

Productivity versus Age

Marchetti, C.

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Productivity versus Age

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Abstract

Personal actions appear to be driven by all sorts of mechanisms, usually hidden, but basically stochastic, with a pinch of free will. In this analysis done on measurable indicators of this activity, we show that the final result obeys simple and predictive rules, usually with just one equation covering all the life span.

Preface

The ups and downs in vitality and productivity during the life history of an individual have always attracted the attention of philosophers, priests, writers, sociologists, economists, entrepreneurs, and of laypeople like ourselves, the wheat churned by the mills of time. If one can sum up the results of their attention in one statement, it is that the results are mostly emotional and descriptive. In the most recent literature on the subject, there are also many attempts to better quantify the evolution of productivity with age, proposing equations that more or less fit the quantities measured empirically.

To tackle the problem, we start with quantities that can be measured beyond doubt and without supplementary hypotheses. The publication list of a scientist, the very carefully catalogued musical pieces produced by Mozart, or the “hits” of a top baseball player are typical examples. The basic discovery we made in the exploratory studies is that most cases can be described quantitatively by a mathematical equation called the Logistic. Actually logistic equations can be fitted to the cumulative number of things produced over a lifetime with extraordinary precision.

Going cumulative has the great advantage of smoothing the time fluctuation of productivity, where actual production, e.g., of publications, can be anticipated or delayed by a certain time span, introducing a longitudinal noise that makes the fitting of a time equation practically impossible. What we discovered as shown in the following is that by eliminating the fluctuations through that simple integration, we all formally appear to behave in a very homogeneous way, meaning that the sequence of our actions always follows a similar course, so preparing the ground for higher hierarchical levels of consideration and analysis.

A logistic equation has three parameters. The first provides the steepness, or concentration in time, of the things produced. The second gives a central point or flex, the date or age at which productivity was at a maximum. The third measures the total of the things produced during the lifetime of the individual. This number is extracted by fitting the equation over the actual data and may not be fully reached in practice, although usual levels reach above 95%, and in many cases more than 99% of the calculated saturation point.

The fact that productivity over a lifetime can be wrapped up in an equation, nonlinear yes, but with only three parameters that can be calculated using only a segment of the curve, has important reverberations in the area of sociology and philosophy. Man’s activity during his lifetime appears here to be locked in a steel corset, not the occasional and contextual ups and downs, but a precise account of what he can actually do during his lifetime: how much and when. Once the equation is fitted to one string of data, one can predict forward (and backward). This is perhaps a bonus for university deans or art merchants, but it is certainly humiliating for those personal

egos supposed to be the central cogs of activity and creativity, if not the center of the world.

A particularly interesting case is that of criminals. Because of the reluctance of judicial systems around the world to provide personal data, even in anonymous form, we were only able to analyze in passing. However, with the handful of cases in our possession, we could reach a conclusion (to be braced with more analysis) that undermines the basic philosophy of the judicial system itself: the criminal is the bad guy who has to be punished and redeemed. A criminal in fact seems to operate like any other person, with a logistic equation covering his criminal life. Certainly his activity is considered illegal by the society in which he is embedded, but we analyzed the quantities of behavior, not its ethical meaning. The really crucial point that can emerge only from the predictive properties of our equations is that if one puts a criminal in prison, e.g., for five years, the crimes that he would have committed during this period of time are not “cancelled” but “postponed” until he is free again. Actually, our logistics seem to represent the description of an unavoidable, if subconscious, duty to be performed, let’s say at any price. The publishing of an academic’s work might be said to be another example.

This upsets the basic tenets of the judicial system, because the punishment, or maybe more specifically, the imprisonment, does not seem to reduce the actual number of crimes committed, but merely displaces them in time. Punishment, therefore, does not seem to protect society from criminals. Redemption of the criminal seems to be a romantic dream, not to be realized in practice. This is well known by prison operators. Furthermore, the criminal appears to act under the spur of an instinct he cannot control (like the publishing or perishing of the academic as said). Consequently, there is the ethical question of whether punishment is justified. We have alas no solution to propose except perhaps to put criminals in territories reserved exclusively for them, a solution that has been used on and off for centuries. Ostracism is a result. But our case histories point to a juvenile activity, like that of the athletes, which may lead to a rational solution.

A last point is to distinguish between creativity and productivity. Creativity is the potential to create innovative structures, in science, art, social systems, and anything else. Productivity is the act of creation, or more plainly of fabrication or execution. Because creative people are afflicted by the logistic that defines their loss in productivity in later years, one can ask what happens to the creativity that we in fact did not measure. We think the two move somehow independently. Productivity seems to be run by a subliminal clock, presumably inserted in the limbic that fits our logistics well. The study of Giuseppe Verdi, however, might open a new line of thought. After his main logistic was terminated, he produced quite a few works of dazzling beauty, which we presume were stimulated externally through the pressure of fans and friends. Perhaps the logistic steel corset can be punctured to free the subjacent if dormant creativity, which can then be exploited with constructive practical consequences. However, a finer analysis may reduce Verdi to the norm.

About the Author

Cesare Marchetti started his career as a physicist, was then manager of research laboratories, and finally spent 30 years as a researcher in IIASA doing system analysis. He produced very simple predictive models, the physicist way, on the most variegated subjects, from the dynamics of energy markets to the evolution of transport systems. His papers are collected on his web site www.cesaremarchetti.org/.

Productivity versus Age

Cesare Marchetti

1. An important distinction: Creativity versus productivity

Creativity is the capacity to generate a new configuration that “works” in a certain context and possibly works better in comparison and under different circumstances. Living things are generally endowed with creativity, mostly connected to DNA in the simpler organisms and to “electronic” information processors such as the brain in more complex ones. The DNA message is modified by mutation, internal shuffling, and external additions of DNA strings. The results are checked by internal quality controls, and if the probability of success in the external world appears low, they are corrected or eliminated (Marchetti, 1998). What happens in a creative brain is neatly mimicked by that process, if at symbolic level. A combinatorial system, probably limbic and certainly subconscious, provides potential solutions to a problem, and a selector system leaves only the candidates to a probable success to emerge to a conscious level.

Mutation, recombination, and selection always lie behind inventions, and some people seem more adapted than others to bring about working results, producing more efficient machines, more striking paintings, more endearing novels, and more competitive social organizations.

For a successful animal species, an excellent strategy is to follow a similar pattern, and as a rule new creations or innovations are pruned out. A queer-looking animal may not find a mate and that closes the line. Something similar is applied in human society: creativity is usually repressed during the learning years while conformity is exalted in contrast to independence. Strong and rebel characters may survive the ordeal to become the few creative people we see. Most of them have still to fight till death, but some of their creations survive to produce what we call progress. History provides the best evidence of the repression process. Let us take the trite examples of Athens and Florence, where creativity was de-repressed, as biologists say, when a gene is put to work and most of the population showed up as creative, one way or another. These two cities of at most 50,000 people each produced the core of Western civilization and the core of renaissance.

Creative people produce a time sequence of works. Let us take Mozart as an example, reported in Section 4. The cumulative number of works by Mozart fits perfectly into a logistic, whose derivative depicting the actual production shows the usual bell-shaped curve we have seen, e.g., for J.S. Bach. The point of maximum productivity, the top of the bell, was reached when he was about 25 years old. This then declines, symmetrical to the build-up before. One can hardly attribute that to the wear and tear of age. There must be some deeper and subtler mechanisms that link creativity

to production. From the age of 25, Mozart was splendidly creative—let us think of the Magic Flute—but his production declined. With Freud in mind, we assume that a creative act is triggered by a deep emotional pulse that we call “action pulse.” We chose the word action because—as we will see—the operation does not need to be creative in the strict sense, but the formal outcome is the same.

In the case of Mozart, productivity extended over the lifespan with the general shape of a full life cycle as described by a complete logistic. We can only say that creativity in qualitative terms presumably increased, but creation—“action pulse” frequency—decreased. The case of Giuseppe Verdi is perhaps more interesting. His logistic for musical composition of operas saturated when he was about 50 years old, when in fact he stopped composing on a grand scale. But he lived to 84. Apparently more or less stochastically he produced a few works of supreme beauty and originality, showing clearly that his genius and qualitative creativity continued to develop. An accurate plotting of all his work, not only opera, shows a small but well defined second pulse of productivity in later years. As we will see, many artists in the film business have a double pulse, which happens very rarely, e.g., among scientists.

This multiple pulsing has a mixed physical significance, and may be the result of too sophisticated mathematics, the real physics being in some wobbling of the actual data around a logistic. We have many cases pointing explicitly in favor of this interpretation. If we look at the evolution in time of the highest value for nuclear particles energy, available from current accelerators, we find a logistic equation.

However, the technology of the accelerators continues to change: we have the electrostatic ones, the Walter and Cockcroft, the cyclotrons, etc. For each of these quite different technologies we have a logistic evolution in time for the maximum energy attainable. These logistics are somehow meshed in time so that current the best values fit again a logistic. On a larger scale we studied the British naval power since 1500. This power grows and wanes in logistic pulses of about 50 years. By using the central points and the weights (saturation values) of these logistics, we can get a super logistic spanning 500 years and showing that the temporal phenomena had a strong internal correlation so that finally their logistics were strongly correlated not only in their timing but also in the saturation values.

2. The current view on the problem in world literature

The subject of productivity and creativity as a function of age has attracted much attention from researchers, as shown by the vast literature on the subject, as well as much emotion, as demonstrated by numerous sayings and folklore. Creativity is assumed to be a characteristic of the young, and in the case of physics of the very young, but we have so many examples of aging individuals with brilliant ideas and revolutionary proposals. As the tests are made statistically, it is often forgotten that due to the high rate of increase in the number of scientists, perhaps doubling every 15 years, their age is biased toward young age and consequently the higher probability of the young ones having a brilliant idea may just be due to their high proportion in the population. In fact Dean Keith Simonton, whom we consider to be one of the most dedicated and perceptive researchers in the field, shows that high-quality papers are evenly spread among several age groups. The number of publications published

fluctuates according to age, but some people are very prolific and others not. There is, therefore, no strong correlation between age and creativity.

Folklore also introduces a gender bias to the subject: Women are said to express their creativity in making children, while men procreate in the form of publications or pieces of art, their children being de facto brainchildren. Today, Western women following careers have very few children, if any, but instead have the opportunity to focus on publishing. In fact a recent paper by Yu Xie et al. (1998), which thoroughly analyzes data for the period 1969–1993, shows that a certain gender gap actually exists, but is rapidly being filled up. At the end of the sixties, the female-to-male publication ratio was about 60%, moving to 75–80% in the early nineties. According to the authors, these differences do not relate to gender but to the contextual positioning of women, and are bound to disappear with the equal positioning of the two sexes in society. By precisely plotting careers with logistic equations in the cases analyzed, we can clearly demonstrate that women operate just like men.

Another problem sometimes discussed in the literature is that of manual workers. Here we found only aggregated statistics showing that there is no change in performance with age. This could be a good argument for increasing retirement age, thereby saving pension institutions from bankruptcy. We think that present industrial systems demand very little in terms of physical performance so that actual performance doesn't measure the full potential as in the case of sports. Actually we found an analysis by Salthouse (1984) on the top efficiencies of typists, a kind of agonistic sport for speed. Salthouse finds that speed doesn't change much in the 20–60 age range, with older typists compensating for their somehow slower reflexes with more efficient mental preparedness and foresight.

Much literature is devoted to athletic performance versus age, much of it in aggregated form e.g., top running performance at various ages for a given year. The current wisdom, supported by aggregated analysis, shows certainly that athletes must be young, but older runners can keep up the pace with practice. It is difficult to obtain a self-consistent set of data for a given athlete over his lifespan, but this has been possible for baseball pitchers, where everything is recorded with the utmost precision. In fact, by counting the number of hits per year we can describe a player's quantitative career. Here we found that the logistics of a player are just like those of anyone else, fitting perfectly the evolution in performance over the professional lifespan, displaced toward the lower end of the age scale, but with center points above 30 years of age. For sports where experience plays an important role, the performance curve can be split into two logistics, one showing the contribution of physical fitness and the other of experience.

For a synoptic view of the literature on creativity and productivity at the intellectual level, the best author appears to be Simonton, now at the University of California. One of his papers, "Creativity as a secondary Darwinian process," which was issued in 2001 and is now available for download from his website, can be taken as a main source of reference. In this paper he quotes a good chunk of the prominent literature in the field, including about 40 papers written by himself over a period of about 25 years. A strong point in his analysis is the attempt to bring quality into play, a subject we avoided because it is difficult to reduce to quantity. Van Gogh could not barter one of his paintings for a meal; that same painting can now be worth tens of millions of dollars. His discovery that quality is a constant fraction of quantity,

independent e.g., of age, is very important because it shows creativity being independent of age too, with everything being reduced to the density of our “action pulses.” We contribute to this theory by showing that the curve for the best-rated films of Antonioni follows quite reasonably that of film production. Simonton’s weak point is that, in spite of numerous attempts, he has not been able to find an appropriate mathematical model to describe and predict the behavior of a person. In fact it is practically impossible to fit mathematically the current behavior due to the very strong longitudinal noise caused by relatively small anticipations and delays in the issue of the works. Integration neatly solves the problem, but we struck on it only through serendipitous chance as mentioned later.

3. Attempts to model productivity versus age and the logistic breakthrough

The vast literature on the subject provides evidence of the various attempts at quantifying productivity versus age, in the case of individuals, groups, and classes, with mixed mathematical support and uncertain quality of fitting. Our methodology stems from a serendipitous hunch coming from a very different line of thought, and appears much more powerful than previous attempts. We had previously studied many cases of market dynamics using logistic equations. These equations are the simplest solution of the differential equations that the mathematician Volterra and the modeler Lotka had set up in the twenties to model the competition between species in a given ecosystem.

In order to get an insight into the way Lotka had arrived at the equations I ordered his master book. Being published in the fifties, after Lotka’s death, the book carried the complete bibliography of Lotka’s work. The serendipity hunch sits in the question: could the Lotka logistics fit the Lotka publication list? It did with utmost precision. It could have been pure chance, but a frantic search of “publication lists” by academics, painters, writers, and musicians soon showed that logistics fitted the cumulative production of their pieces almost perfectly. It means that a logistic equation can be applied to the cumulative number of objects produced by an individual, be they paintings or scientific papers or pieces of music or baseball hits. It must be clear that using the cumulative is a basic trick because it eliminates longitudinal noise. Actual distribution in time of the pieces produced is in fact very noisy due to anticipations and delays, which make it practically impossible to apply any equation, even the actual derivative of the logistic, a bell-shaped curve much resembling normal distribution. This may explain the systematic lack of success in precisely describing productivity in mathematical terms. However, the noise being longitudinal, i.e., along time, it is compensated for by integration, because all the pieces are finally produced. In this paper, we will come across more of these bell-shaped curves, which best represent the actual evolution in time of the productivity. However, they do not carry data points because they are too scattered, and the curves are actually calculated just as derivatives of the fitting logistics. They represent a sort of time program, as once started these equations are kept usually for life, in a sense like a software DNA.

The tool has therefore proven to be very effective in mapping the doings of a person. The coincidence with the Lotka logistics in biological growth and competition may be accidental. There is apparently no competition between some sorts of species in people’s minds. But the logistic equation can also describe faithfully other phenomena,

like the growth of a plant. In this case we can assume a potential of growth given by the size of the plant itself, and an inhibiting feedback represented by the difference between the actual size and the final one genetically coded. The product of the two gives rise to a logistic equation.

Apart from the background mechanisms, the study of which can be useful for the next step in interpretation, the fact is that logistic equations are perfectly suited to describe the production of a certain individual (and class of individuals) in time, as we have proven with hundreds of cases analyzed. This mathematical precision mapping of an individual's creativity over his lifespan is philosophically challenging as it poses serious constraints on the much-glorified free will. The study of anthropological interpretations shows that man appears to have his limbic system very much in control, what sometimes is called the snake brain to give a visual definition, and primary causes of human behavior should be searched in the operation of the limbic. A very illuminating example of creativity and its biological connections is that of J.S. Bach, and his large number of children. By applying a logistic (again) equation to all of them, we can see that the logistic has a flex or center point (point of maximum productivity) at 45 years, at exactly the same age as the logistic determining their father's musical productivity.

Coming to the arithmetic, logistics are S-shaped three parameter nonlinear equations of the form:

$$(1) \quad N(t) = N_{sat} / [1 + \exp(-(at + b))]$$

where N_{sat} is the asymptotic value of the function and has to be calculated together with a and b , by fitting the data.

