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
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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 be-

cause 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 equi-
valent procedures are followed: the fight can be seen as one
against all the others, and so, e.g., mortality from a given di-
sease 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 in-
sights. 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 syntheti-
cally the mathematics of the analysis.

In order to stress the formal analogy with socioeconomical be-
havior, 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 wriggled 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 detahs 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-put 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 intro-duction 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 ill-nesses 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 sub-
stantially 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 gastointestinal diseases is reported in Fig.9, showing their
practical disappearance, in a logistic phase-out. The sudden break-
down in 1965 is probably an error in the statistical tables. A re-
duction 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 param-

eters 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.

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[3]  Marchetti, C.  Society as a Learning System:  Discovery,
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     (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

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

Figure 1.

WORLD PRIMARY ENERGY SUBSTITUTION



IIASA Version 14.10.1982 by N.Nakicenovic
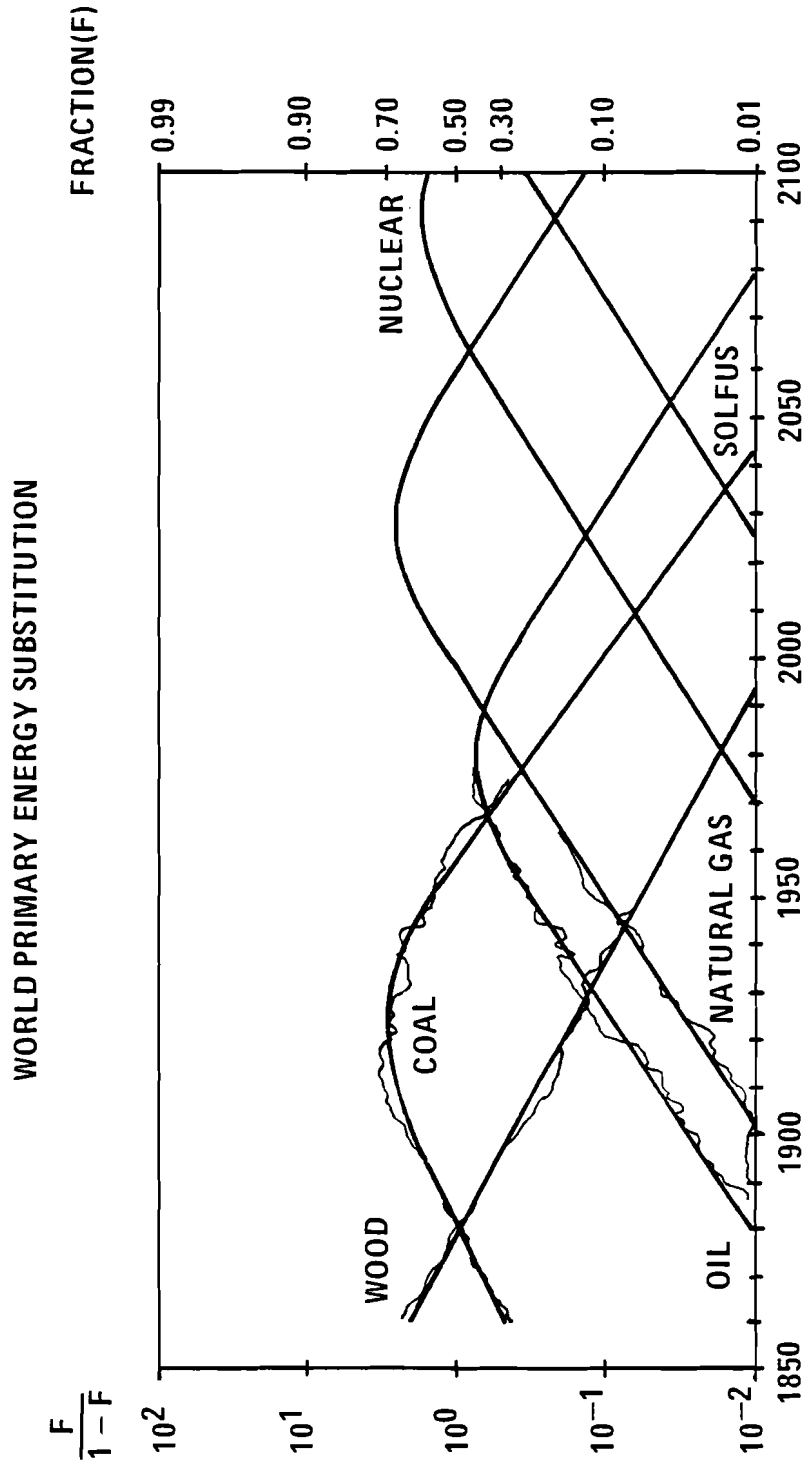
Figure 2.

