuristically to apply them to all sorts of situations where the concepts applied, even at a very abstract level of definitions [2,3].

The results of these scouting operations are curious because they show iron order in places where one would expect perfect disorder with occasional divine intervention, and they are striking because an extremely light mathematical apparatus can organize the most disparate occurrences.

I will briefly report here on the application of this kind of analysis to mortality by various diseases in a certain human population expressed by geographical area, e.g. United States, or by social categorization, e.g. elderly people in the city of Florence. The leading concept is very simple and a little queer: I visualize humanity as a kind of big broth, where different populations of microscopic creatures swim and thrive. The size of the pool being limited and the populations striving for number

and power, the dynamics of the battle keeps them growing and fading. If their presence manifests itself through a certain number of host killings, I will use them as a proxy for the strength of the populations.

I am very aware that this logic does not have a delicate flavor; on the other hand, the naked results are usually hard to digest. So I have to strike a compromise, hoping to improve the case in a second iteration.

In this Volterra-logistic analysis two mathematically equivalent procedures are followed: the fight can be seen as one against all the others, and so, e.g., mortality from a given disease checked against total mortality. Or it can be seen as the summation of one to one fights, where, e.g., tuberculosis competes with pneumonia for a share in carcasses. Since I am exploring I will use the two, as they permit different outlooks and insights. The fitting equation in both cases is the same.

$F/1-F = at+b$ , where  $a$  and  $b$  are constants,  $t$  is time and  $1$  is the total set of cases. So the competitor is expressed as  $F$ , the fraction of a total number of cases. If the competitors are only two, then  $F$  can be seen as the cases attributable to competitor one, and  $1-F$  to competitor two. Table 1 reports very synthetically the mathematics of the analysis.

In order to stress the formal analogy with socioeconomical behavior, Fig. 1 reports the competition between primary energy sources for the world market. The smooth curves are a system of two parameter logistics as described on the right side of Table 1. The wiggled lines are the actual statistical data. In view of the very long time span, the fitting can be considered very good. Fig. 2 reports the competition between surface and underground mining in the U.S. Both competitors are reported here when only

one is necessary because the curves are mirror images. Usually one curve is deleted, that of the loser.

Figure 3 reports the evolution in time, from 1900 to 1970, of the deaths due to flu plus pneumonia in relation to all causes of death, in the United States. The definitions are taken from the statistics [4] and may sound a little mixed up to a medical ear. The secular trend, however, is neat and clear as a simple downward logistic that, in our coordinates, appears as a straight line.

As many other case histories show, deviations from the secular trend are elastically reabsorbed, i.e. they do not leave a long-term trace. Noticeable here is the "Spanish flu" peak at the end of World War I, which by the way may not have been a flu at all. The time constant of the process is by definition the time necessary for the function  $F/1-F$  to go through two decades in our ordinates. In the special case of Fig. 3, deaths take about 100 years to go one decade down from 10% to 1%.

The evolution of deaths by malignancies, i.e. cancer in various forms, are reported in Fig. 4. As often said, their toll has been on the increase. What we add is that its evolution in time follows a precise rule for almost 80 years (our statistics reach only 1977). A saturation level followed naturally by a phase-out is actually in sight. Both could be calculated if we had a complete map of all other causes of death. In the logic of competition, in fact, phase-out of one of the contenders is normally due to phase-in of some other more successful contender.

In Fig. 5 the collective progress of major cardiovascular diseases is reported. Here again the smooth curve shows a good fit with the equations. Cardiovascular diseases have been increasing their share in the death toll since 1900, lately getting

more than 50% of all deaths. The level point appears to be reached, which will be followed by a progressive phase-out. The time constants are however very long, and one should not hope very much on miracle drugs. A very interesting case in that sense is given by diphtheria.

Diphtheria is a disease caused by a double-ax bacterium, and one could expect an efficient drug to sweep it away, at least in countries with an efficient medical system, like the United States. The evolution of deaths by diphtheria are reported in Fig. 6, vs all other causes of death. The large-scale introduction of the antidiphtheric serum occurred at the beginning of the thirties, year more year less, and one should expect a sharp kink in the mortality curve. What the curve shows, however, is that mortality was very regularly decreasing since 1900, and no kink appears in 1933, the only difference between the periods before and after that date in the smoothness of the data. The effect of the serum, if any, at the population level, was to impede epidemic outbursts without however influencing the total number of deaths.

Apart from that, one should deduce from the analysis, it was basically useless, as the fate of the illness was sealed for other reasons yet to discover. Medical doctors will not be ready to accept that, as they have bitterly resisted the logic consequences of an analysis I have made on the evolution of illnesses with age. But they could not propose a solid counter-logic proving the effectiveness of their craft.

The case of tuberculosis is reported in Fig. 7. Here the curve is quite irregular, with kinks and all, and I propose to start a finer analysis. As I learned from other competition

cases, kinks usually appear due to improper categorization, i.e. when two populations behaving in a sufficiently different way are lumped together. E.g., jet, prop and turbo prop planes. They are all planes but, for instance, when they compete with ships for transatlantic passenger transportation, each class has a substantially different behavior. Another point is that populations become irregular when they are thin, i.e. below a fraction of 1% of the totals; the logistic behavior is often not followed, and irregularities may propagate occasionally to the 2-3% level.

In the case of tuberculosis, perhaps the miracle drug was discovered in 1955, and the kink is a consequence of that. I leave these questions open for a second round. After all, I am just reporting a very early exploratory stage in these matters. The ratio of killings by cardiovascular and cancer diseases is reported in Fig. 8. It shows that cancer slowly wins. The reason for presenting data this way is that many disturbing influences are eliminated, showing the clean progress of the fight. The case of gastrointestinal diseases is reported in Fig. 9, showing their practical disappearance, in a logistic phase-out. The sudden breakdown in 1965 is probably an error in the statistical tables. A reduction by a factor of ten in one year of a categorization, putting together many things from many causes, is improbable. A synopsis of the cases analyzed is reported in Fig. 10. Fig. 11 gives, in linear terms, all deaths in the United States per 100,000 population.

Two years ago, I suppose in preparation for the Year of the Aged, the World Health Organization supported a vast statistical survey on the situation of the elderly around the world.



Questionnaires were sent out with hundreds of questions and numbering in millions. The head of the Gerontological Clinic in Florence, Prof. Antonini, showed me a huge pile of computer printouts of the data, asking me if something could be done with them. Apparently all the survey had been done before asking such vital question.

My interest is in time-dynamics of competing structures, and in this case time was flat because the data referred only to the year of the survey. But the people were classified in age-groups. So to generate a time perspective, I made the assumption that people in different age brackets could be considered as the same population observed at different times.

The data which I analyzed referred to three population groups, one living in a city, Florence (Fi), the other in a village, Quarrata (Q), and the third scattered in the mountains of Amiata West (AW). Each group was split into males (M) and females (F). I looked at motor inabilities and total inabilities versus age, as they seemed to me to be reasonably categorized. The mean number per person is reported.