For practical reasons (drawing and comparing S curves is more complicated than drawing and comparing straight lines), I mostly use a transform of the axes that makes the logistic appear as a straight line (Fisher-Pry transform). Taking the saturation value of the logistic N_{sat} as a reference point, the actual values can be defined as a fraction $F(t)$ of that value. The space left for growth is then $1-F$. The transform of equation (1) can then be written as:

$$(2) \quad \log F/(1-F) = at + b$$

which is linear on semi logarithmic coordinates. It must be clear that we are not taking the logarithm of the function that would compress the deviations in the charts. The formalism of equation (2) keeps it practically linear around the flex, but expands the deviations away from it so that actually we use the transform for precision fitting of the data. To enable a visual connection for the three methods, we will present the data in the form of charts. As the few examples reported in this section show, we seem to have the appropriate tools for a large-scale analysis. Logistics seem to work consistently in describing lifecycles. The real problem for a general survey is obtaining data of an

appropriate quality, especially for jobs that do not appear statistically in the correct format.

4. A set of case histories in various fields of productive activity, especially intellectual, as a base for further consideration

As mentioned in Section 3, serendipity brought the solution of productivity mapping for an individual, Lotka being the first case. A frantic search for complete vitae led us soon to conclude that the pattern is general. We will give examples for five different classes of activity to show the quality of the matches. The only real departure from the Lotka scheme is that some people have a sequence of two pulses of productivity. For university professors, one can be malign and suggest that the first pulse represents his personal activity to get the chair, but the second comes from co-authoring the papers of his pupils and associates. In our view this may represent a pulse of organization and inspiration on third parties, which can be again considered as productivity. The two pulses are not uncorrelated, so that in many cases one can sum them and get a wobbly but acceptable logistic fitting. We took the precision course, hoping that it could help to cast light on the internal gears of the action pulses. Double pulses seem quite common in the film industry, among actors, producers, and writers.

A perplexing case is that of Schubert, the Austrian composer. It is known that he was schizophrenic, having two distinct personalities of which he was fully aware, so much so that he had christened each personality with a different name. The time sequence of his compositions is best split into two periods, superposed in time, one ending long before the other. It looks as if the two personalities had two separate clocks for forming and displaying “action pulses.”

Despite Schubert’s young death, at 31 years of age, each personality produced 600 musical pieces, with time constants of 10 and 15 years, respectively. At the time of his death, his second personality had reached saturation, in strict analogy with Mozart, who died at the age of 35 with a logistic reaching more than 95% of the saturation level. For deeply engaged persons, as great artists usually are, the productive period tends to cover the whole lifespan, with large time constants, and logistic saturations just preceding death. John Huston, by the way, seems to have threatened death by producing the second half of his last film when the logistic appeared already saturated.

The time constants of the logistics that give the spread in time of the productivity period cover a wide range. In some cases we have a flash lasting a limited number of years, in others it covers a long lifespan. As we will see, really creative people, such as many Nobel Prize winners, tend to have large values for the time constant, meaning a long stretch of productive activity and an advanced center point. A random sample of Nobel Prize winners shows a mean time constant of around 35 years. However, candidates for the Italgas Prize, a provincial Italian Nobel Prize for researchers all over the European Union, shows a mean time constant that is about 10 years lower, translating into an active period 15–20 years less than Nobel Prize winners.

4.1. The Nobel Prize winners

The great care that Nobel Prize committees take in choosing their candidates for top quality above any suspicion makes the prize one of the most coveted distinctions for a scientist. This special subset of the scientific community, branded for excellence, allows us to take a closer look at productivity versus age and whether there are particular patterns that may formally distinguish them from the rest of the community. A first-level examination shows business as usual. The cumulative number of their publications neatly fits logistics. Even in the case of Einstein, whose life logistic exceeded saturation level during the last 10 years of his life, an analysis of the titles shows that they were repeats or official addresses, not really scientific publications.

Most logistics are single, with good fitting, meaning a smooth and regular productivity. A comparison with another group we had the opportunity to study, the candidates of the Italgas Prize in Italy, coming from the whole of European Union, had a time constant shorter by about 10 years, as mentioned above. The Nobel Prize winners, therefore, have a longer scientific life in their genes, so to speak. This is not due to the prize because it usually comes quite late in life and incidentally does not modify the further tract of the equation. Contrary to popular belief, the prize may fill the ego but doesn't stifle creativity, or, just to stay in our furrow, productivity.

The Nobel connection and the abundance of good data makes it easy to enter the analysis of higher hierarchical levels, e.g., taking about 50 Nobelists for each of the three disciplines, physics, chemistry, and medicine, we obtained acceptable logistics by fitting the age of the Nobelists at the time the work to be prized was done. This seems to put an end to the theory that all creative work is done before the age of 30. The center point for physics laureates is 34 years, for chemistry 37 years, and for medicine 40 years, meaning that half of the discoveries leading to the prize were made before the ages indicated, and the other half later. A difference between the various disciplines exists, but is not very remarkable, although it shows a certain precocity for genius in physics. The time constants, i.e., the spread in time, is the same for the three disciplines, at 23 years. The data bend down with respect to the fitting curve for low ages, as usual, as a certain professional maturity is necessary in order to exploit an idea, which takes time to build up. However, the fitting is fairly good for higher ages, showing that productivity has certainly a peak, but extends, if with progressive attenuation, practically to all ages.

A similar analysis of ages at the time of the award shows again a logistic spread, with central points at 46 years for physics, 50 years for chemistry, and 54 years for medicine. The logistic fitting is here much better as there is no warm-up period. The distance between the center points of the discoveries and that of the prizes is 12 years for physics, 13 years for chemistry, and 14 years for medicine. The time constant is 22 years for chemistry, like that for the discoveries, making the two logistics parallel in the Fisher and Pry plot, displaced by 13 years as said. For physics and medicine, the time constant is 28 years. All this shows an unexpected order and regularity in the extremely complex system of discoveries and the way in which society recognizes them. To make a rhetoric comment using medieval words, one feels the celestial order of the spheres.

Because the Scandinavian Journal of Economics publishes systematically the publication lists of the economics laureates, we were able to profit from these data to deepen our analysis. One of the most common characteristics is the late central point of

their production, say 50 years and over, and the large time constant, say 30 years and over. This means that these persons spread their activity over a long period of time and in a sense they mature late (and live long too). Although the Nobel Prize in economics is still relatively recent, almost all the laureates are still alive.

This seems to pertain also to other classes of laureates. However, from the chart of the age at death of laureates in literature, the central point is 74, much in line with the general population. Incidentally, in scientific folklore there is the saying that mathematicians that deal with geometry tend to enjoy a great longevity. In a super connected biological world there might be a subterranean connection between the leaning for a certain profession and the biological stamina, e.g., the immune system.

Legend for Nobel Prize winners in economics

Nobel Prize winners represent the best of intellectual creativity and one may expect their productivity to be bumpy and flashy. According to the basic tenets of economic theory, it should also be contextual enough to be unpredictable. Context changes so much during the lifespan of a person. Contrary to these very sensible and orthodox statements, Nobelists' productivity runs like a clock during their lifetime, smooth and predictable. As usual one life, three numbers, the parameters of the logistical map. The only freedom seems to be that of a few geniuses who got two pulses. To help get a feeling of the situation without overloading the report with charts, we plucked from our collection three of the first kind, Maurice Allais (b. 1911), Gary Becker (b. 1930), and James Buchanam (b. 1919), and three of the second kind, Harry Markovitz (b. 1927), Robert Mundell (b. 1932), and Douglass North (b. 1920). As a generic comment the salient characteristic of the first three is an oversized time constant, meaning a very long productive period and a central point well over 50 years of age. The reader can form his own opinion as the charts are easy to decode.