USA - UNDERGROUND AND SURFACE MINING
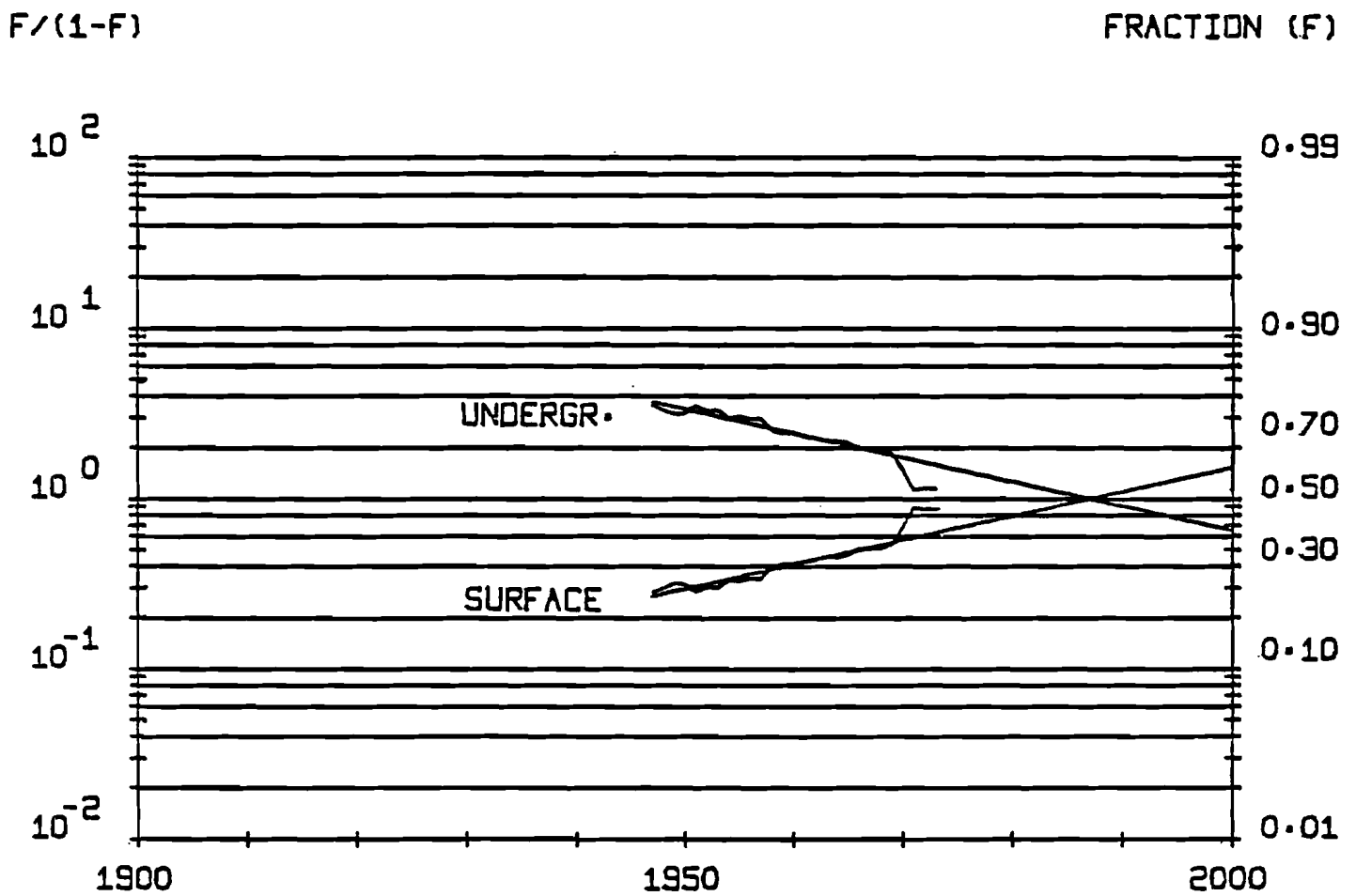
Figure 3.

PNEUM. & INF. VS. ALL CAUSES OF DEATH : US
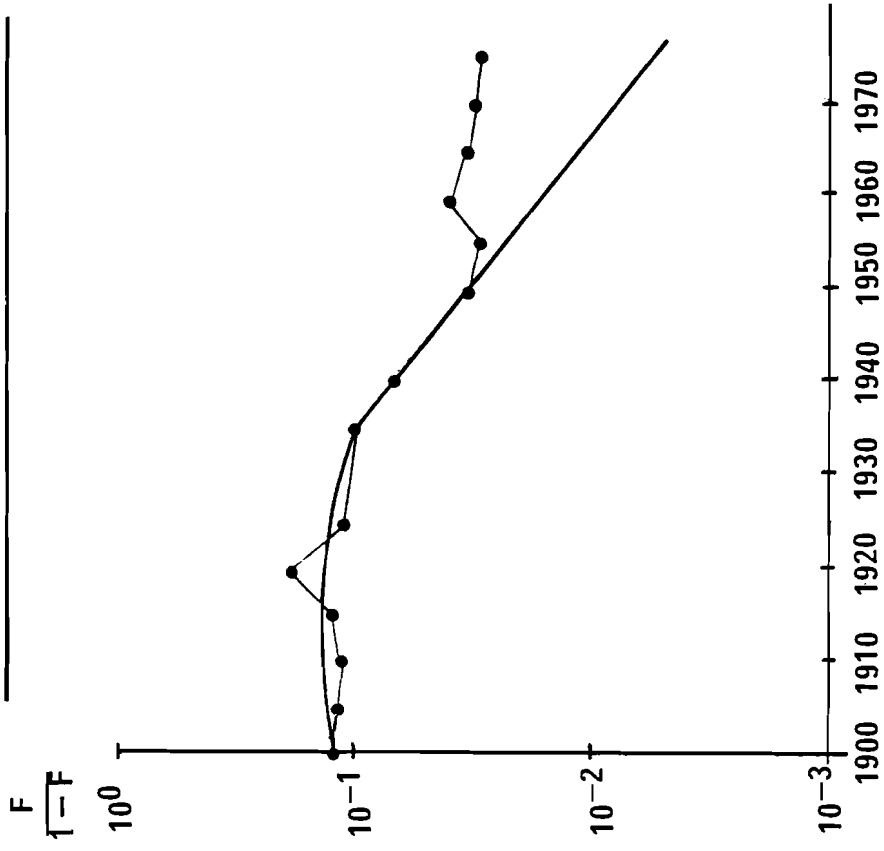
Figure 4.