The technique I used to analyze these data is slightly different from the previous one, because I did not have a total against which to measure. So I fitted the data with three parameters logistics to find the saturation point out of the data themselves.

The results of the analysis are reported in Figs. 12 to 15. (Each point represents an age group, from 60-65 for the point on the left to 85-90 for the last one). Although the results cannot be classified as brilliant, they are certainly encouraging if one looks at all the twists I had to make to compensate for improper data collection.

If the results are true, then a mean is provided to estimate the evolution of a number of illnesses in a given population, after it has been under observation for a number of years, which could be a boon to facility planners. What the doctors on the other hand are not ready to accept is the loss of glare in the magic of their healing practices implied by my results. This implies a changing perception of the relationship between patients, drugs, doctors and institutions which may lead to criteria for optimizing the result in view of simply defined objectives.

As I said at the beginning, this analysis is occasional and exploratory. It shows, however, unsuspected order and regularity in an area where both have always been difficult to find, using different and more complex analytical procedures. It may be an encouragement to proceed and deepen in this direction, to provide an organized outlook first and the viable tool for planners we are groping for.

REFERENCES

- [1] Marchetti, C. and N. Nakicenovic. The Dynamics of Energy Systems and the Logistic Substitution Model. RR-79-13. International Institute For Applied Systems Analysis, Laxenburg Austria. December 1979; and Nakicenovic, N. Software Package for the Logistic Substitution Model. RR-79-12. International Institute for Applied Systems Analysis, Laxenburg, Austria. December 1979.
- [2] Marchetti, C. The Evolution of the Energy Systems and the Aircraft Industry. Chemical Economy & Engineering Review, May 1980.
- [3] Marchetti, C. Society as a Learning System: Discovery, Invention, and Innovation Cycles Revisited. RR-81-29. International Institute for Applied Systems Analysis, Laxenburg Austria.
- [4] Historical Statistics of the United States Colonial Times to 1970. Part I. Department of Commerce, Washington D.C. (1975).

Table 1.

THE MATHEMATICS OF COMPETITION

Two Competitors

Market = 1

$F_1$  Market fraction of competitor 1

$1-F_1$  Market fraction of competitor 2

$$\log \frac{F_1}{1-F_1} = at+b$$

where a and b are empirical constants.  
t is time.

Many Competitors

Market = 1

n-1 competitors are in the growing or declining phase

$$\frac{F_i}{1-F_i} = a_i t + b_i$$

One of the competitors is in transition. It is the oldest of the growing ones and it is defined as

$$F_j = 1 - \sum_{n \neq j} F_n, \text{ i.e. as a residual.}$$



Figure 1.

### WORLD PRIMARY ENERGY SUBSTITUTION

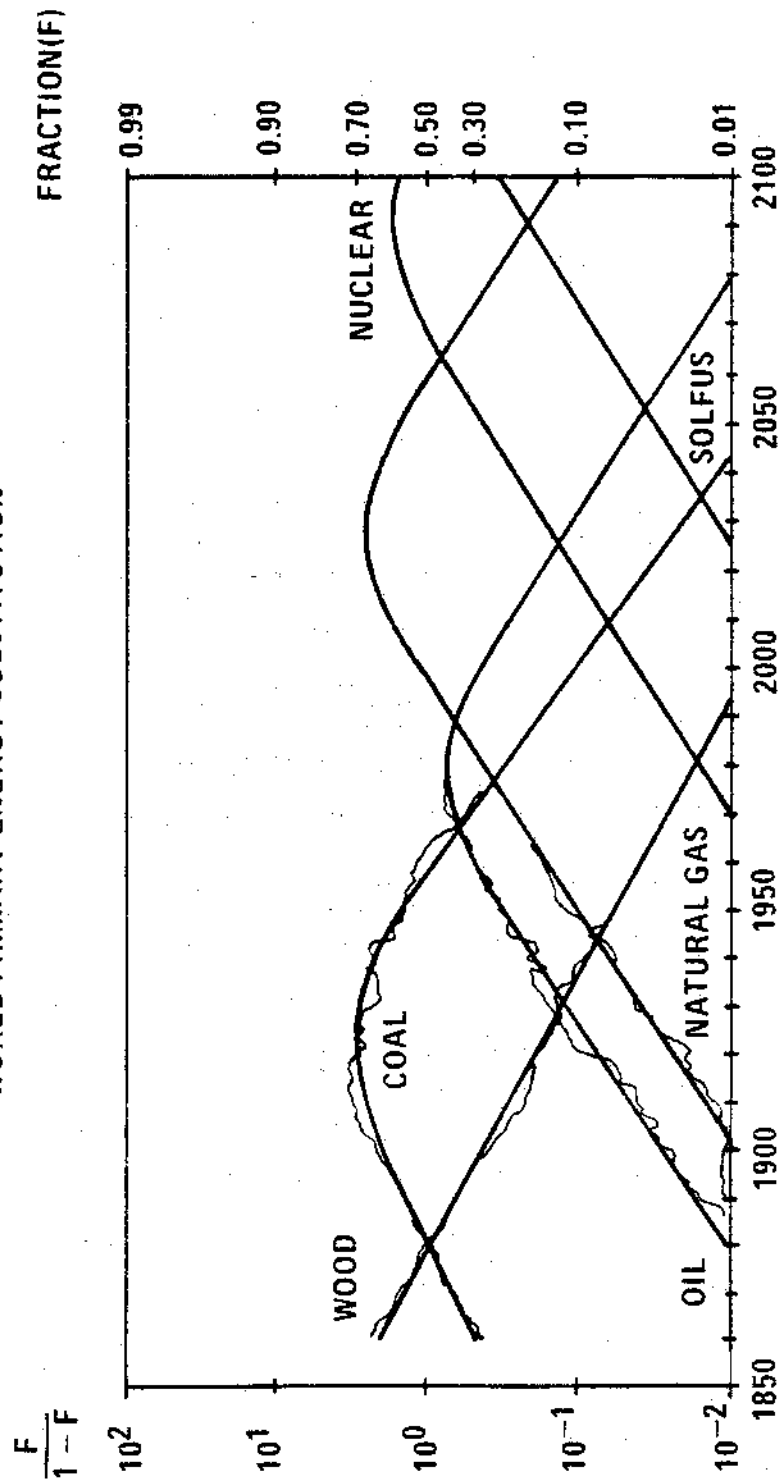


Figure 2.