Figure 4.1.1a

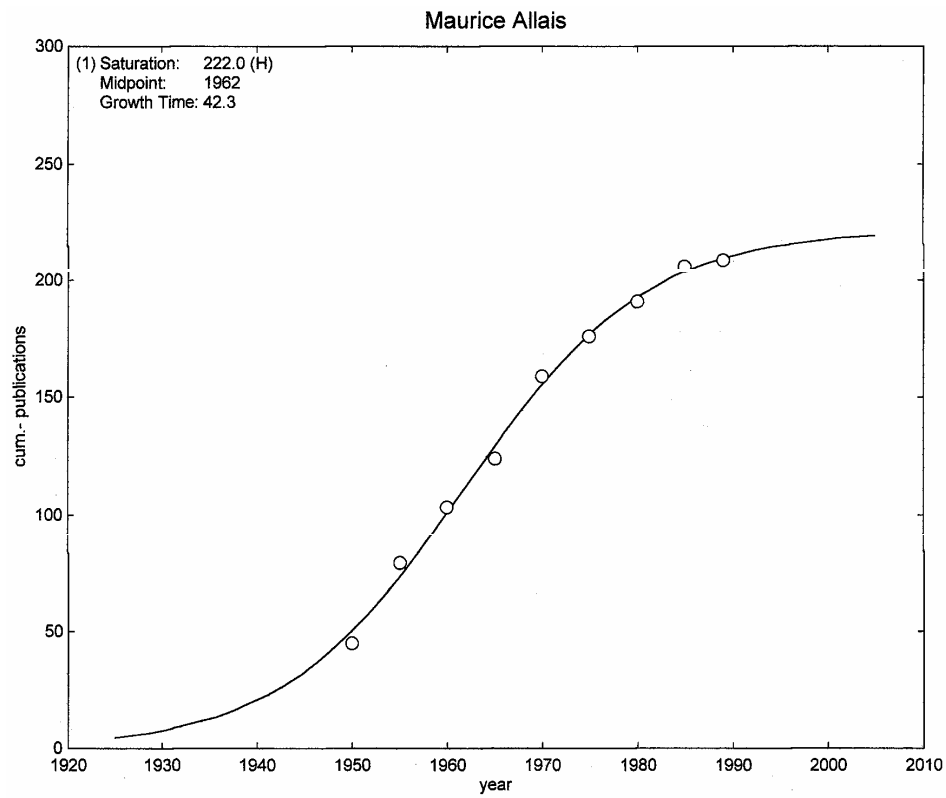


Figure 4.1.1b

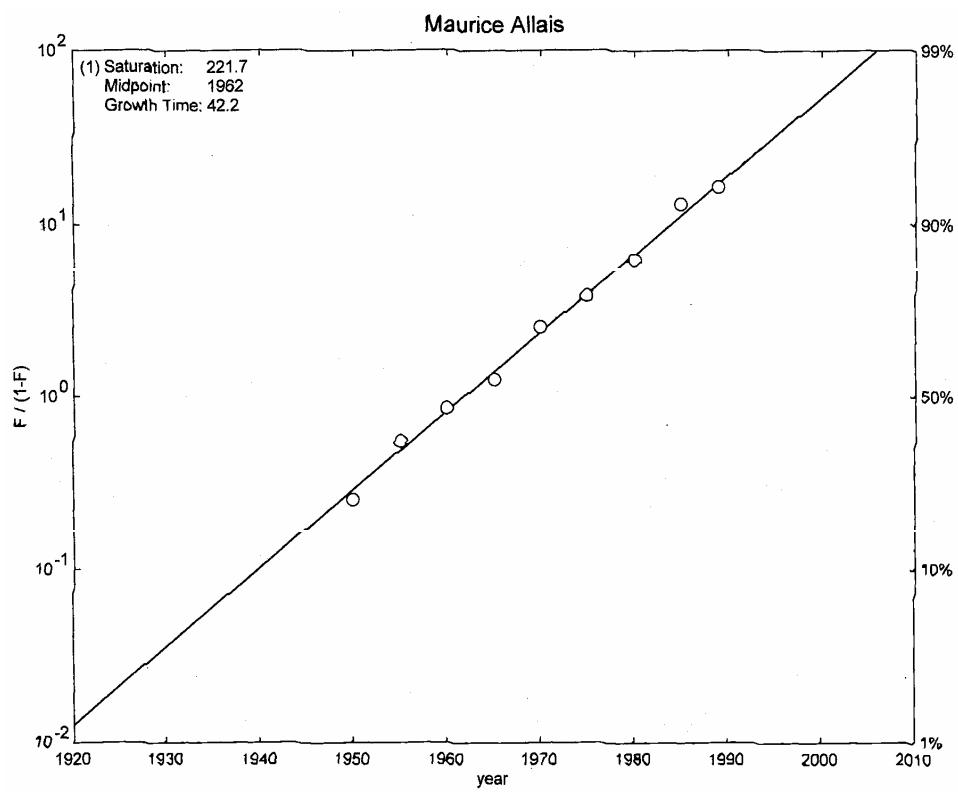


Figure 4.1.1c

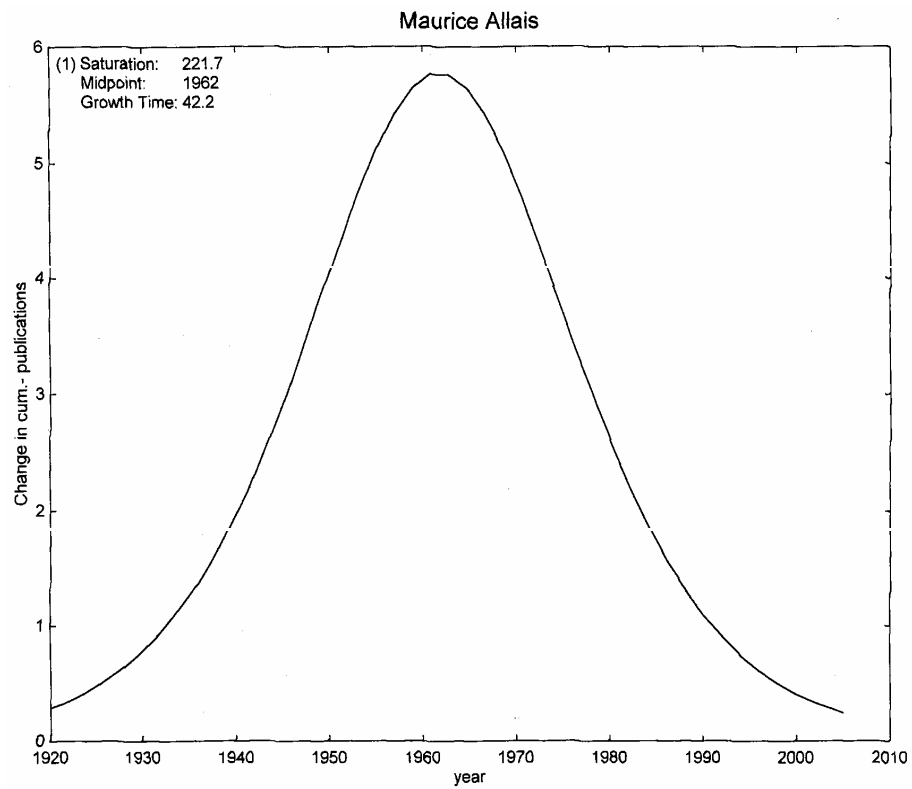


Figure 4.1.2a

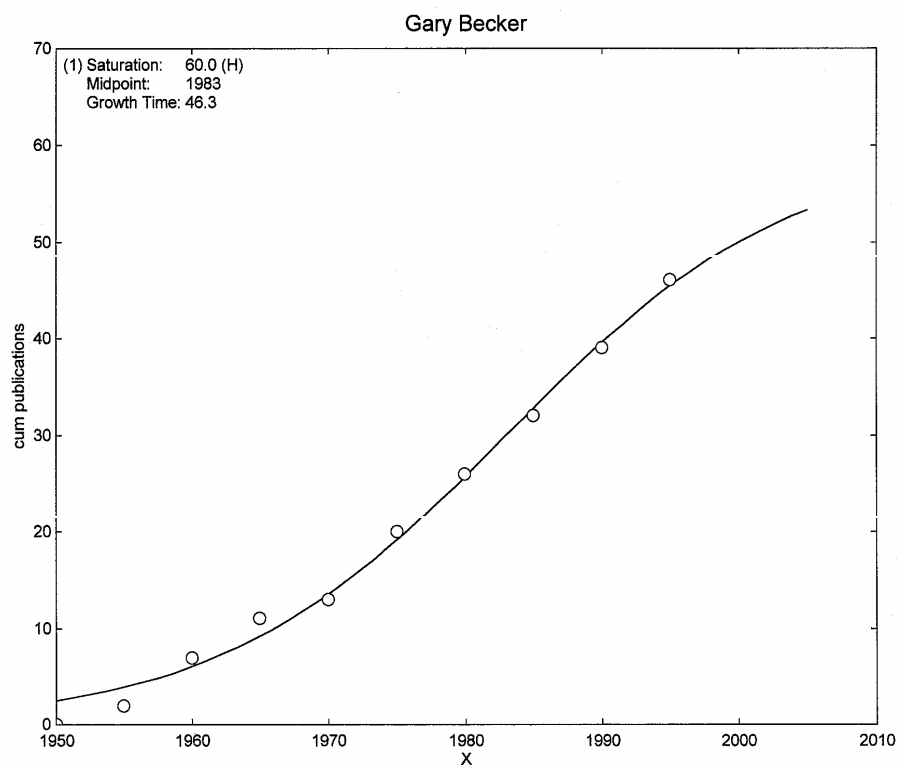


Figure 4.1.2b

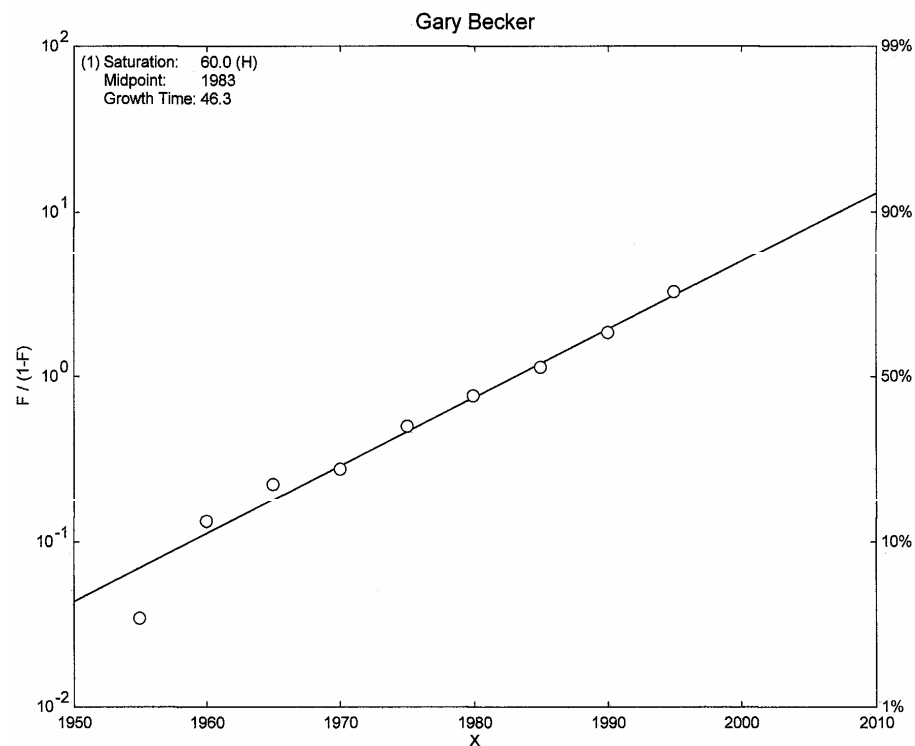


Figure 4.1.2c

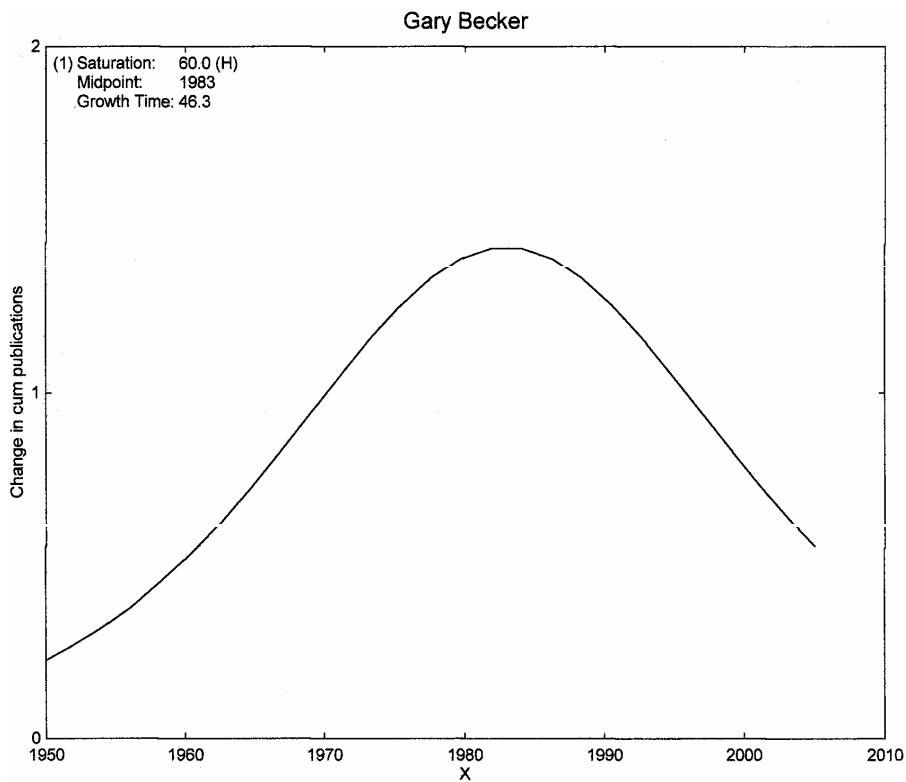


Figure 4.1.3a

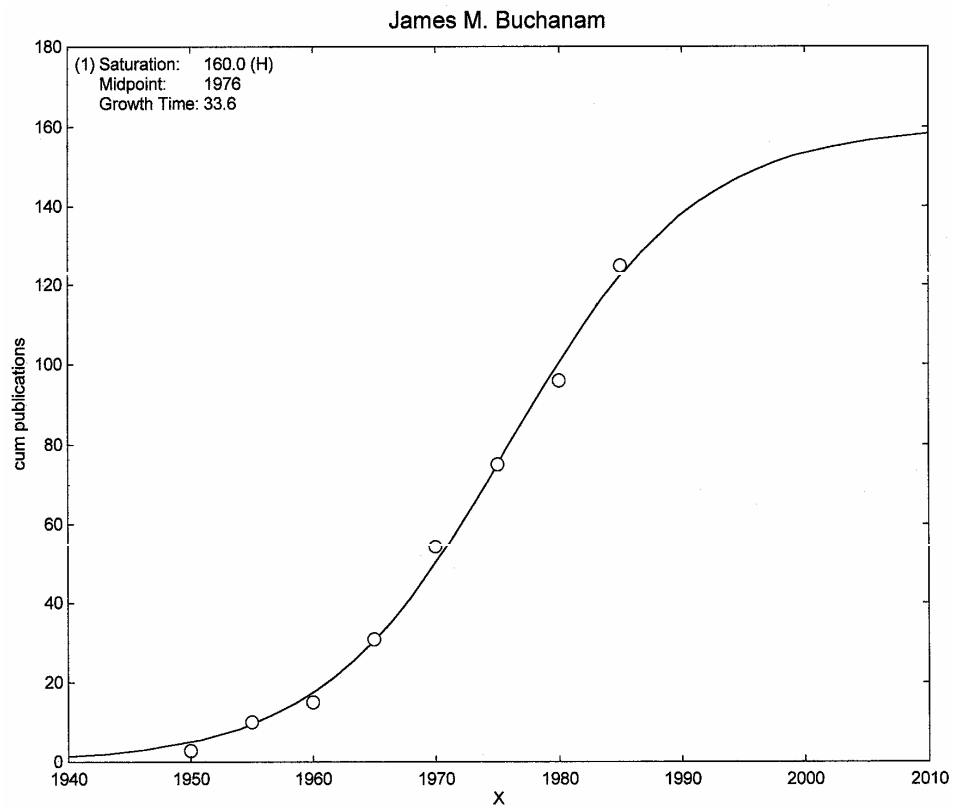


Figure 4.1.3b

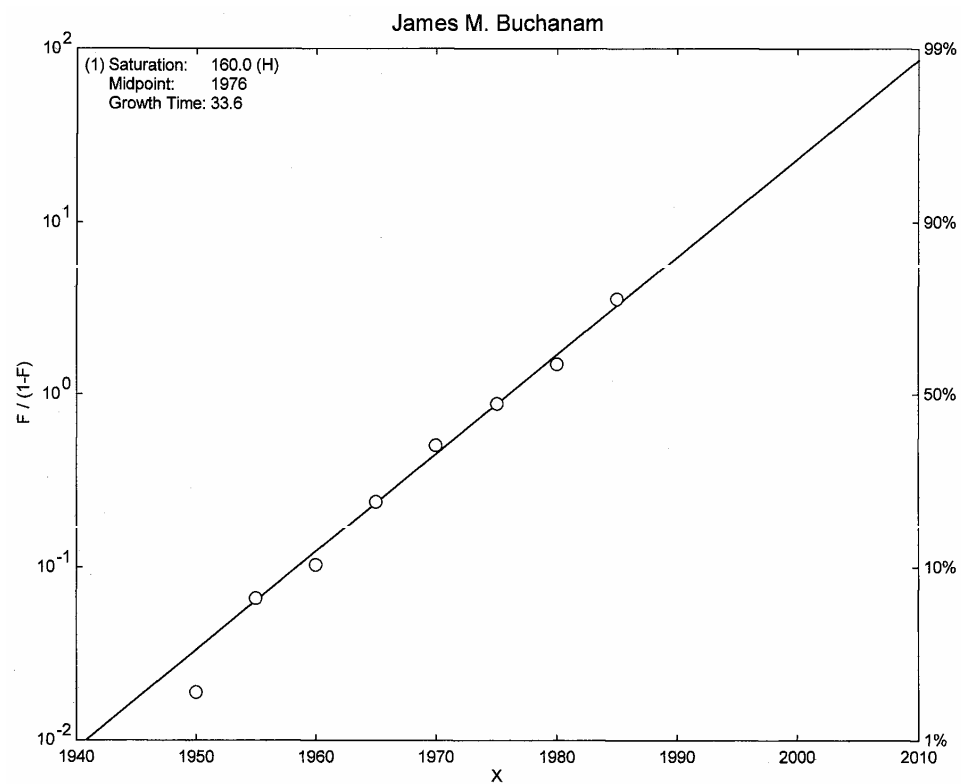


Figure 4.1.3c

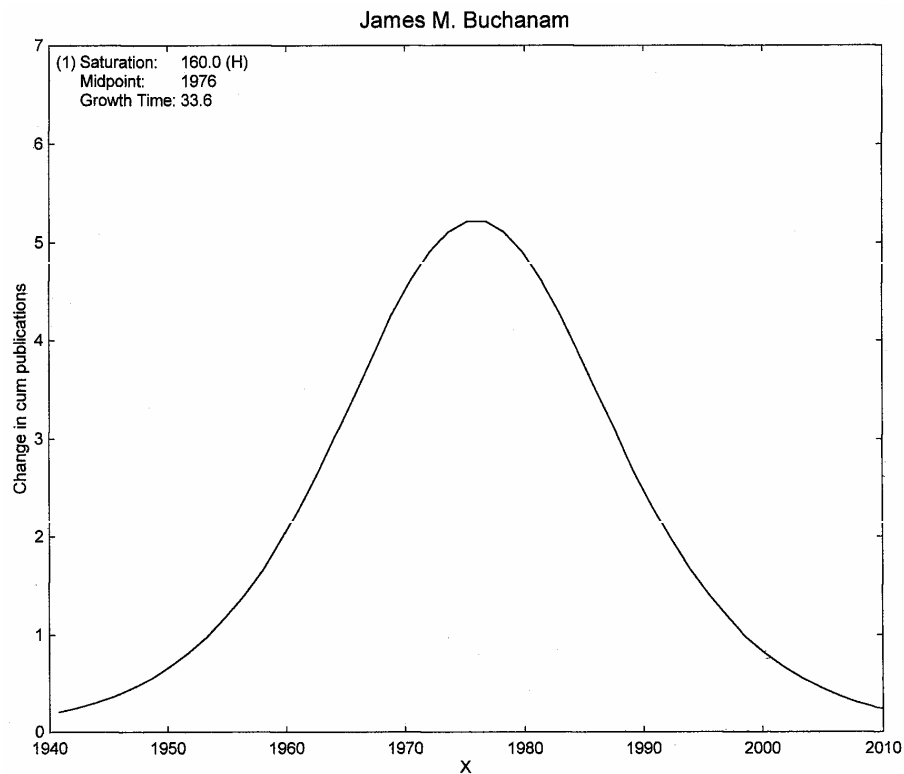


Figure 4.1.4a

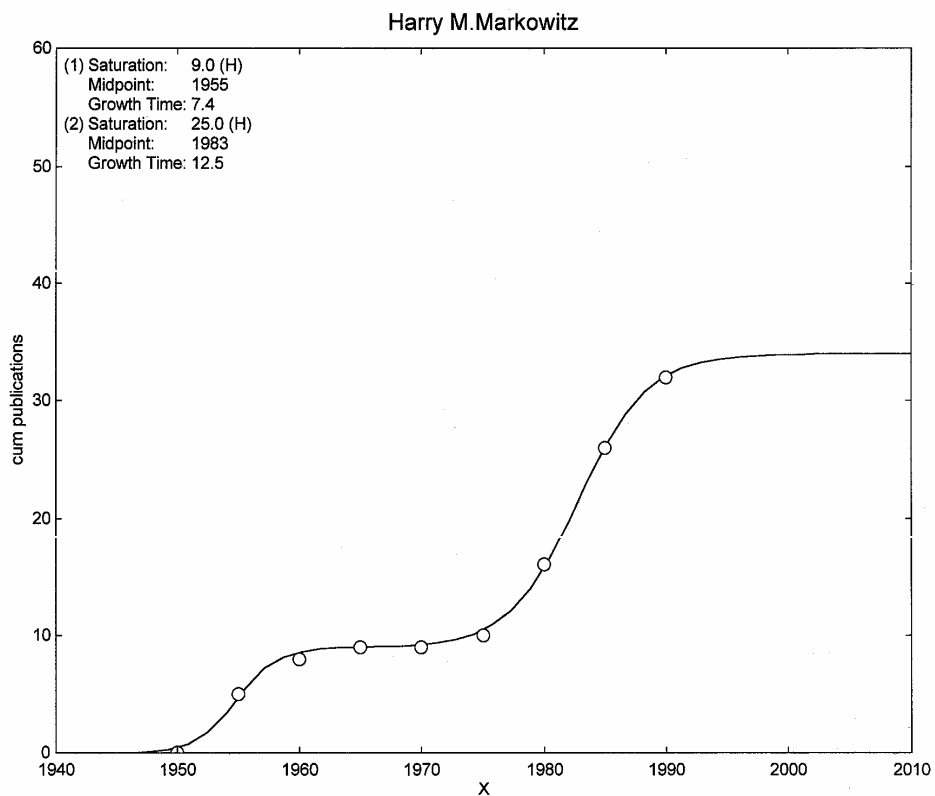


Figure 4.1.4b

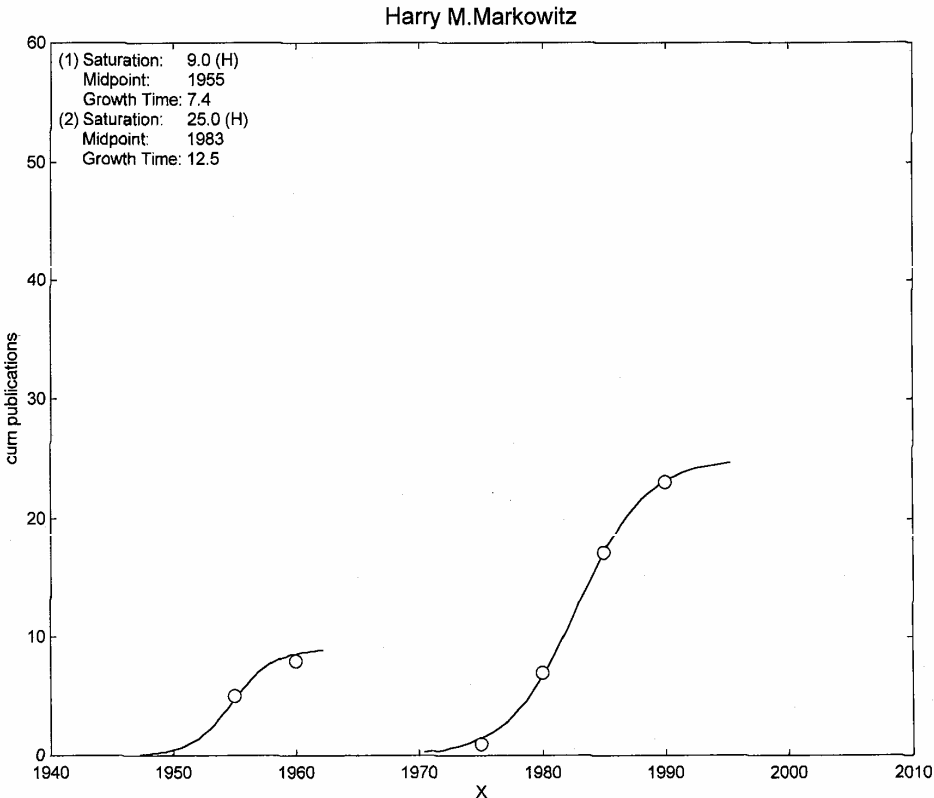