## NEOPLASTIC VS. ALL CAUSES OF DEATH : US
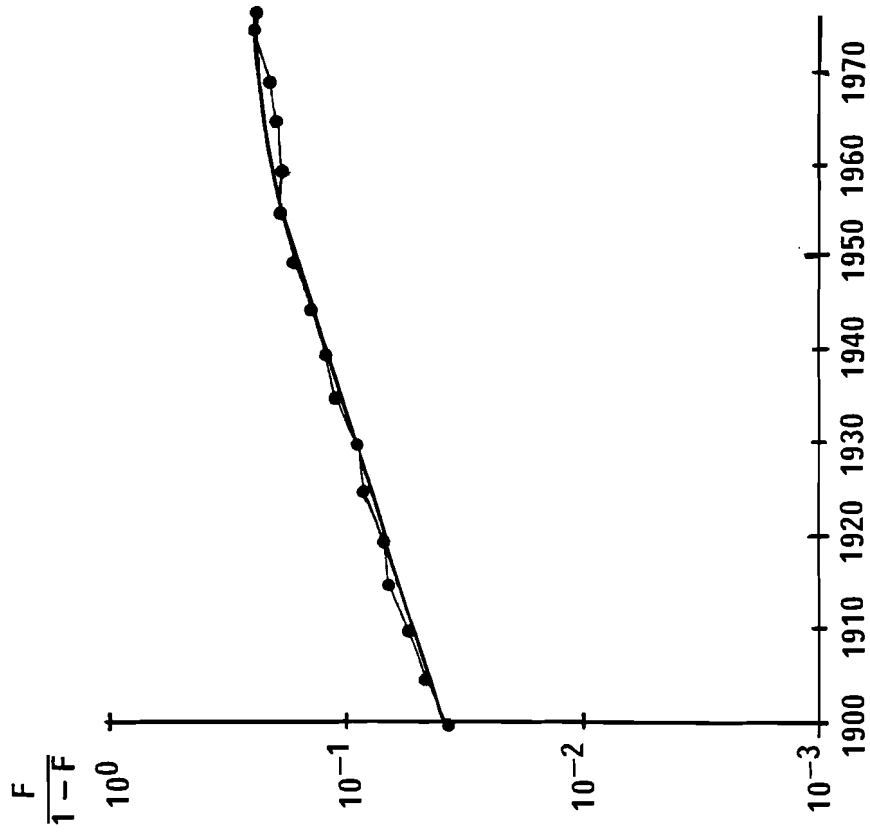
Figure 5.

CARDIOVASCULAR + RENAL VS. ALL CAUSES OF DEATH: US

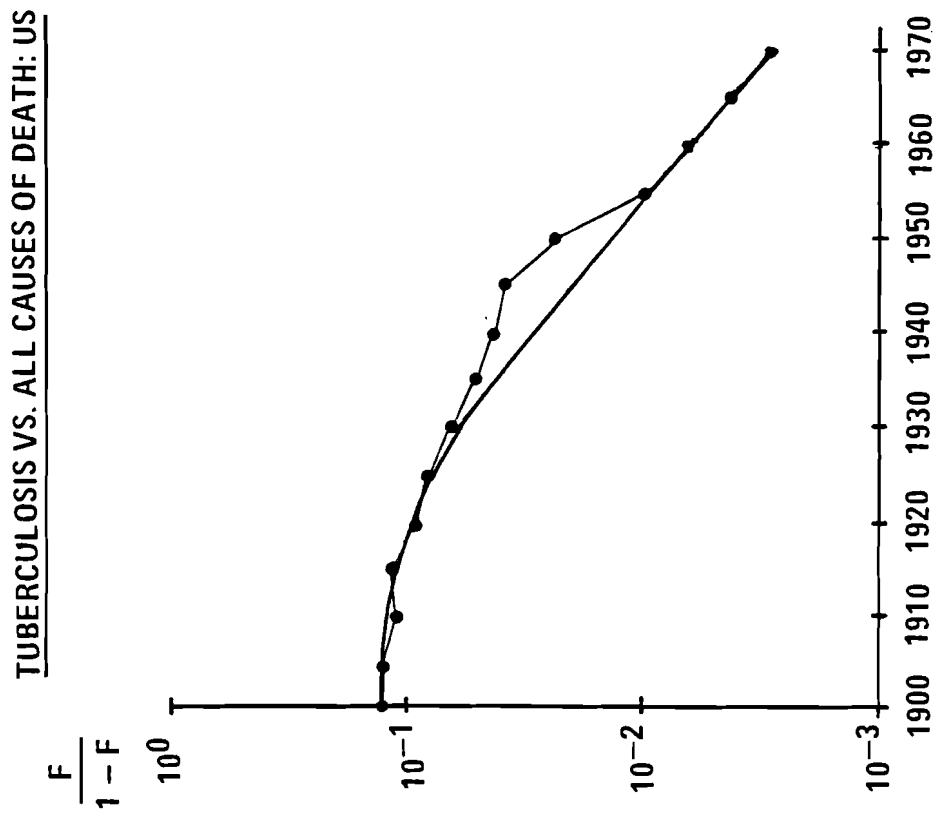Figure 6.