USA - UNDERGROUND AND SURFACE MINING

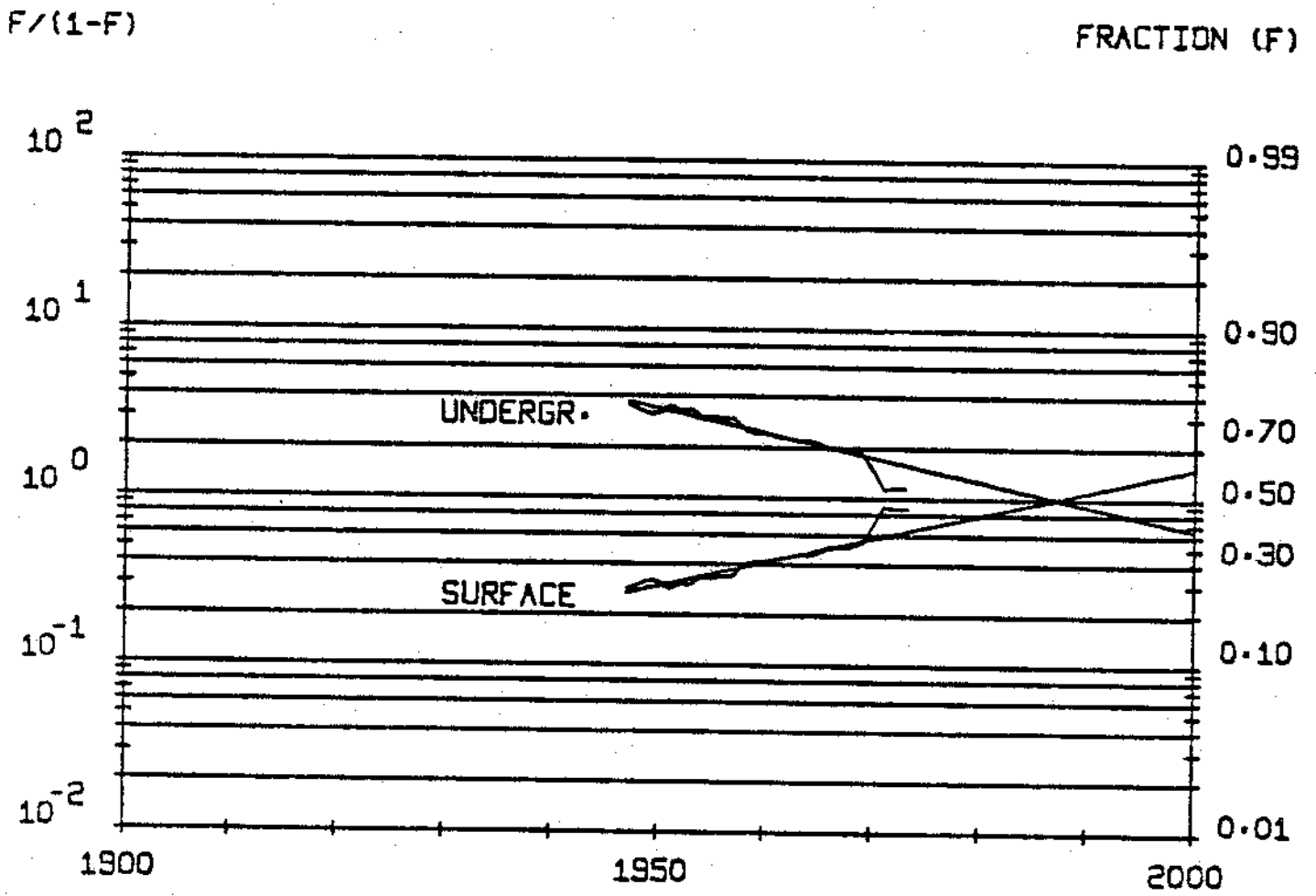


Figure 3.

PNEUM. & INF. VS. ALL CAUSES OF DEATH : US

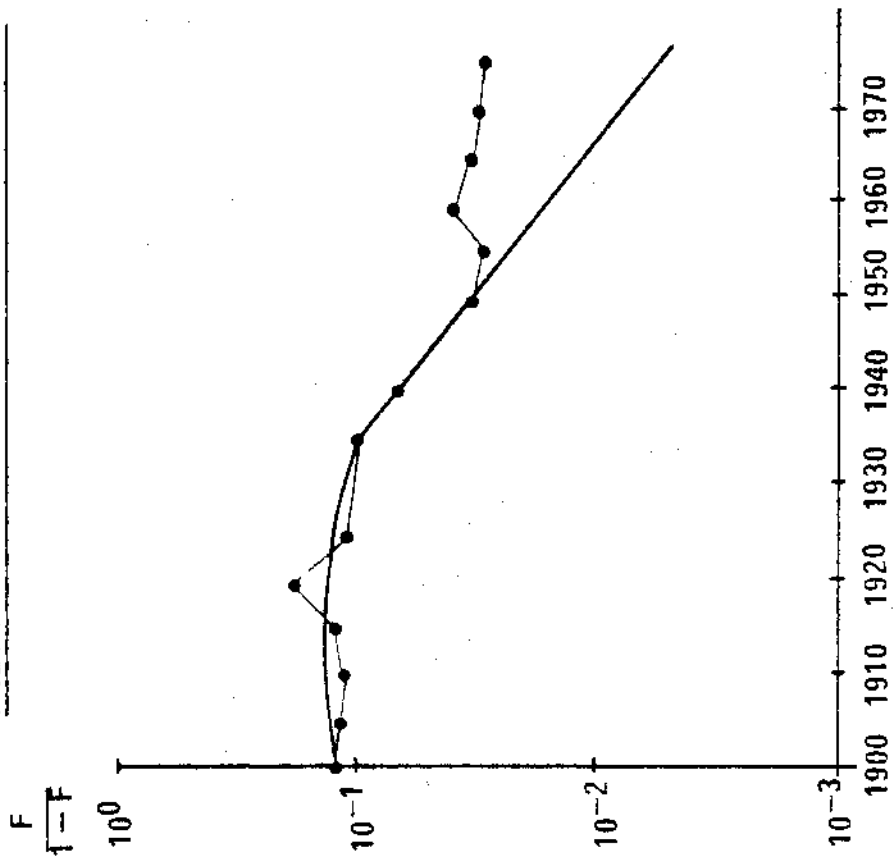




Figure 4.