Figure 4.1.4c

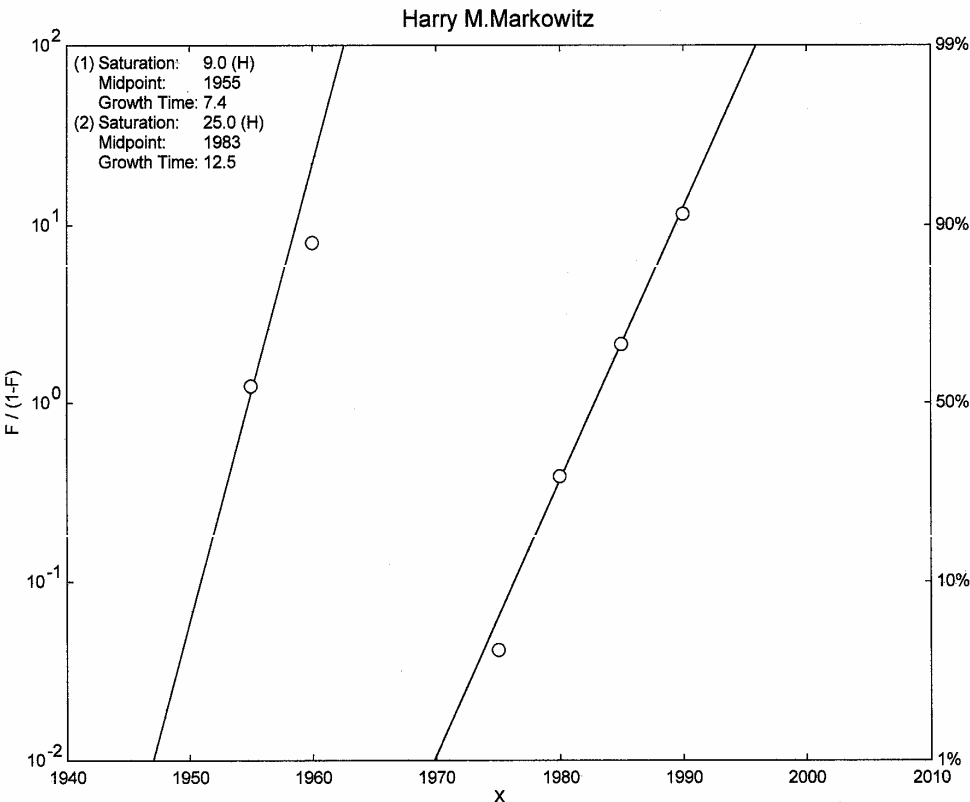


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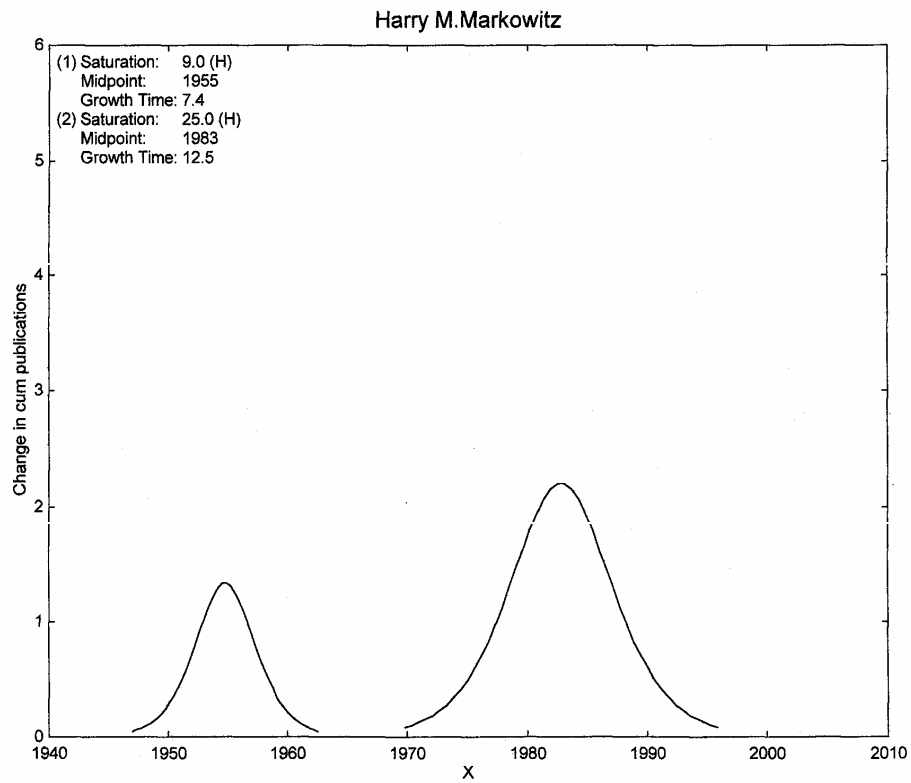


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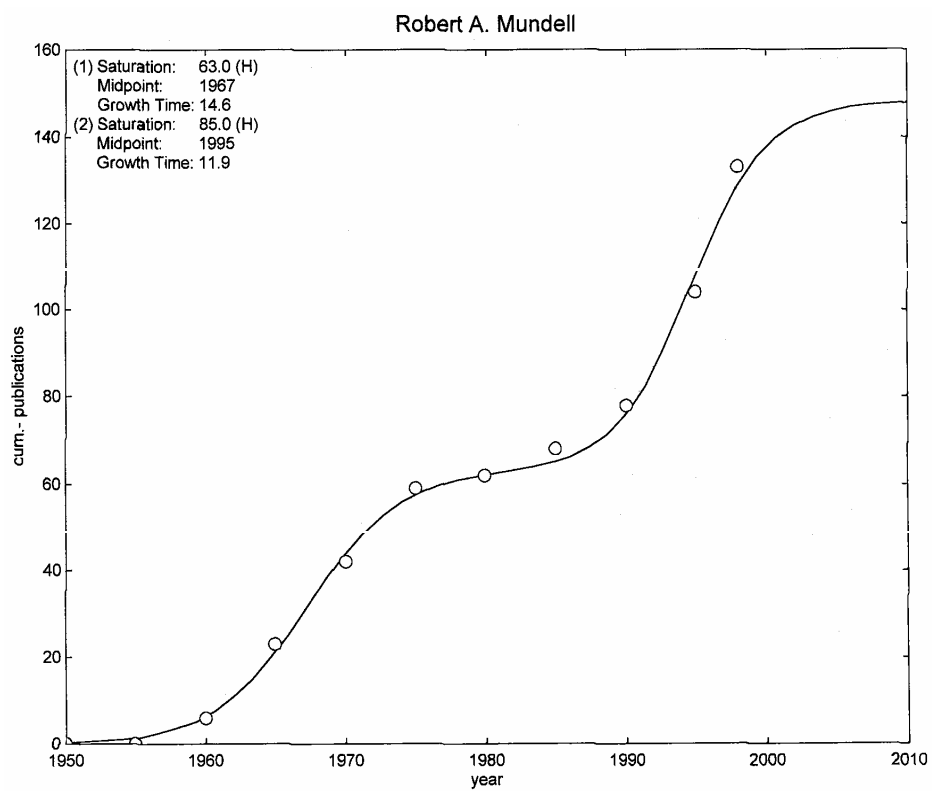


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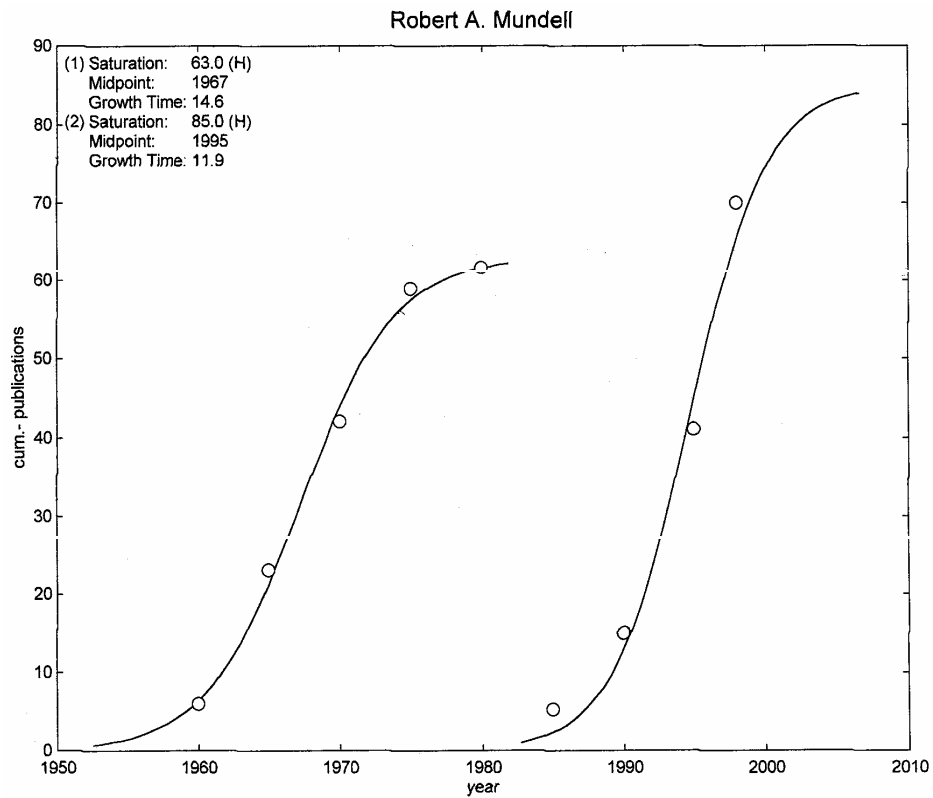


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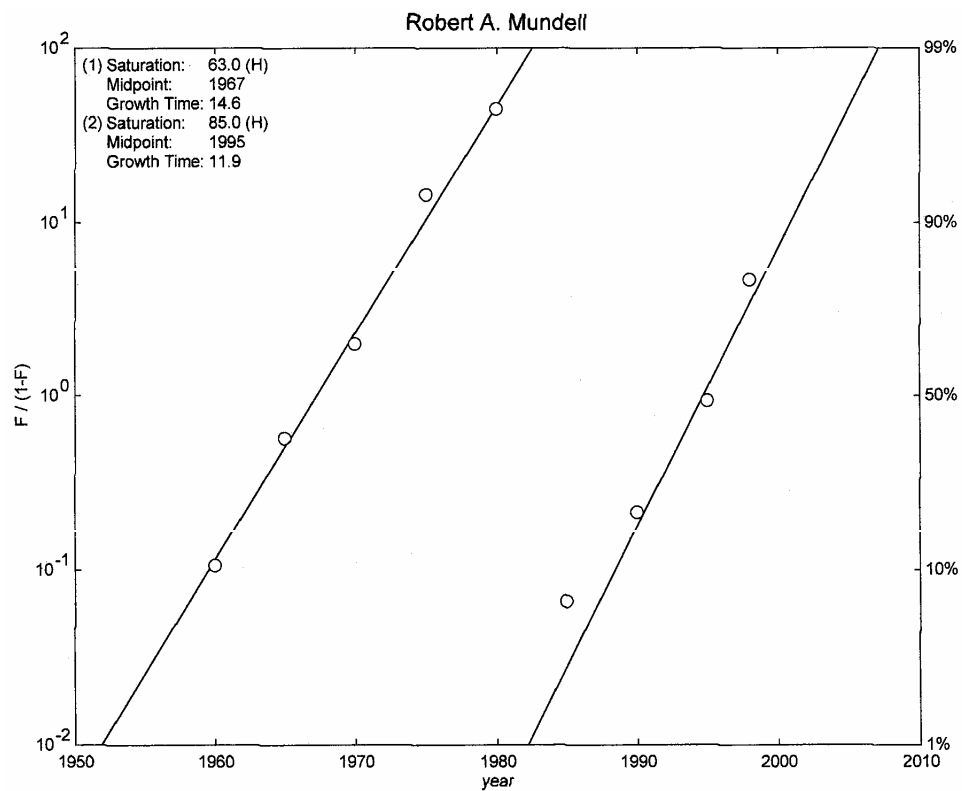


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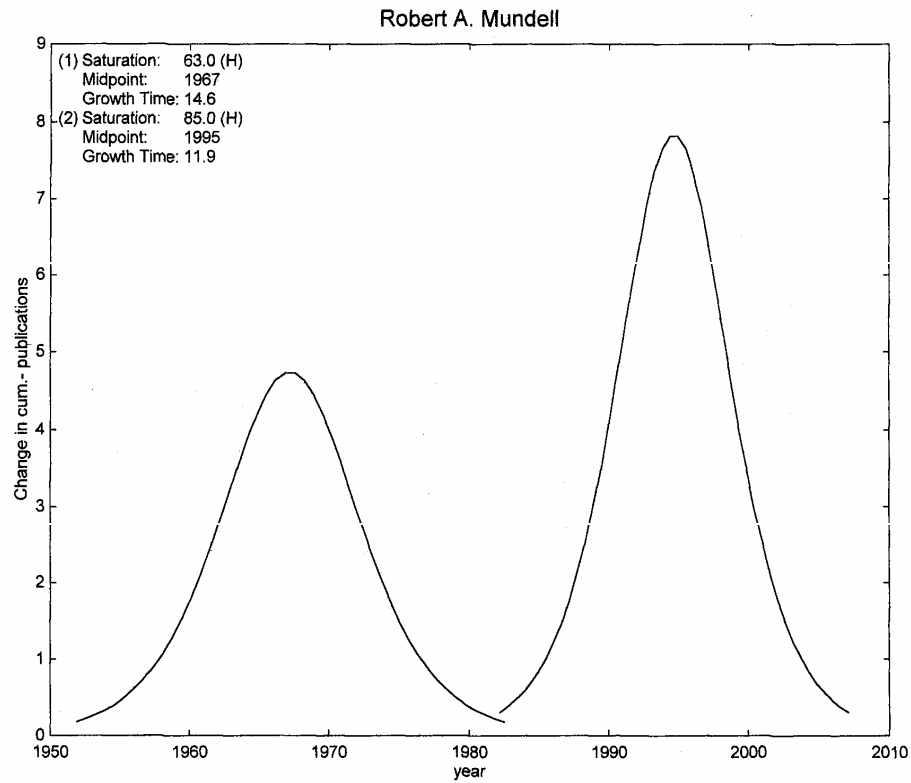


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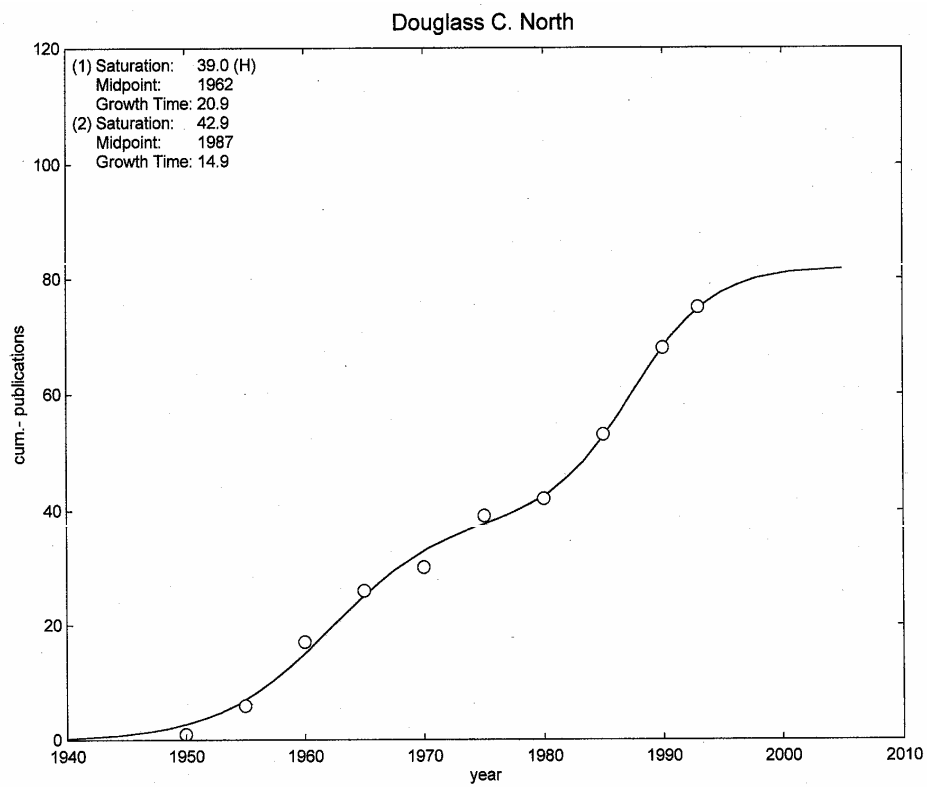