DIPHTERIA vs. ALL CAUSES OF DEATH (US)
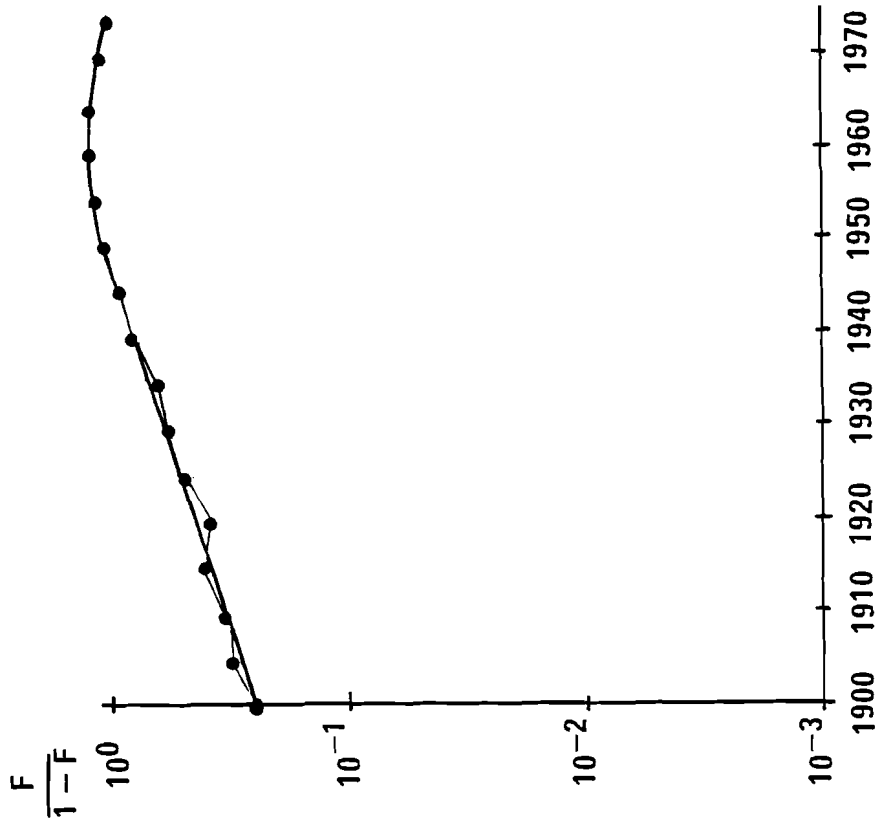
Figure 7.