NEOPLASTIC VS. ALL CAUSES OF DEATH : US

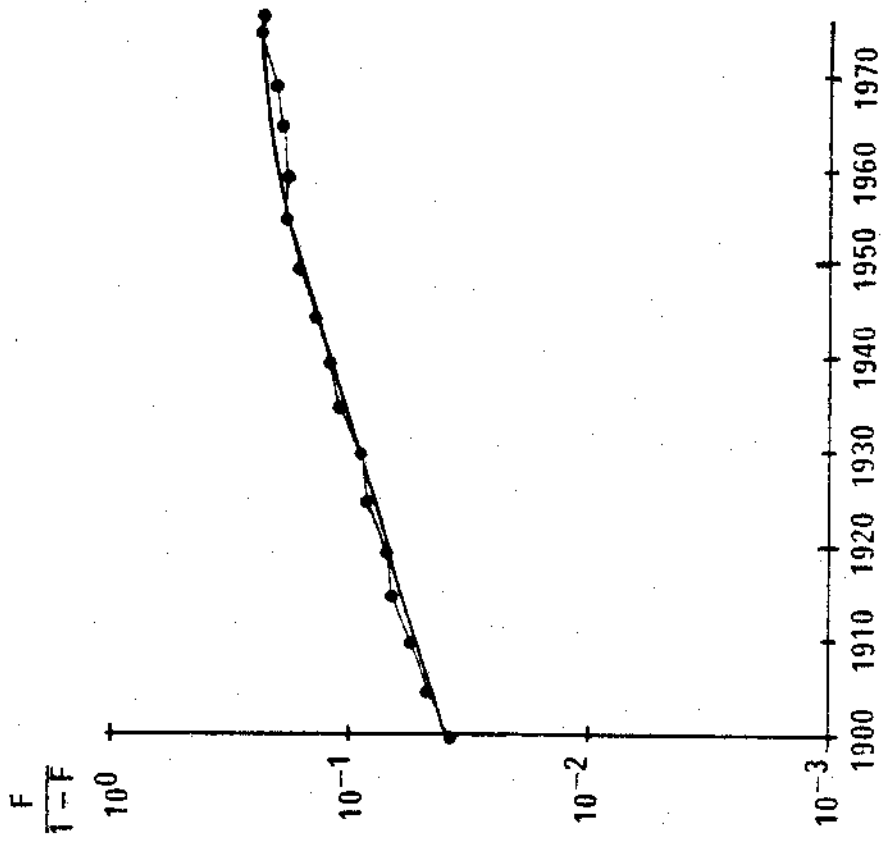


Figure 5.

CARDIOVASCULAR + RENAL VS. ALL CAUSES OF DEATH: US

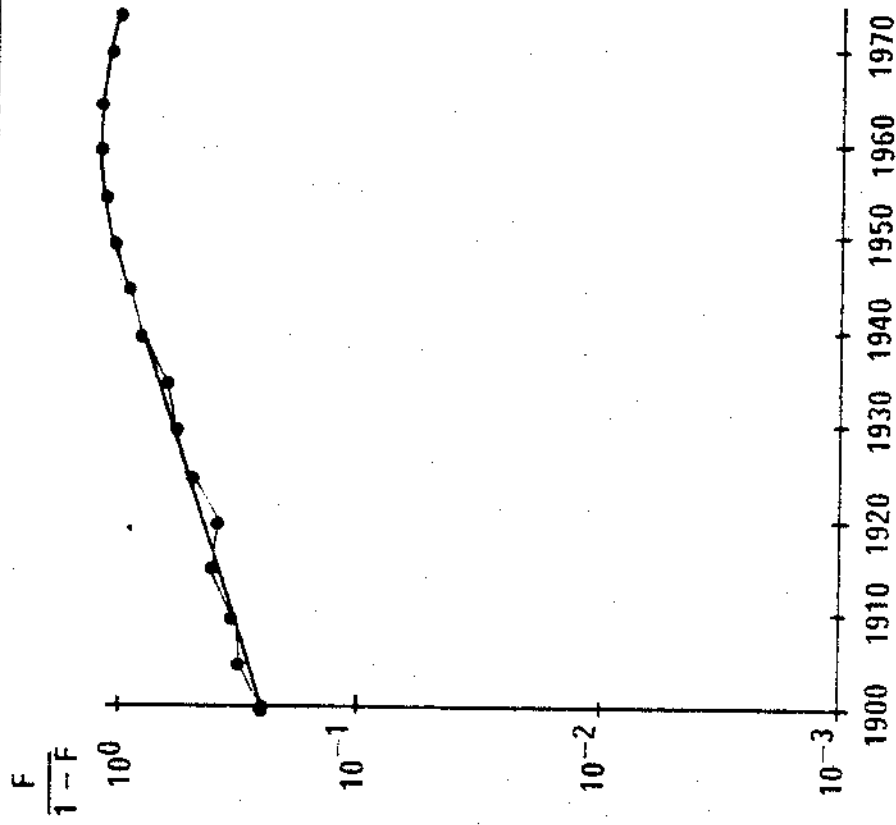


Figure 6.

DIPHTHERIA vs. ALL CAUSES OF DEATH (US)

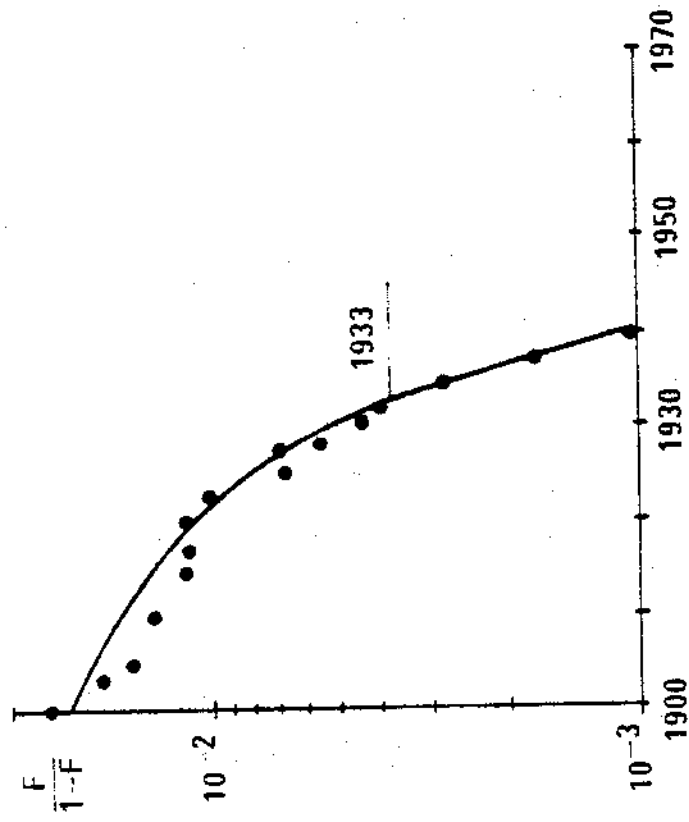


Figure 7.