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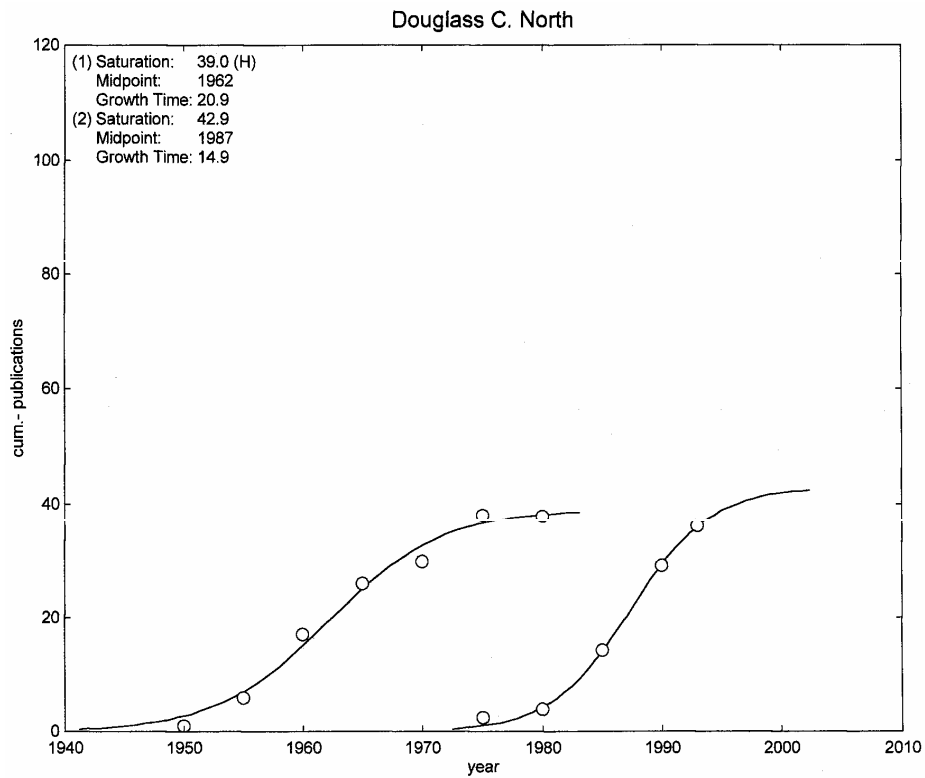


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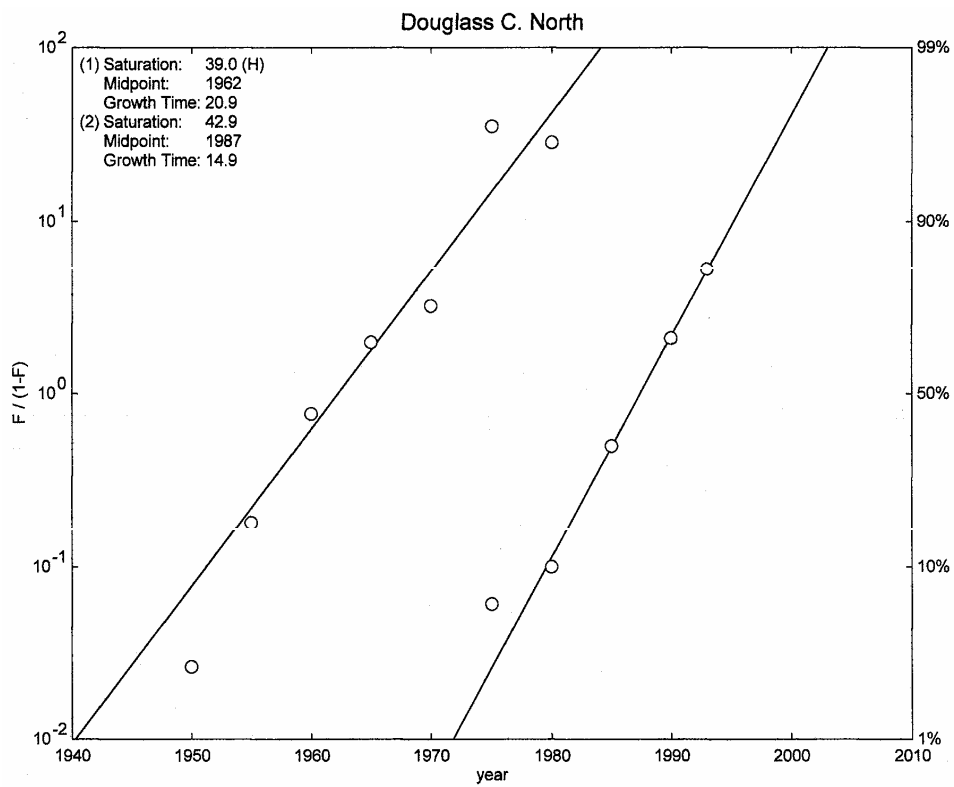
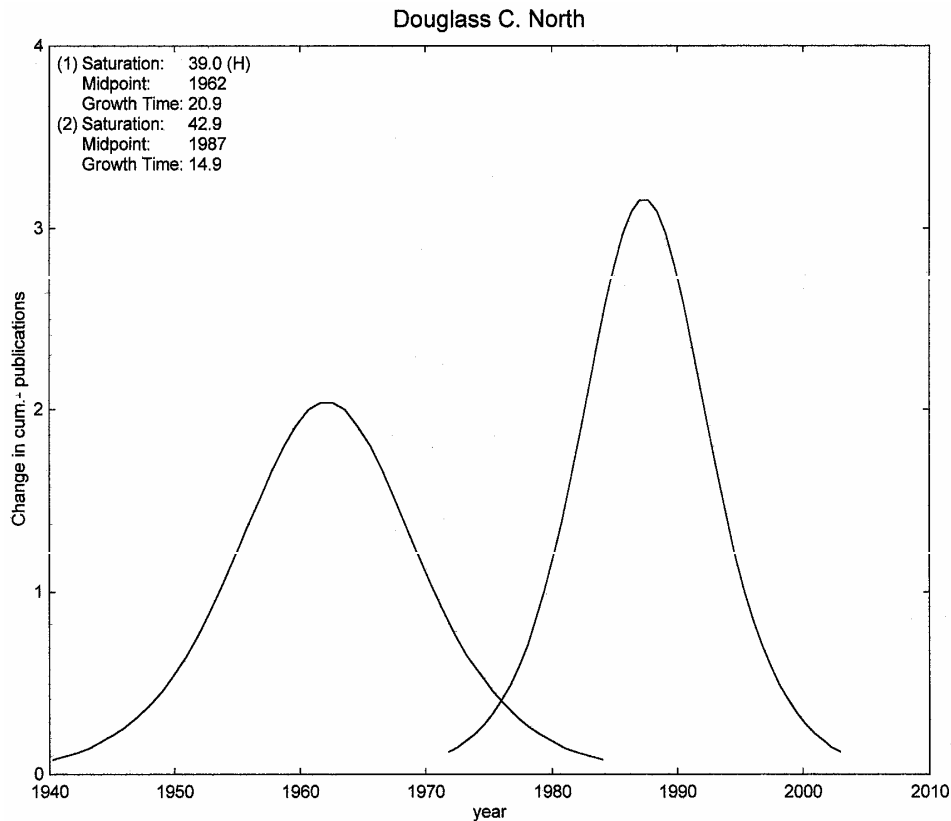


Figure 4.1.6d



Legend for Nobel Prize winners in science

Nobelists in physics, chemistry, and medicine-biology can be aggregated as they represent different facets of the scientific endeavor. In fact we will make an aggregated analysis for relatively large groups of about 50 to detect general features. One should say in terms of time distribution that they do not differ from, e.g., Nobelists in economics. They tend to have long productive lives, i.e., high values for their time constants and late center points for their logistics. A notable deviation from the mean, if not very marked, is that of Einstein, whose center point is at 42 years of age, while the others tend to be after 50. Fowler (b. 1911) has a center point at 56 years with a very large time constant of 44 years, beaten, however, by Von Humbolt (b. 1769) with 55 years. Von Humboldt lived till the age of 90, and one could say he was geared to produce science from the cradle to the grave. Murray Gell-mann has two pulses quite well separated, as best seen in Figure 4.1.11c and he is worth exploring to see the background of this feature. Burton Richter is slightly anomalous for a Nobelism, with a short time constant of 19 years and production peaking at a relatively early age. The Nobel Prize almost coincides with the peak, and may have fueled the legend that winning the Nobel Prize boosts the ego and stifles productivity.

Abdul Salam is the norm with a time constant of 36 years and a center point in the late forties, similar to Steven Weinberg (b. 1933). Roald Hoffman (b. 1937), a chemist, biologist philosopher, poet and writer is more fitted to the Nobelists with a

time constant of 28 years, and a center point at 48—and not forgetting almost 500 papers at saturation.

Coming to aggregated values, we studied the distribution of ages at the time of the work that later won the award, and found that the time constant is exactly the same for the three disciplines mentioned, the only difference being the center points that are somehow displaced, by three years, in the sequence physics, chemistry, medicine. We have no interpretation for this delayed blossoming of the three classes of disciplines, but the phenomenon is absolutely clear. At the initial ages, below 30, there is a fall in the number of discoveries with respect to what the back casting of the logistic fitted to the ensemble of the data would suggest. This is current in many other cases, and can be interpreted as a still insufficient mastery of the technical tools. A curious fact is that the fall is largest in medicine, where one would think the difficulties would be less. We also studied the distribution of age at the time of the award, a subject less central to our search as we are looking for productivity and not for medals. However, it serves to round off the picture. It is curious again that the time delay for the prize, in an aggregated form, is 12 years for physics, 13 for chemistry, and 14 for medicine. We have no hints about the reasons.

Figure 4.1.7

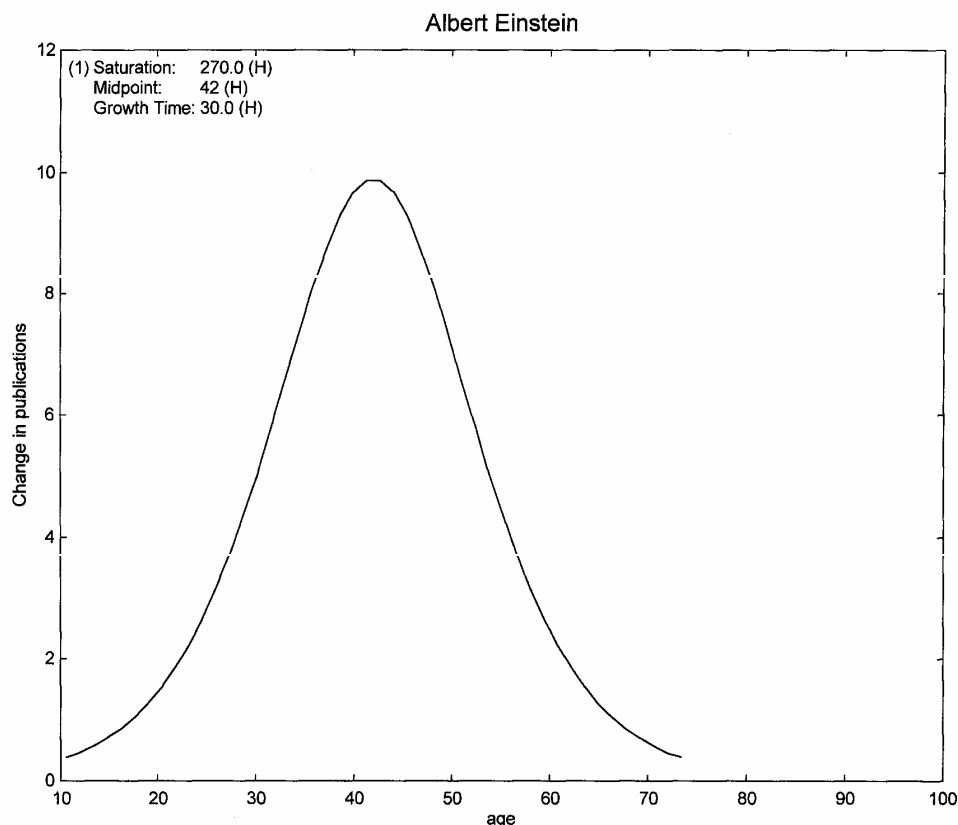


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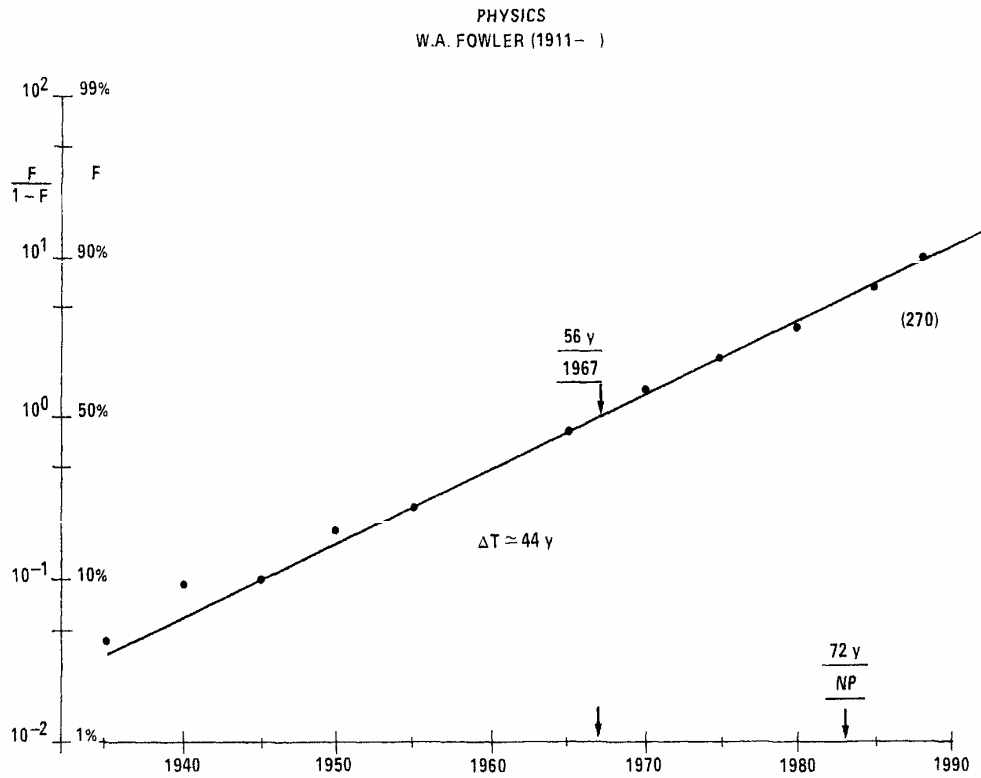