## TUBERCULOSIS VS. ALL CAUSES OF DEATH: US
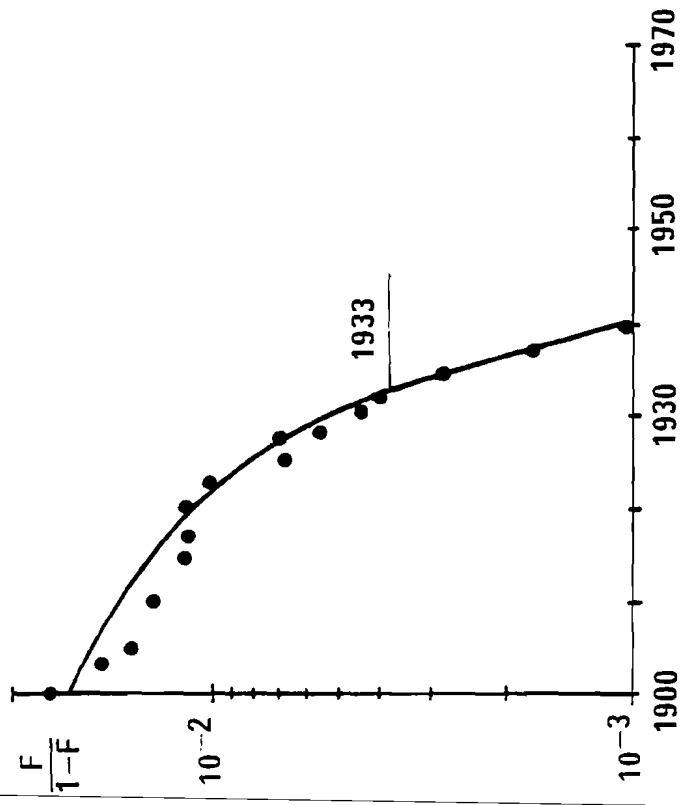
Figure 8.

CARDIOVASCULAR vs. NEOPLASTIC (US)
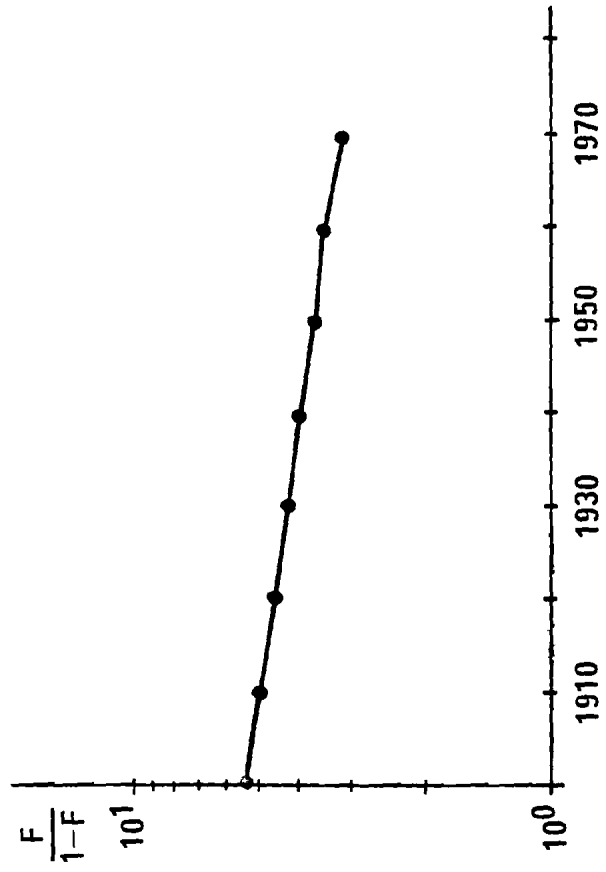
Figure 9.
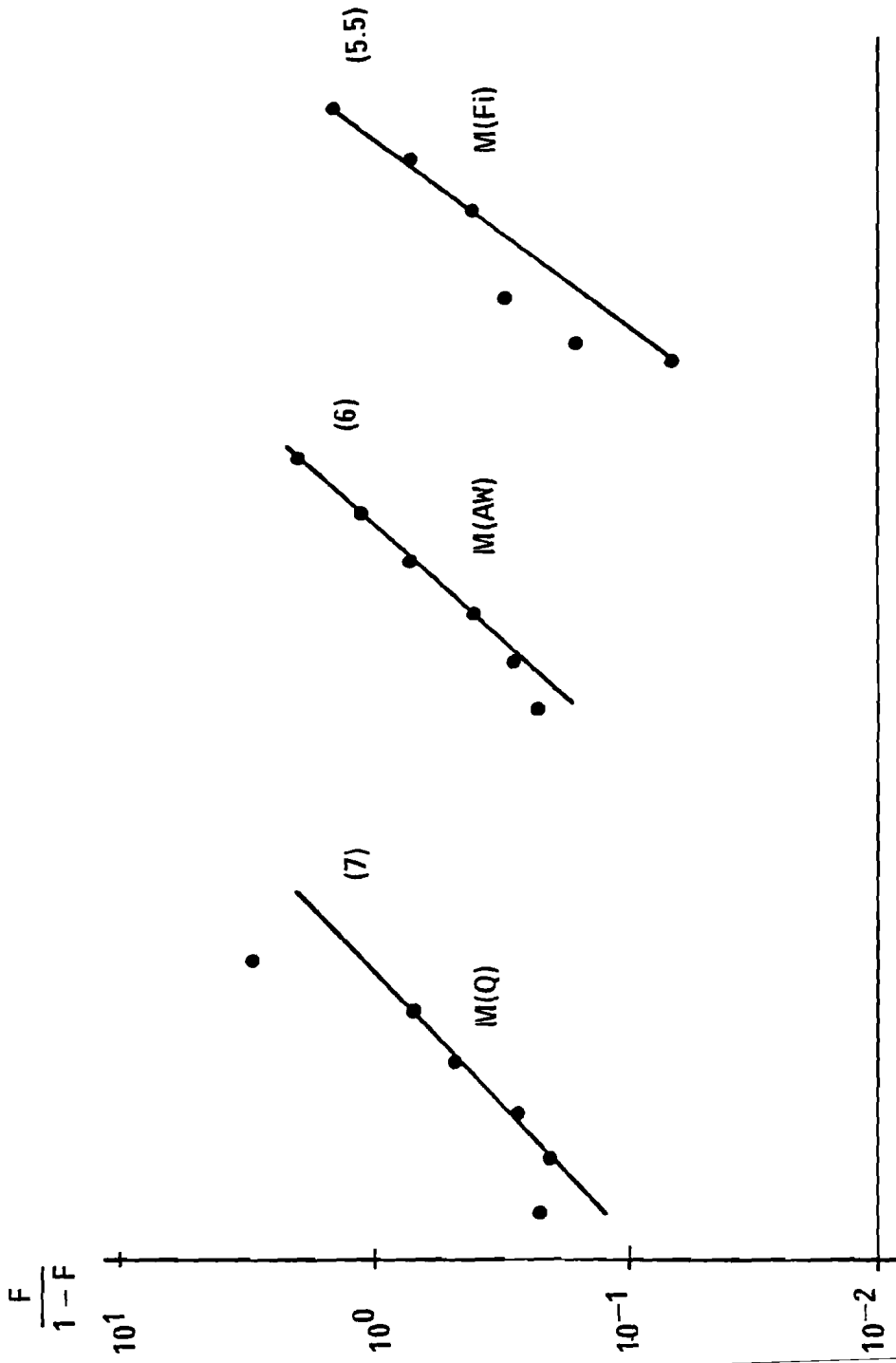
GASTROINTEST VS. ALL CAUSES OF DEATH : US

Figure 10.

PNEUM. + FLU
NEOPLASTIC
GASTROINTEST
CARDIOVASCULAR
+RENAL
TUBERCULOSIS
} VS. ALL CAUSES OF DEATH   US

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

$10^0$

$10^{-1}$

$10^{-2}$

$10^{-3}$

CARDIOVASC.

NEOPLASTIC

PNEUMO + FLU

TUBERCULOSIS

GASTROENTERITIS

1900  1910  1920  1930  1940  1950  1960  1970

Figure 11.