TUBERCULOSIS VS. ALL CAUSES OF DEATH: US

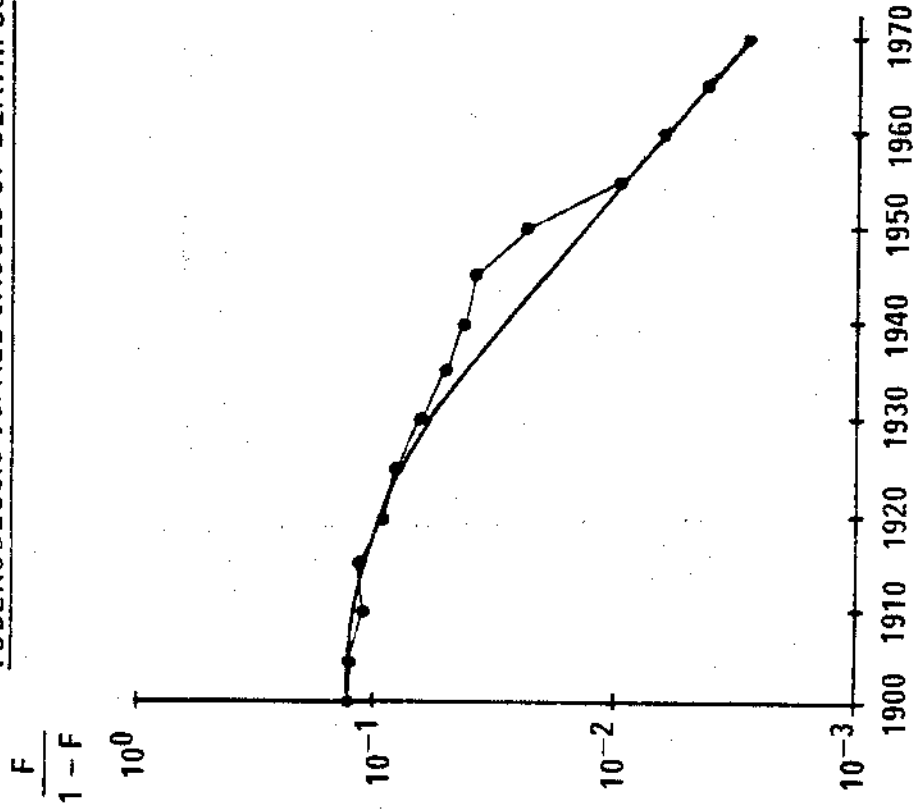


Figure 8.

CARDIOVASCULAR vs. NEOPLASTIC (US)

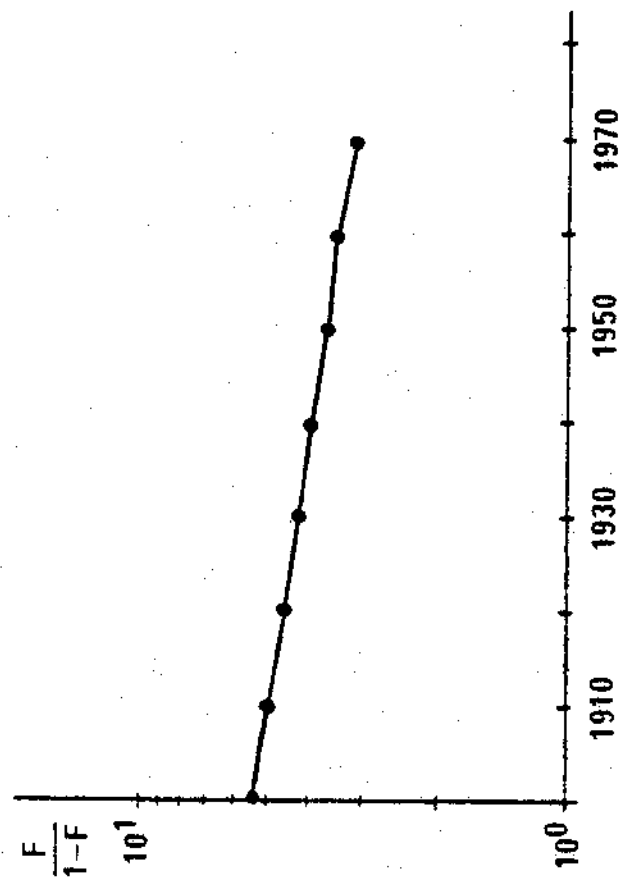


Figure 9.

GASTROINTEST VS. ALL CAUSES OF DEATH : US

$$\frac{F}{1-F}$$

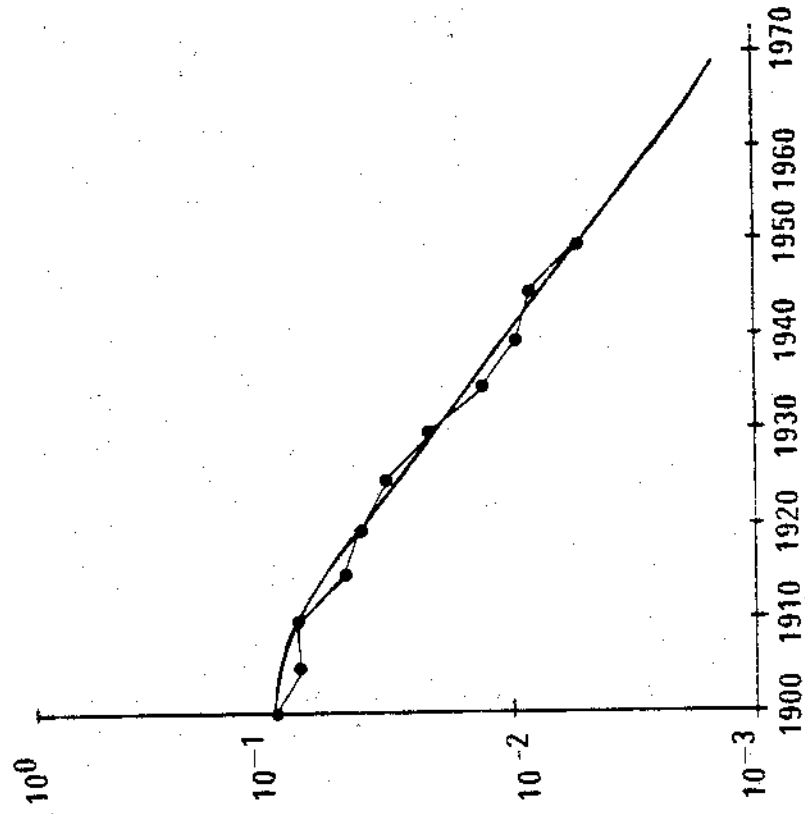


Figure 10.