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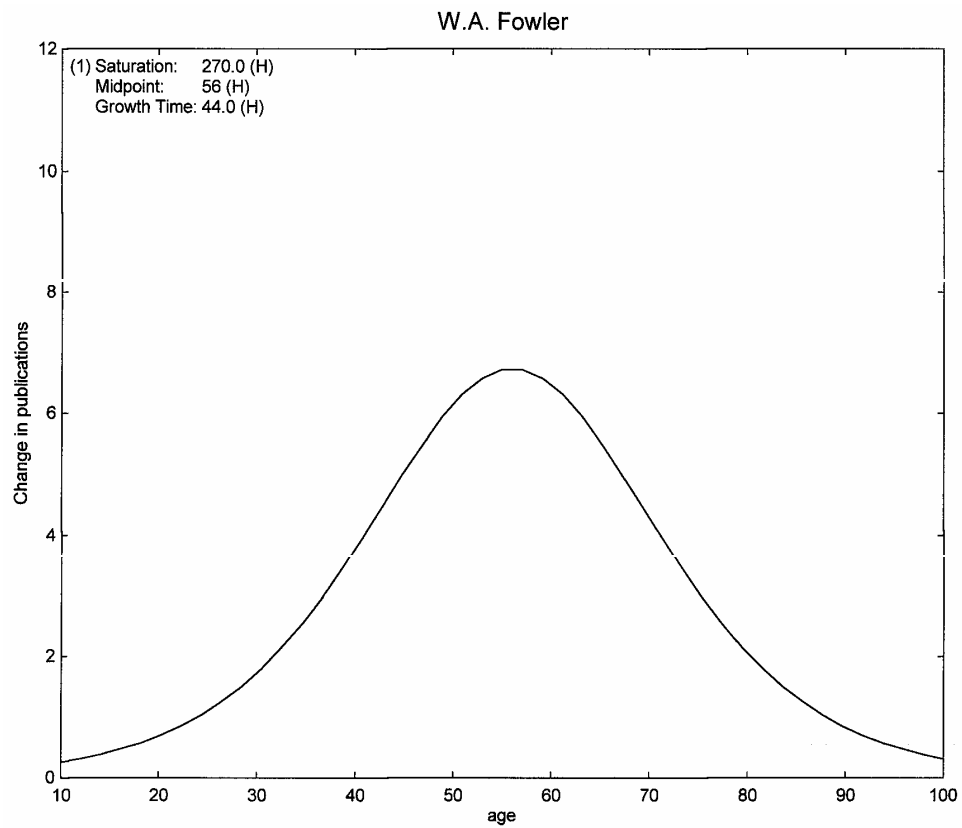


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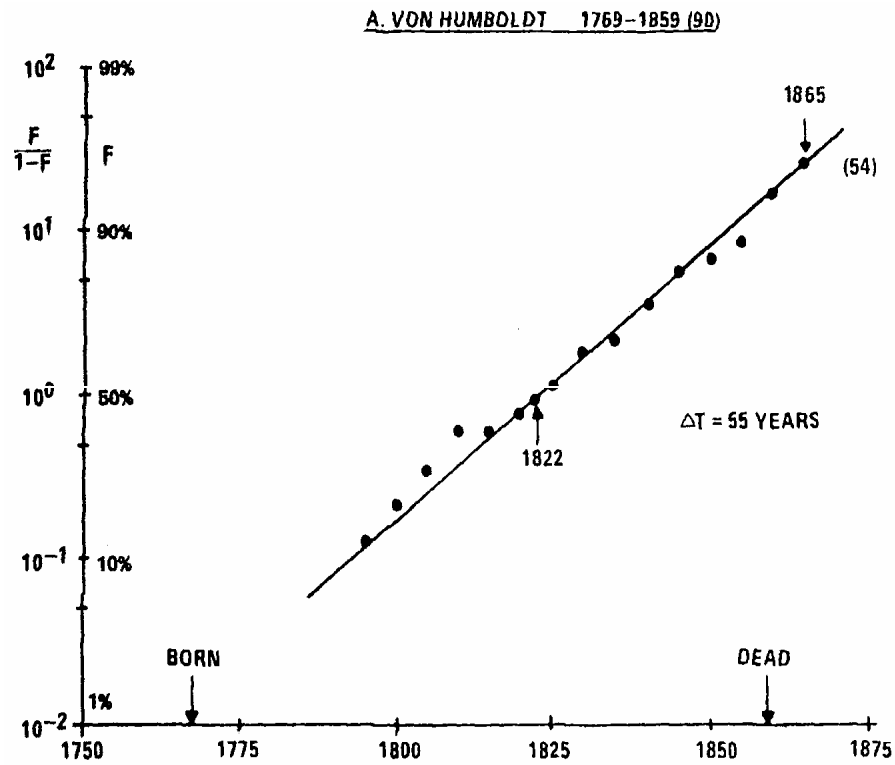


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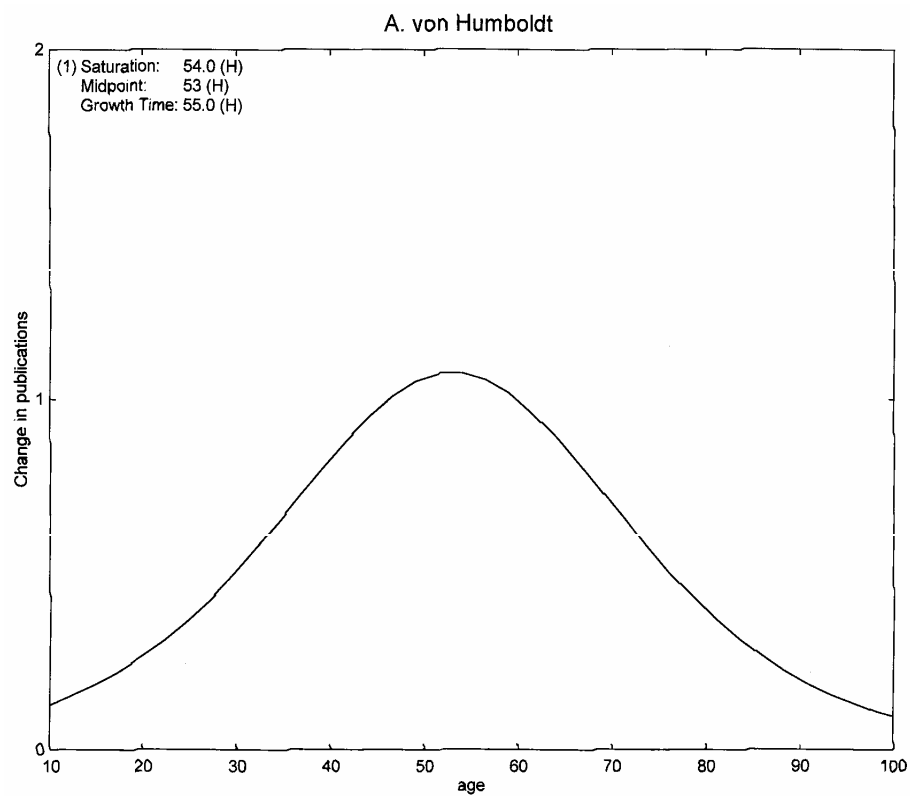


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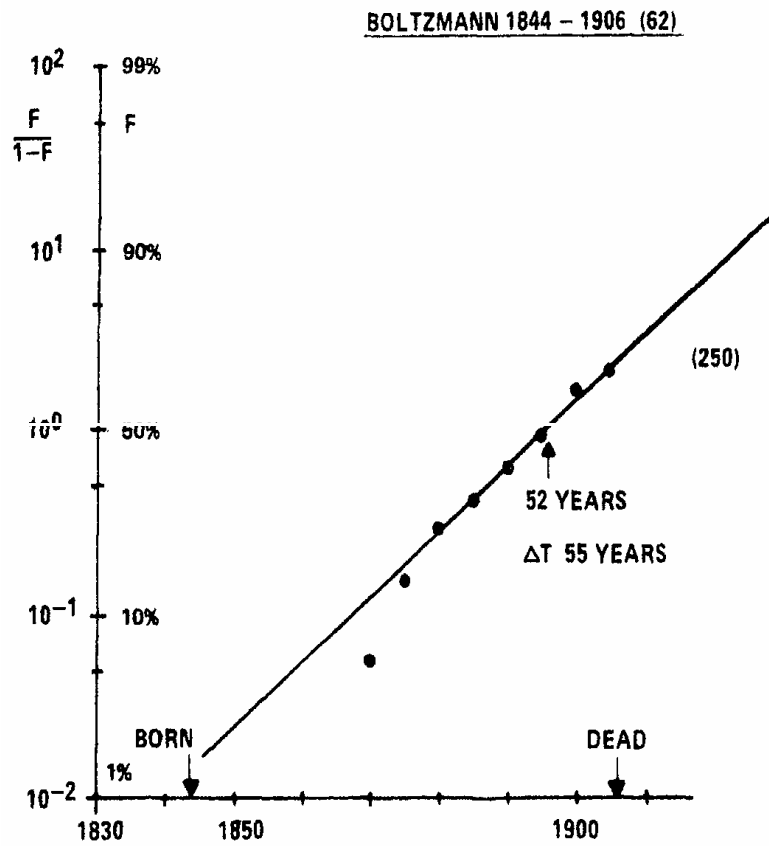


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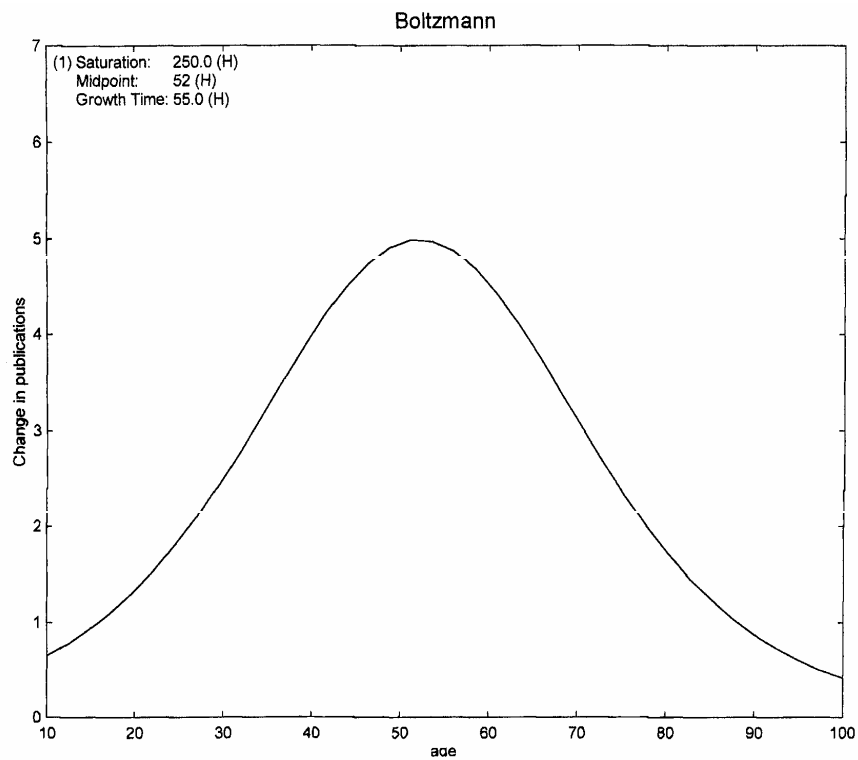


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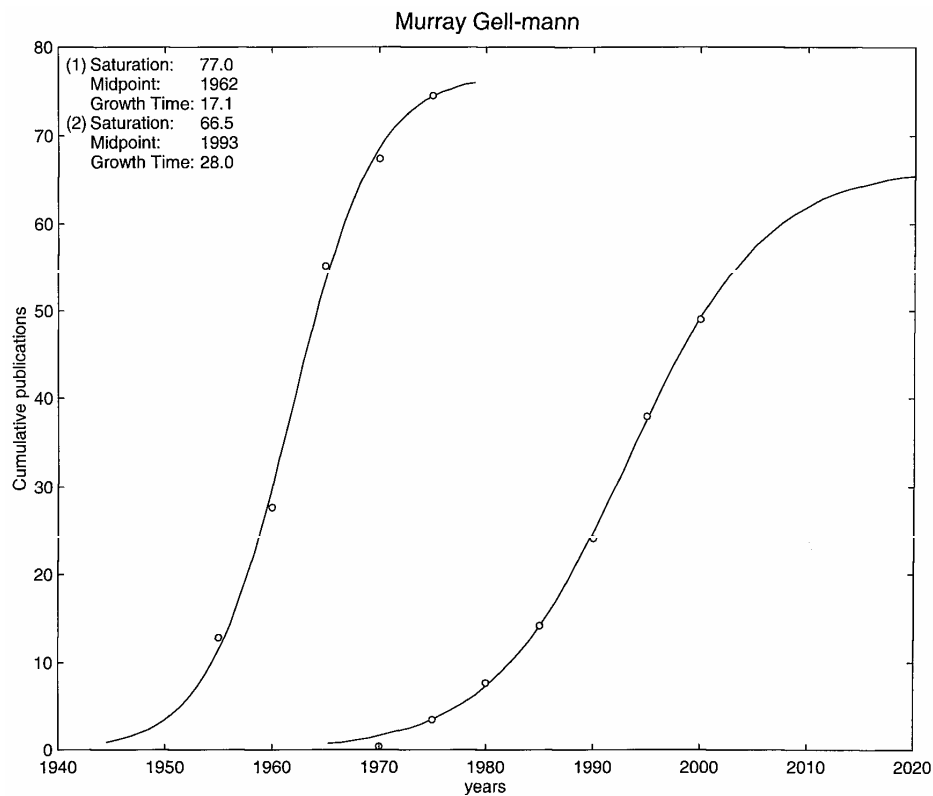


Figure 4.1.11b

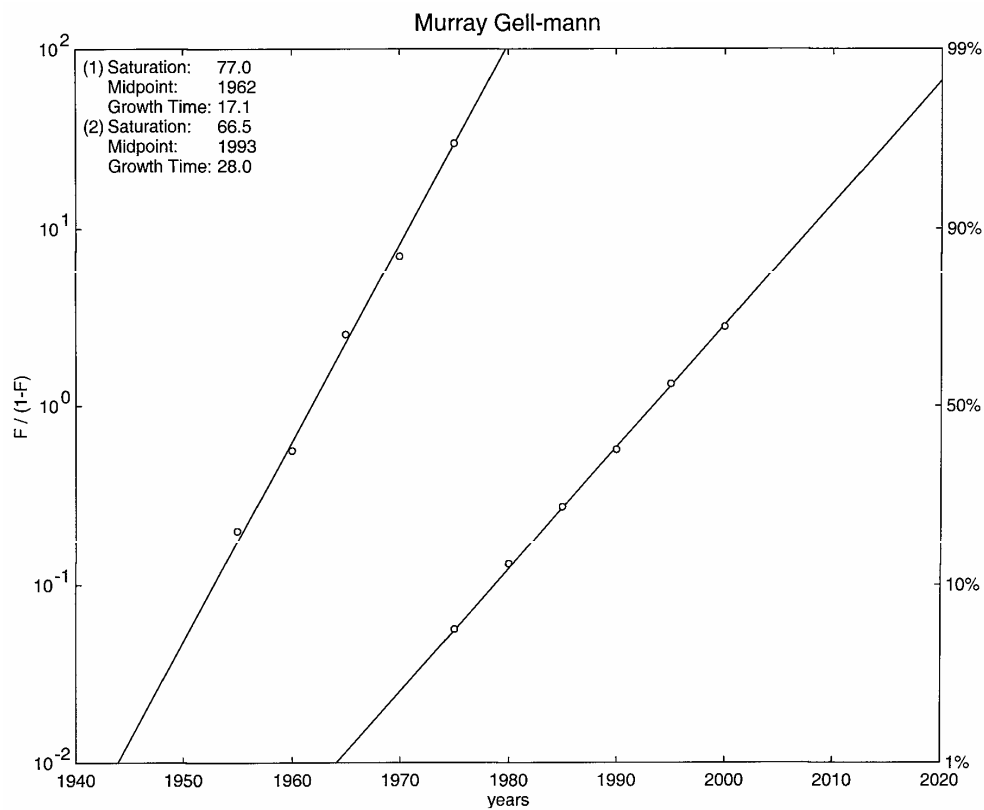


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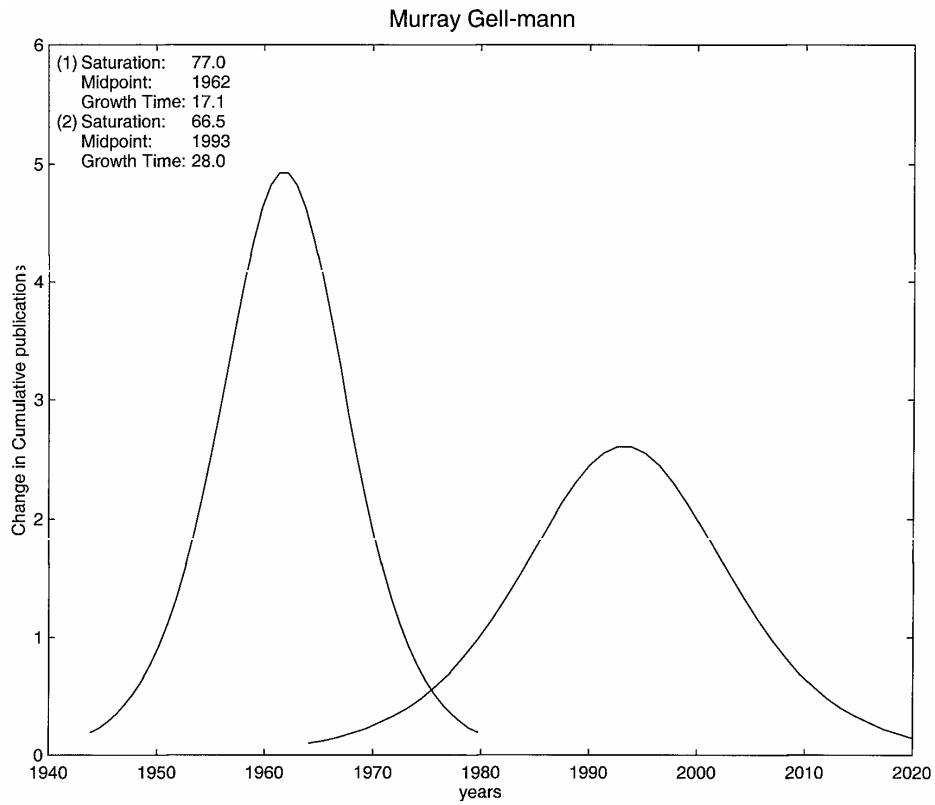