ALL DEATHS US PER 100000 POP
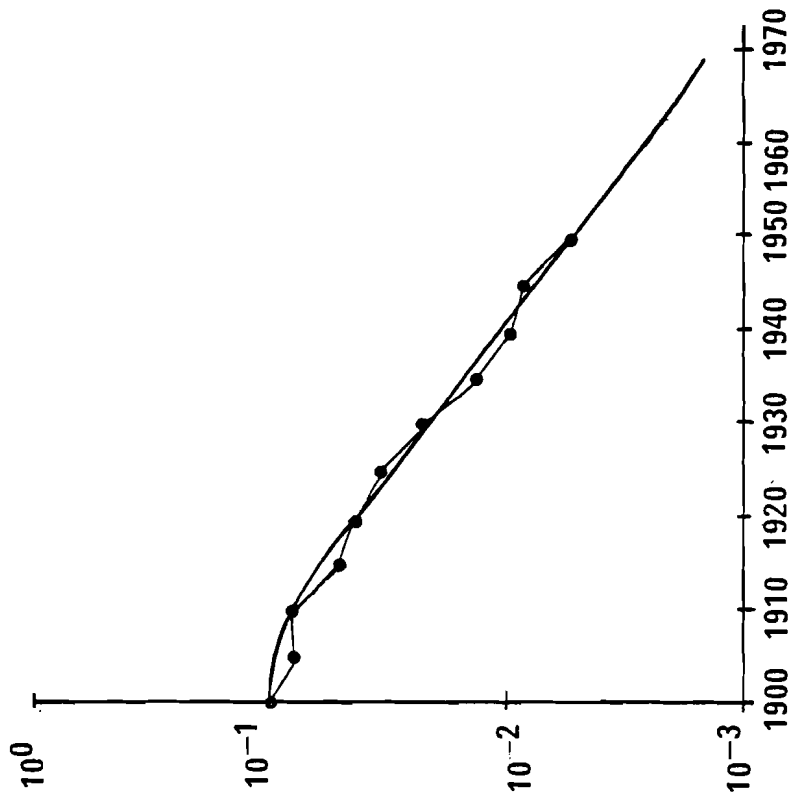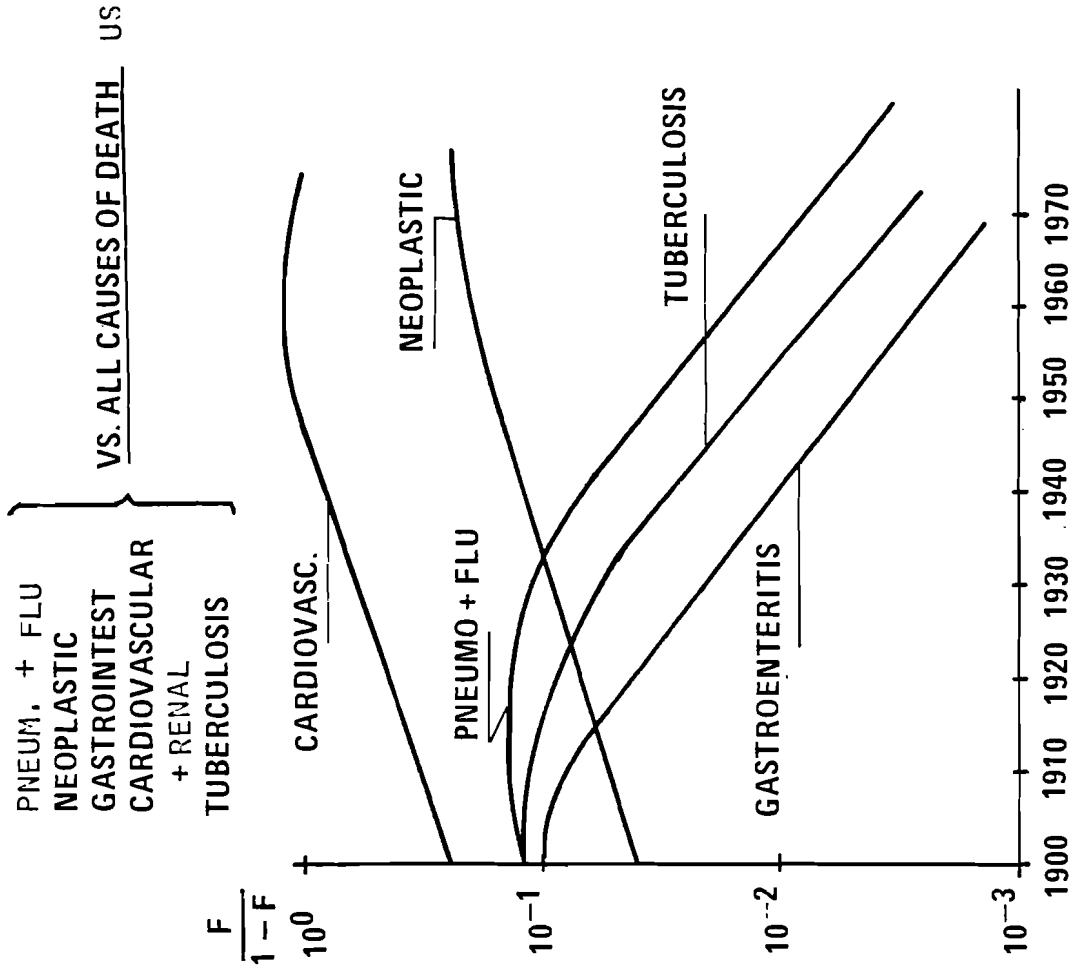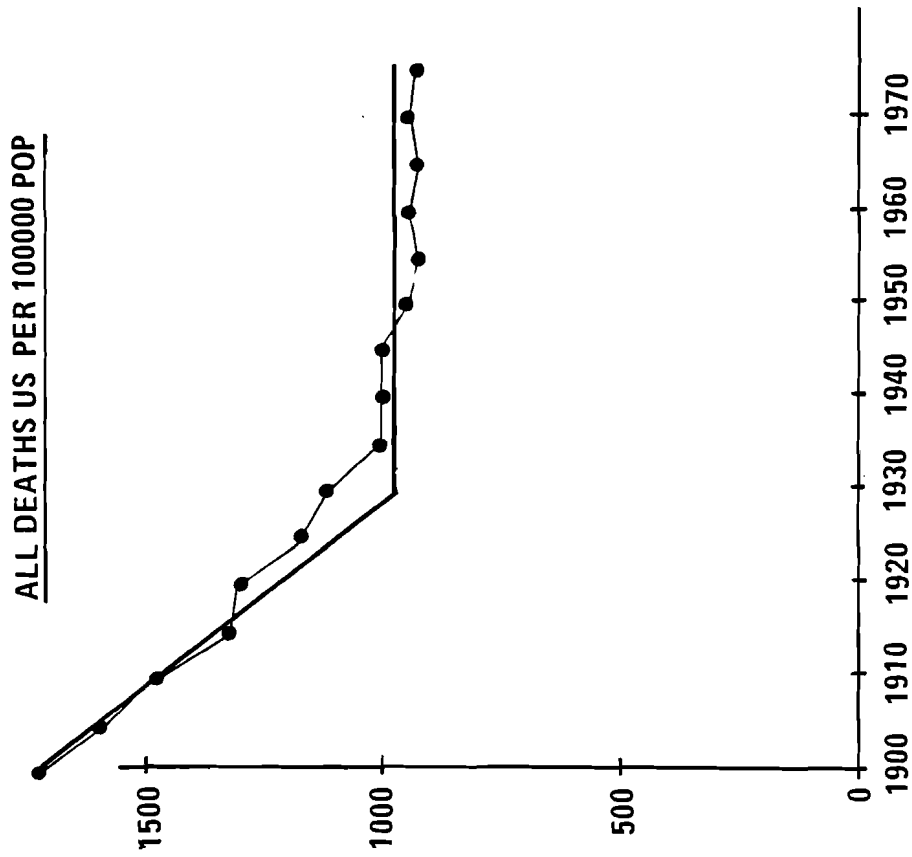
Figure 12.