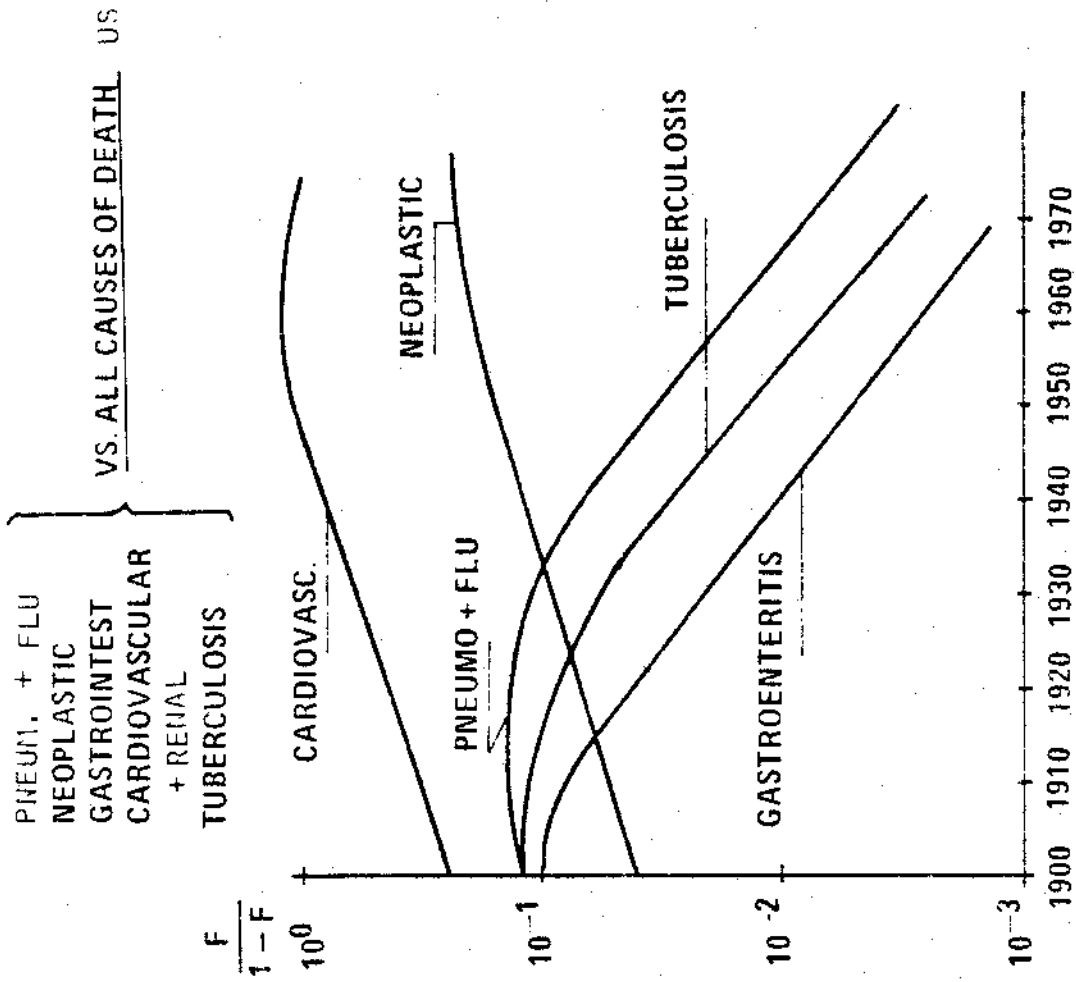


Figure 11.

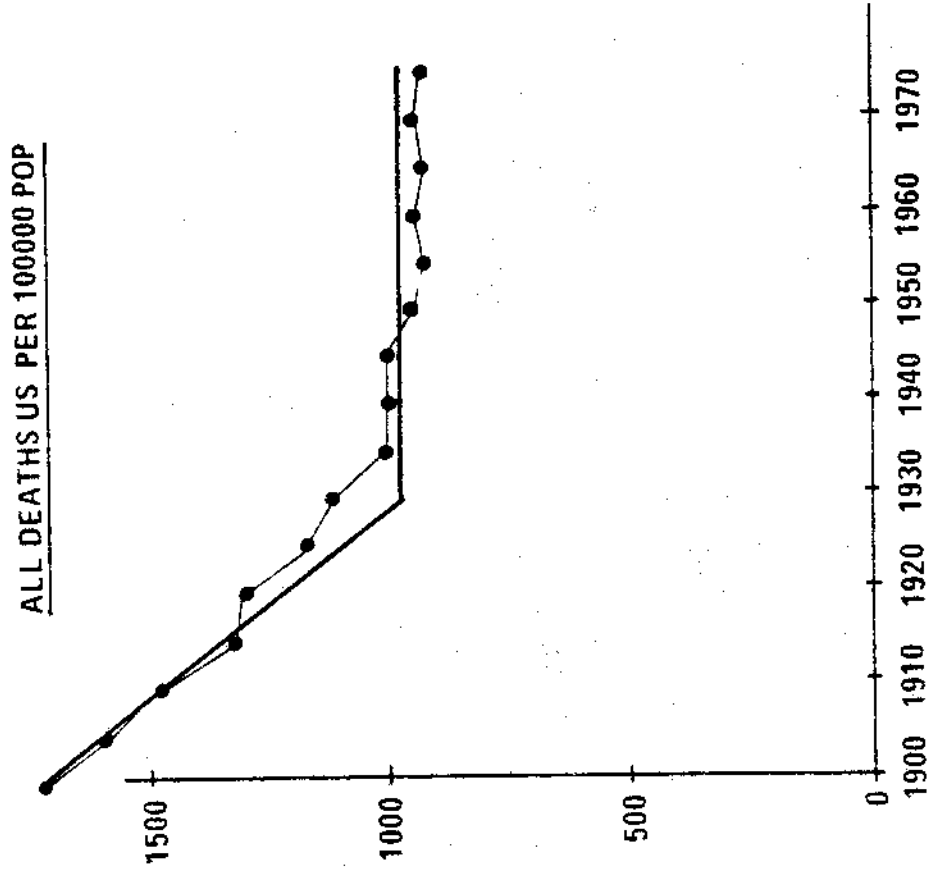
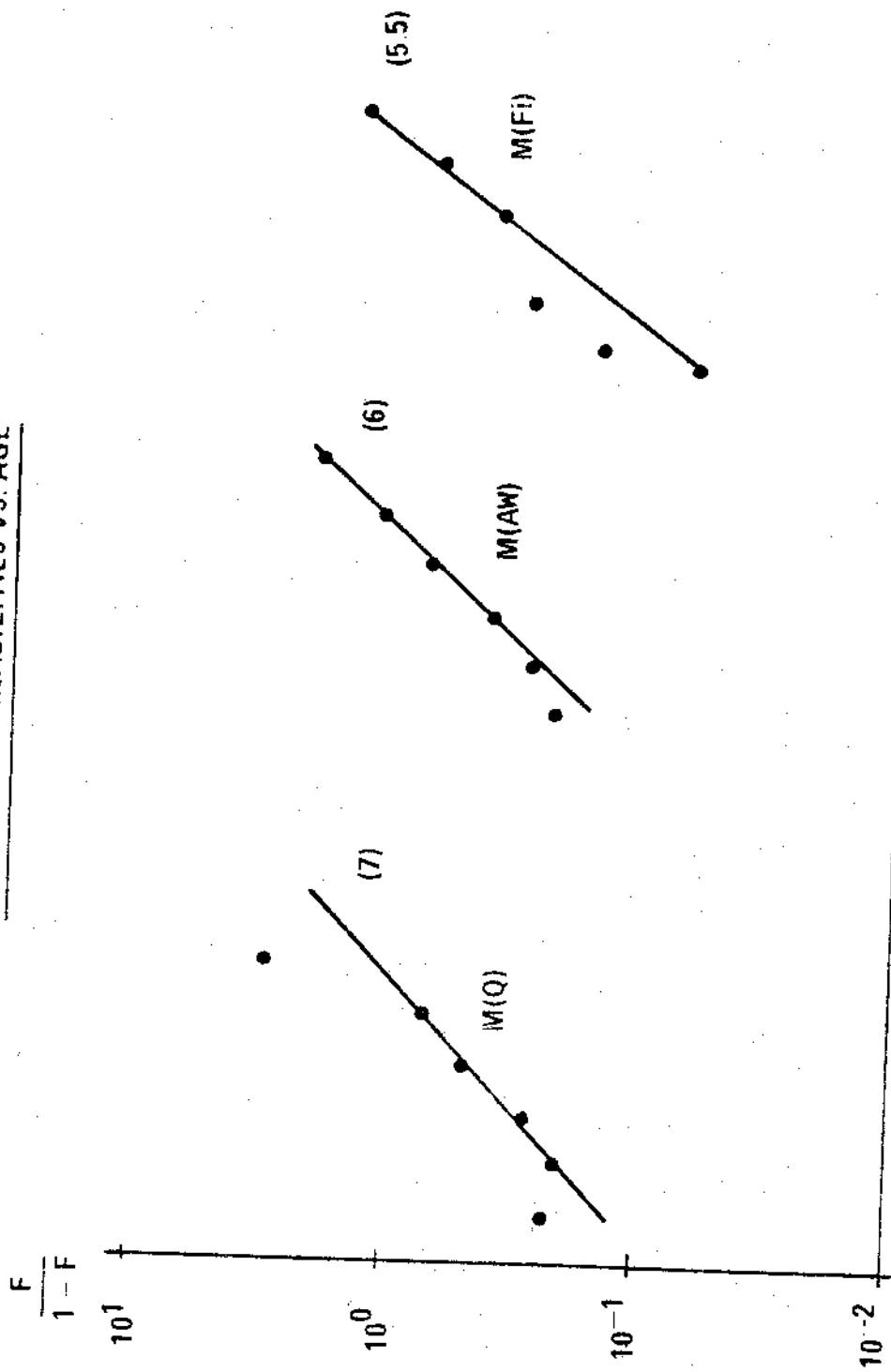