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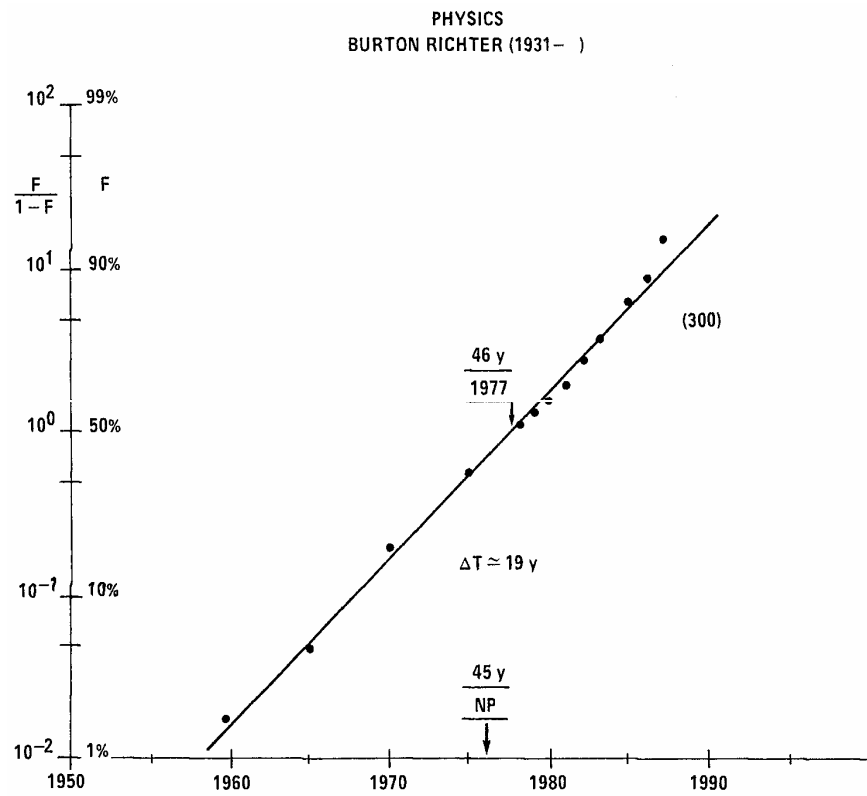


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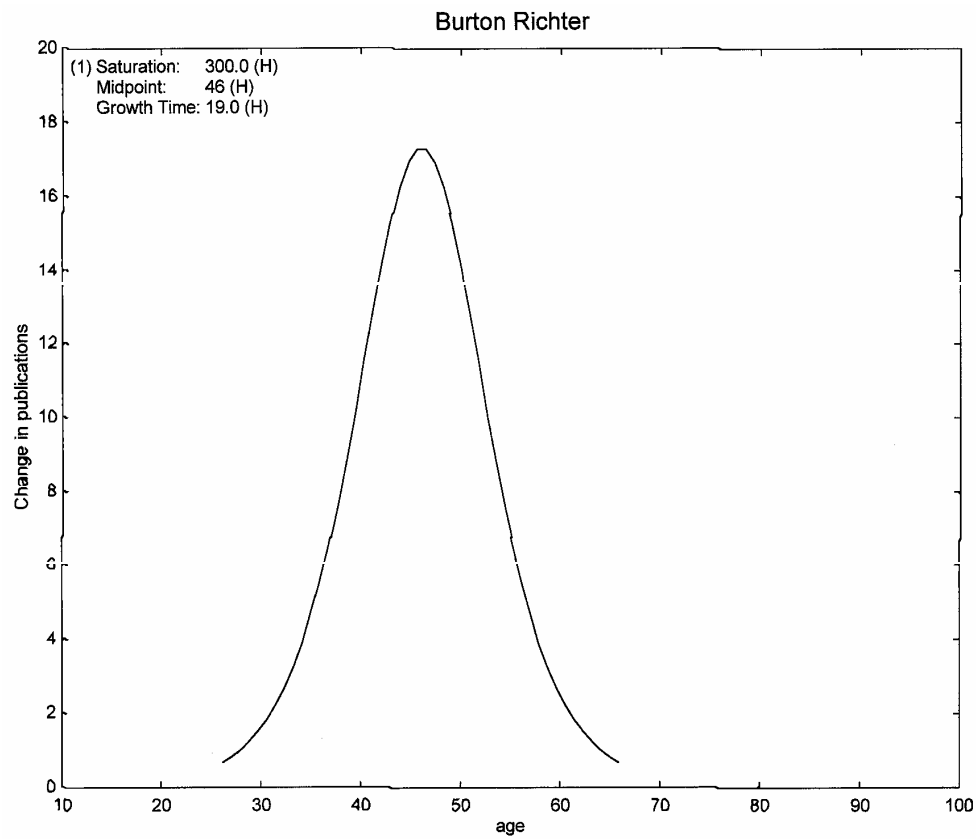


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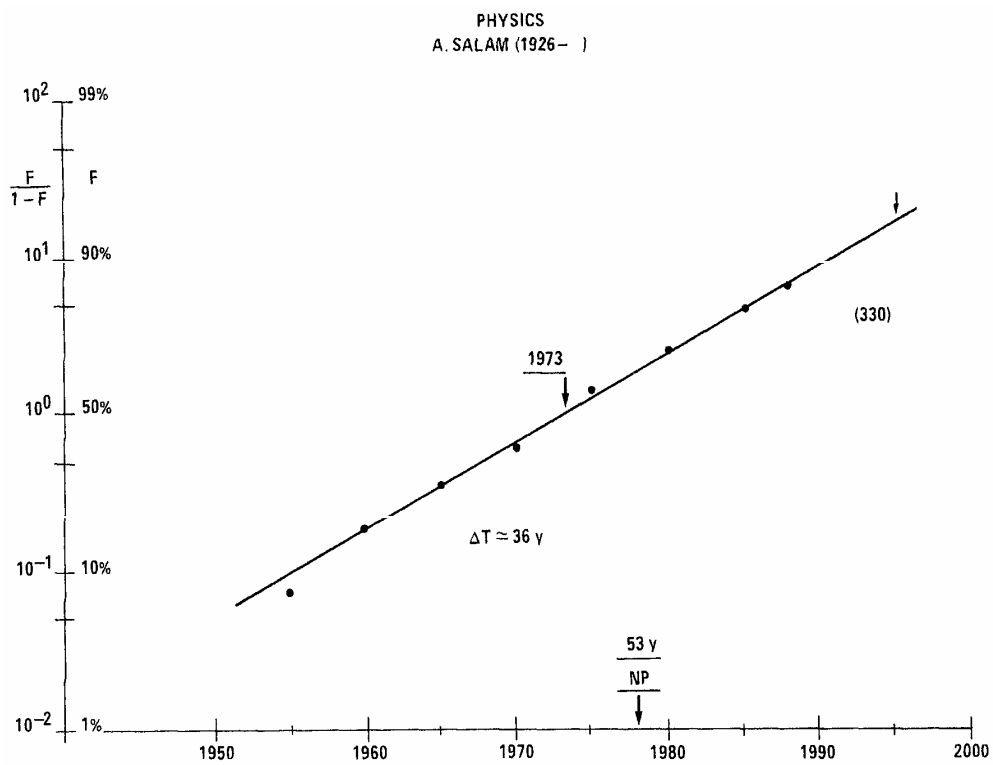


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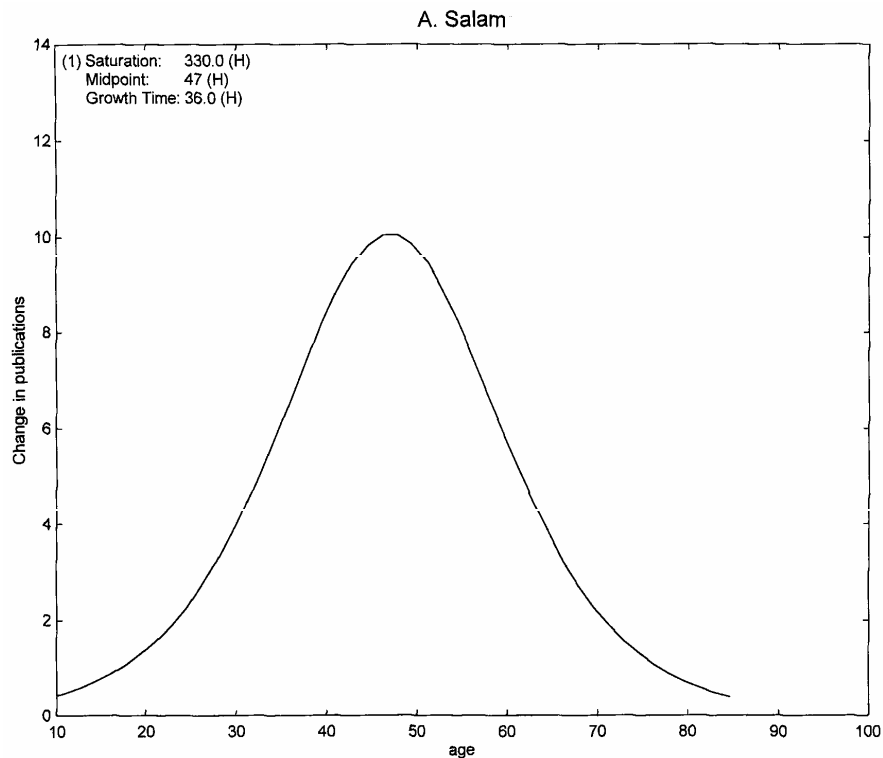


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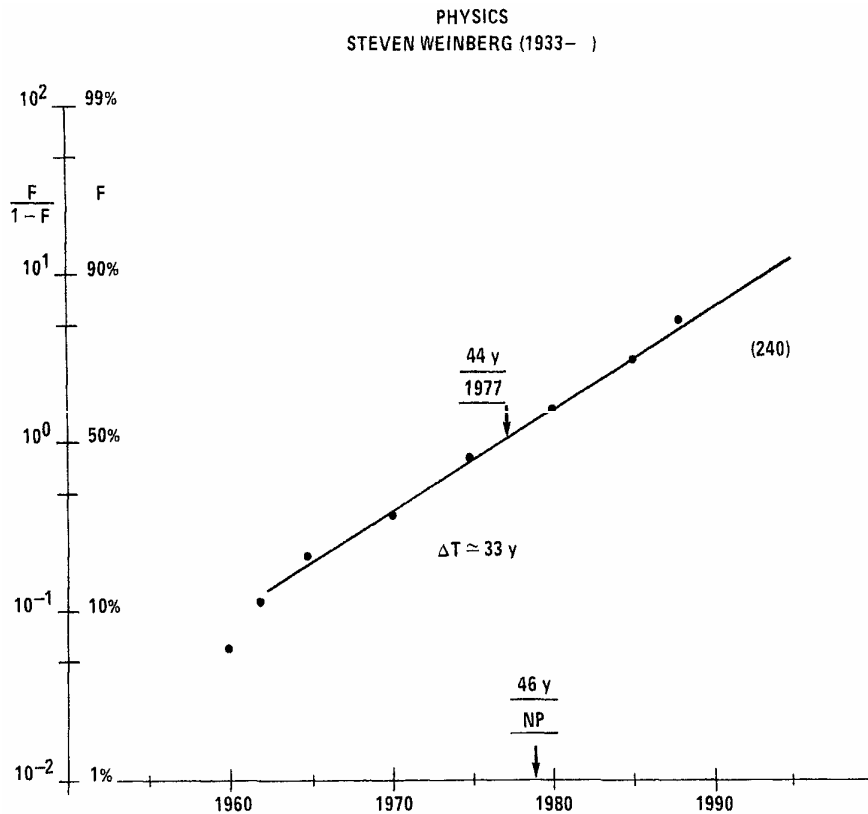


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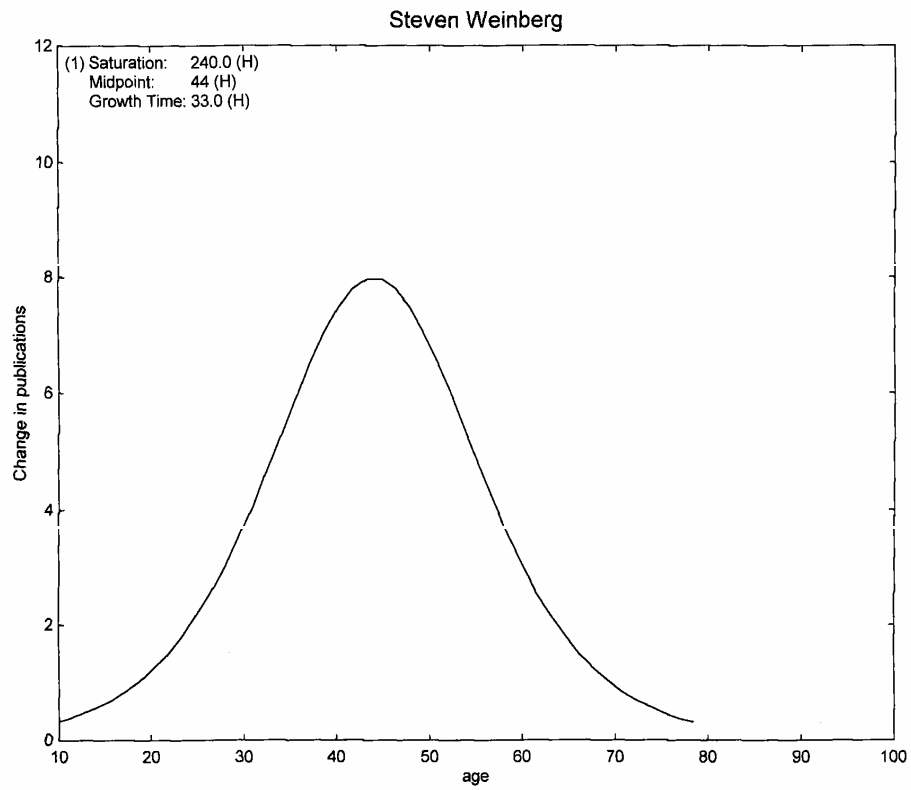