EVOLUTION OF INABILITIES VS. AGE



$\dfrac{F}{1-F}$

$10^1$

$10^0$

$10^{-1}$

$10^{-2}$

(5.5)
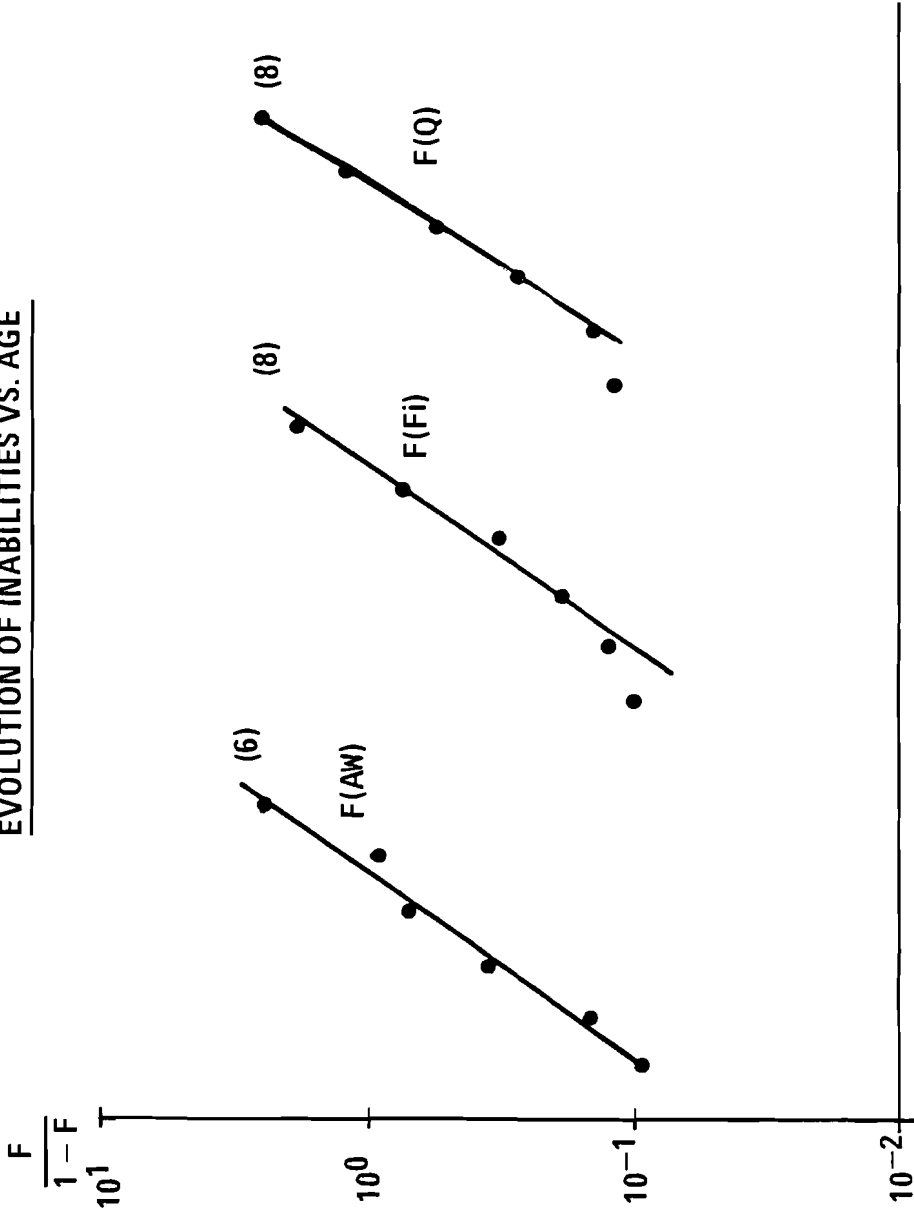
M(Fi)

(6)

M(AW)

(7)

M(Q)

Data from World Health Org.(1981)

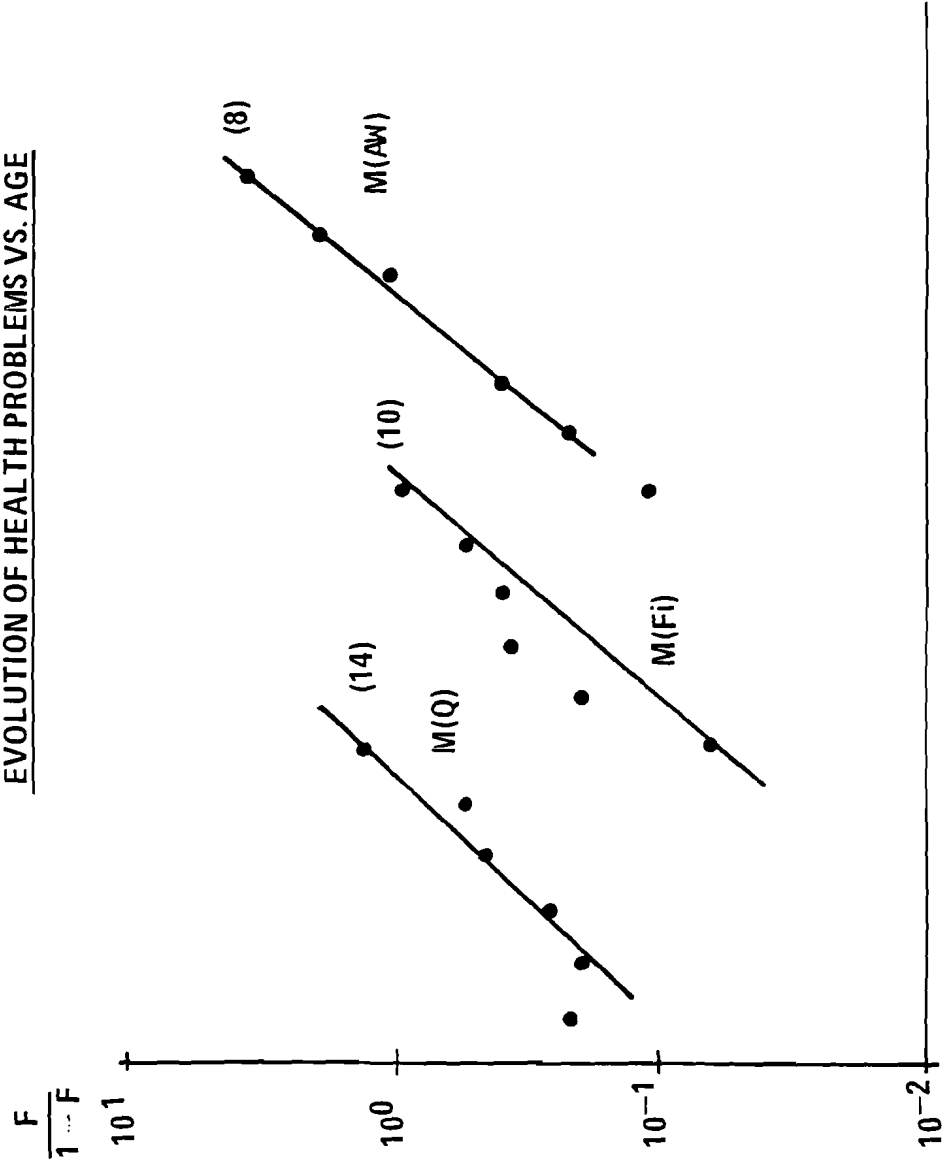(Explanation in text, page 6)