Figure 12.

EVOLUTION OF INABILITIES VS. AGE

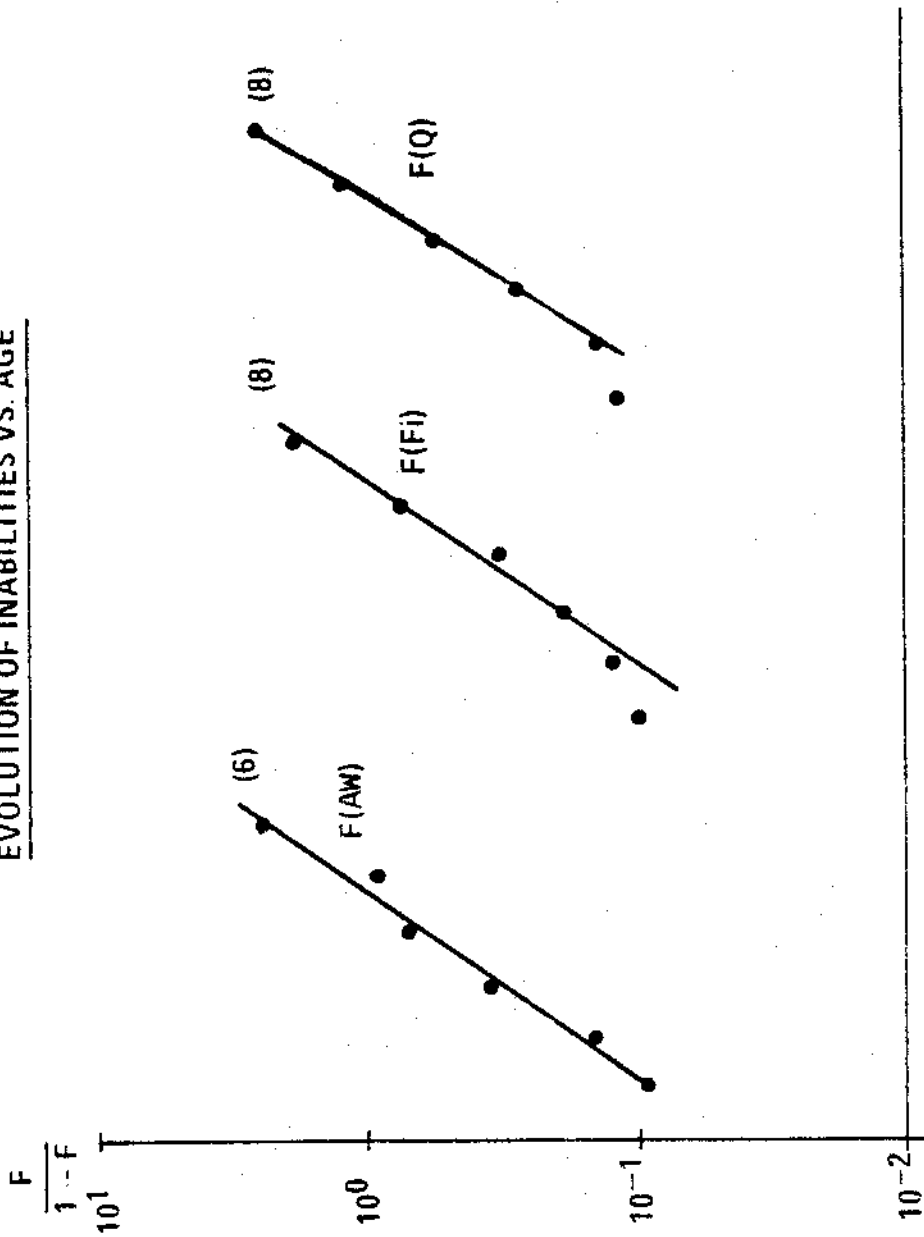


Data from World Health Org (1981)

(Explanation in text, page 6)

Figure 13.