Figure 13.

## EVOLUTION OF INABILITIES VS. AGE



Data from World Health Org.(1981)
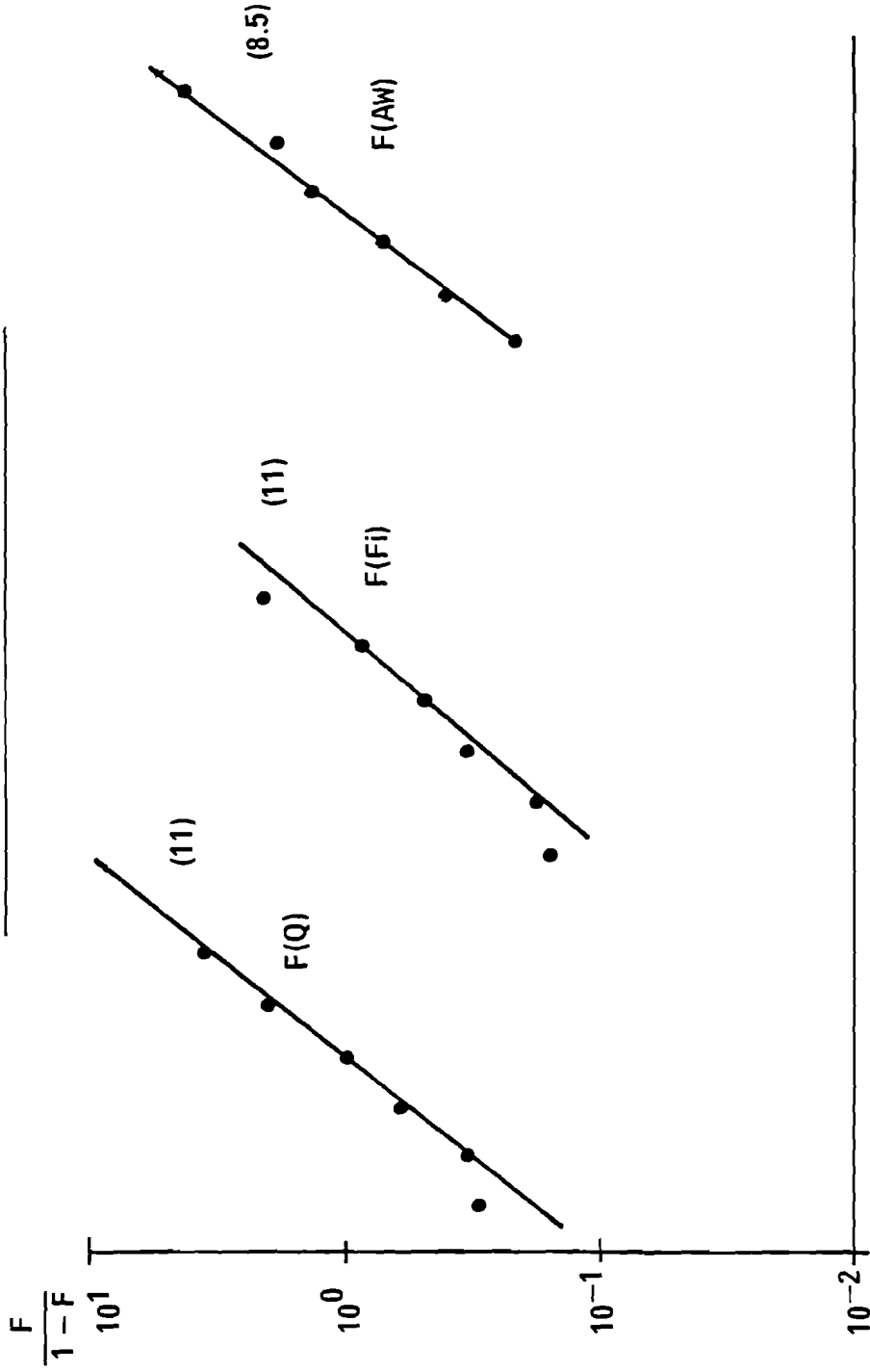
(Explanation in text, page 6)

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)