EVOLUTION OF INABILITIES VS. AGE

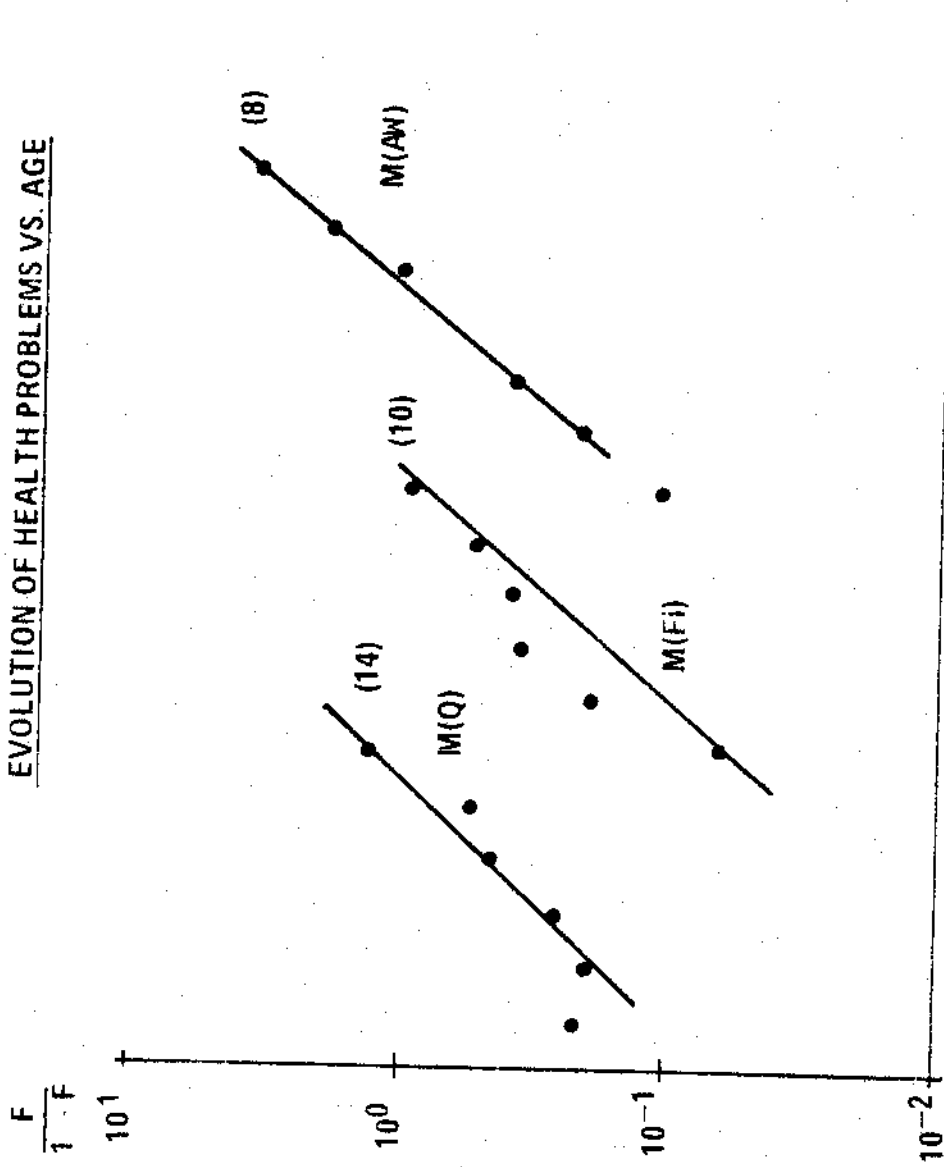


Data from World Health Org.(1981)

(Explanation in text, page 6)

Figure 14.

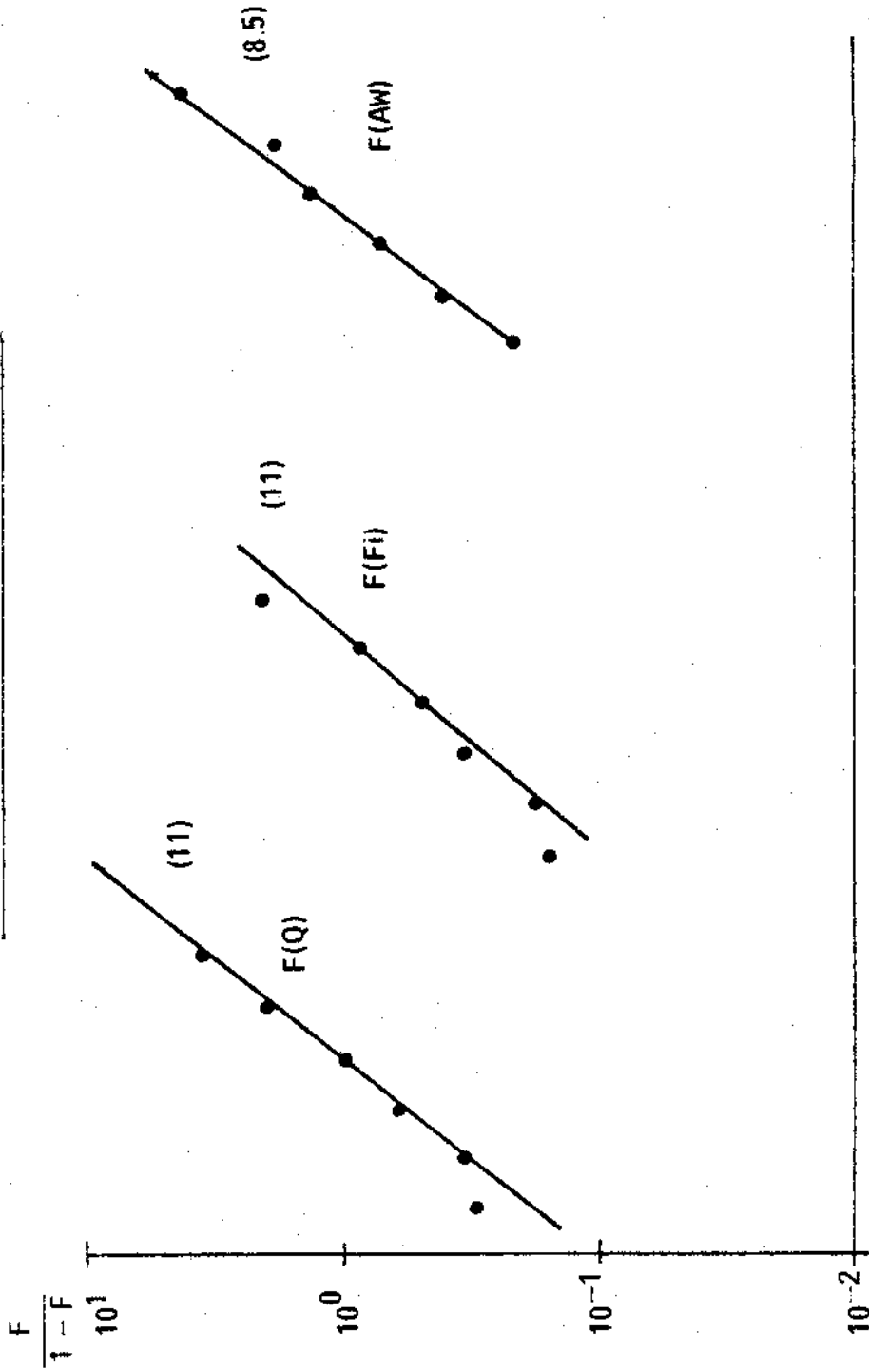
EVOLUTION OF HEALTH PROBLEMS VS. AGE



Data from World Health Org. (1981)

(Explanation in text, page 6)

Figure 15.  
EVOLUTION OF HEALTH PROBLEMS VS. AGE



Data from World Health Org. (1981)

(Explanation in text, page 6)