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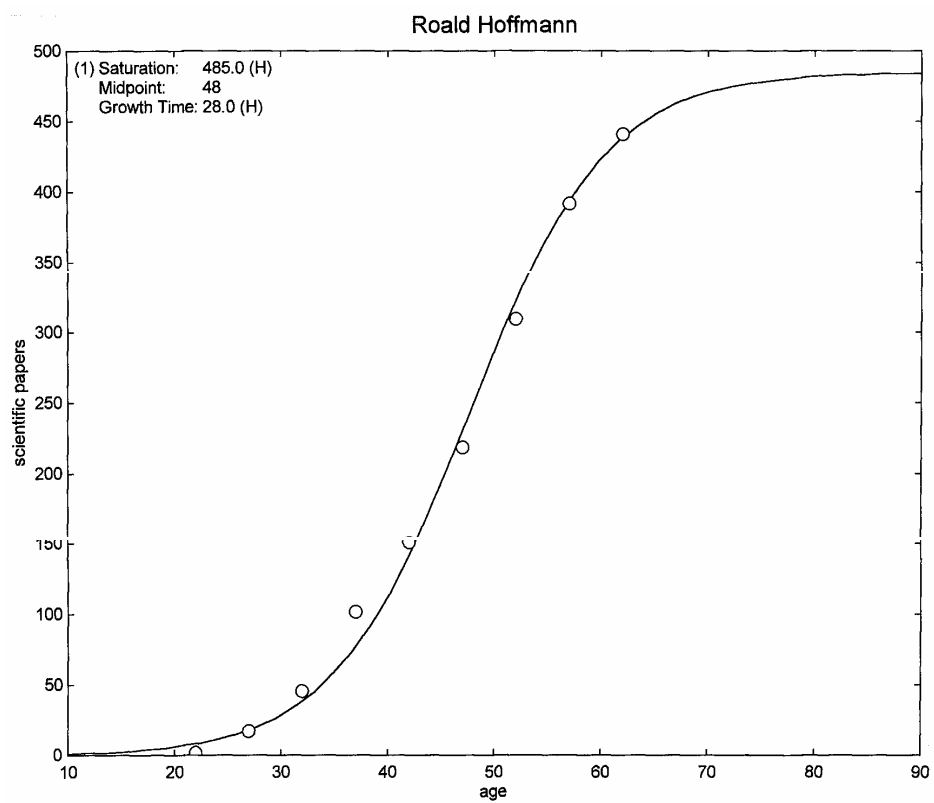


Figure 4.1.15b

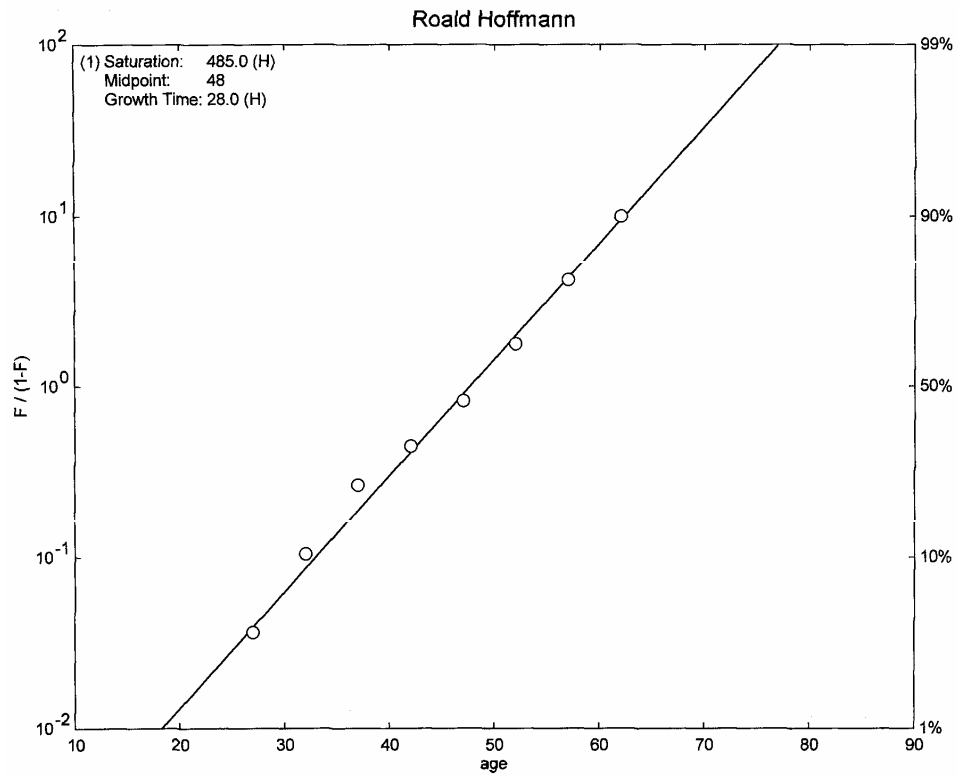


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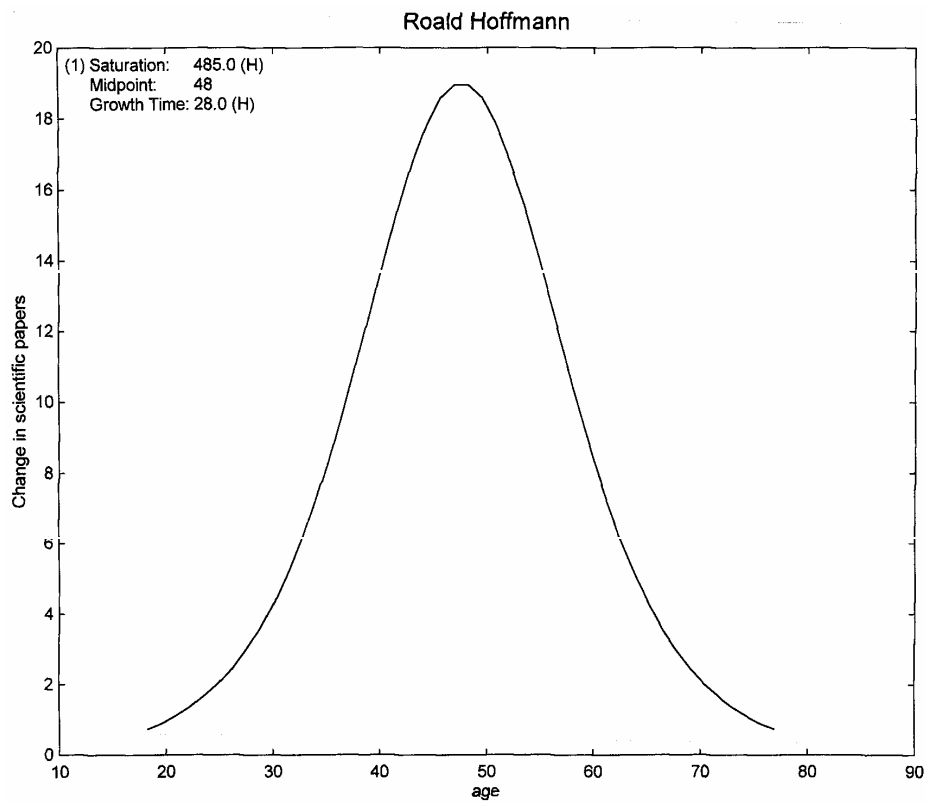


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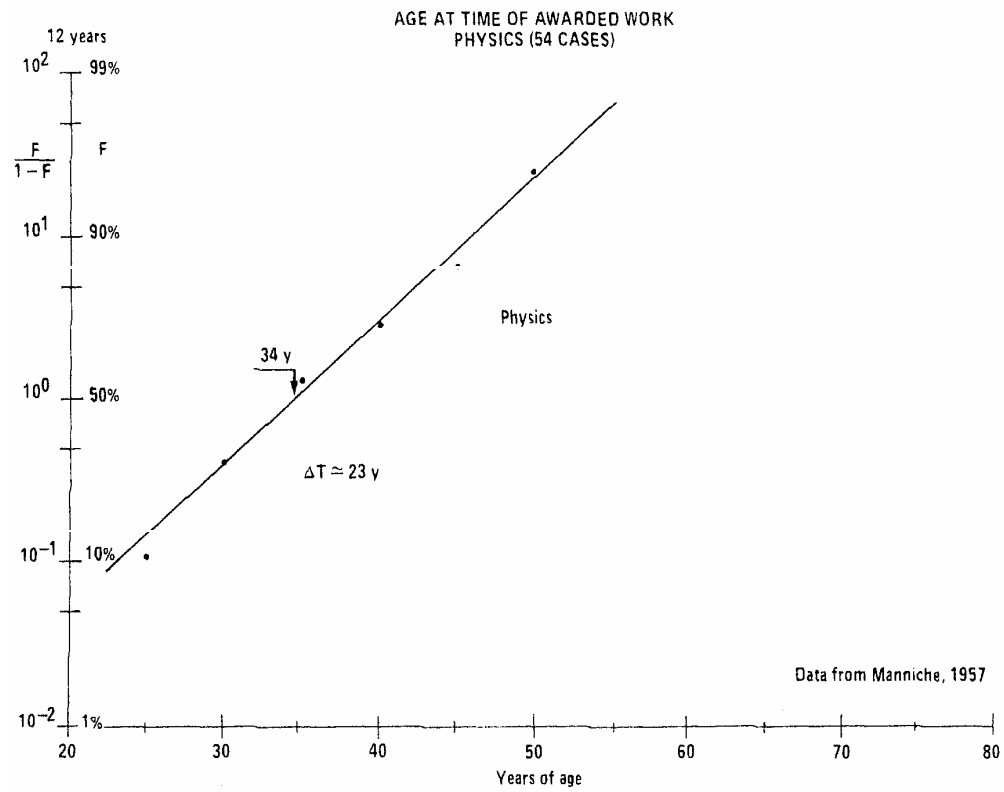


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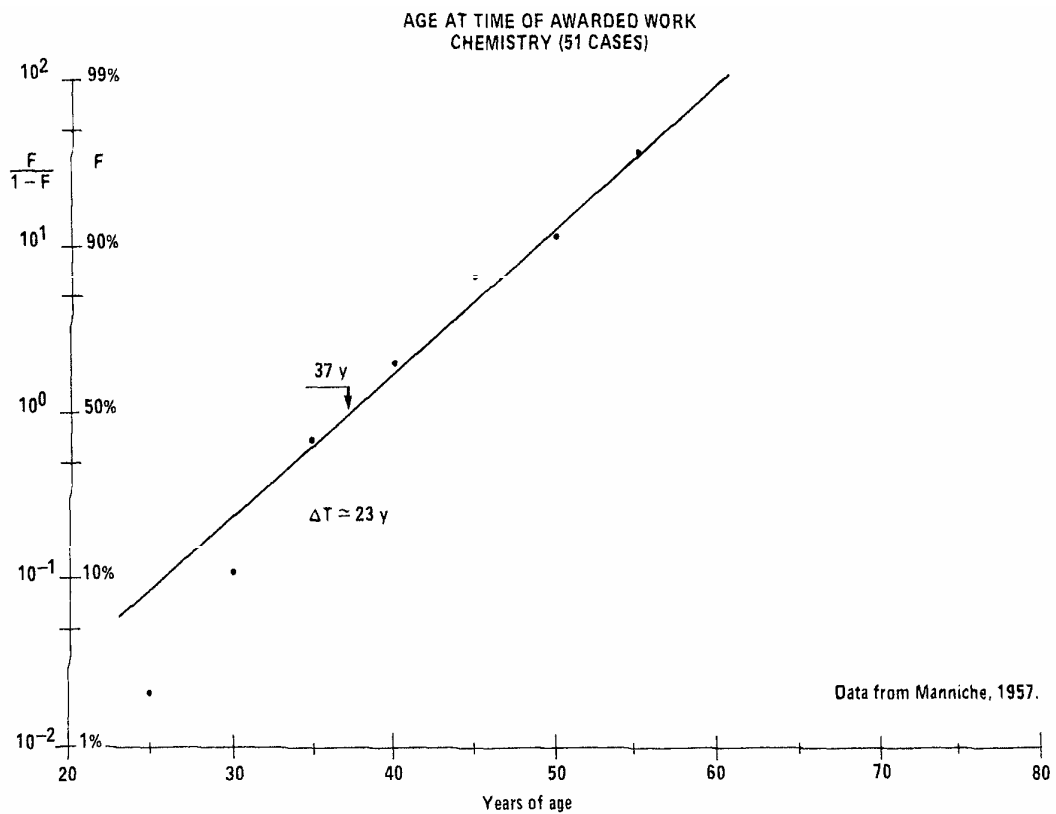


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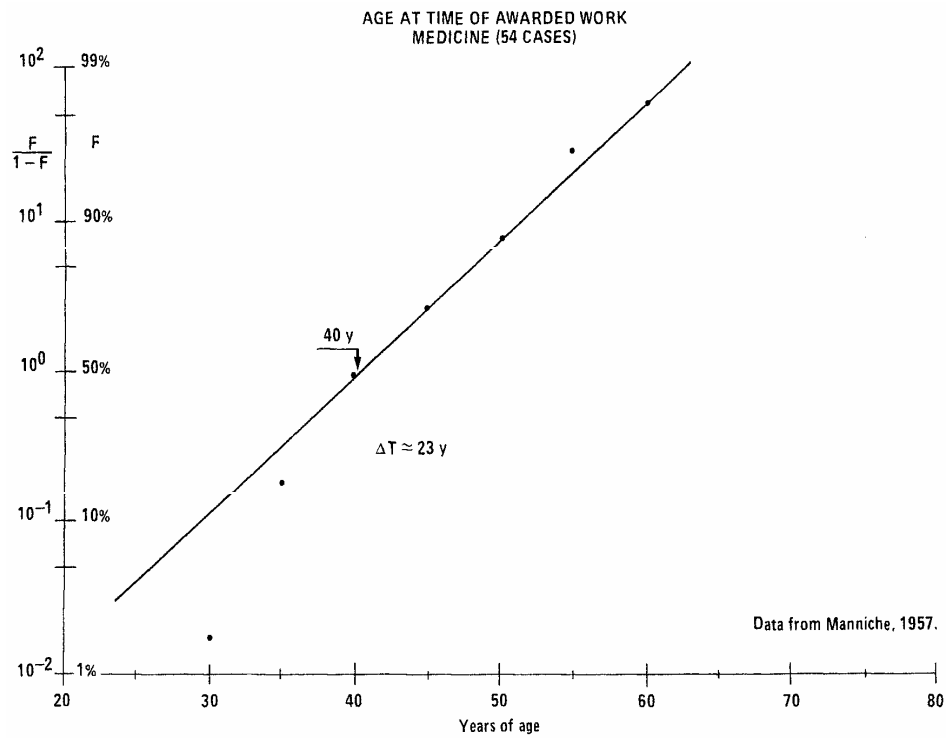


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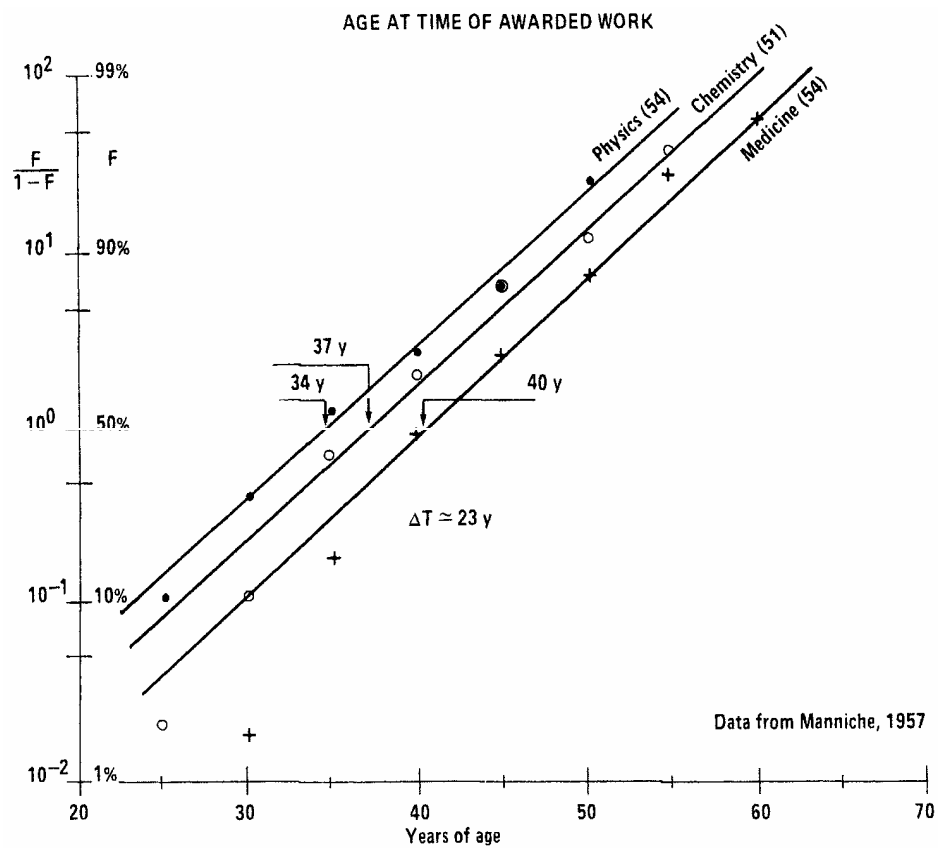


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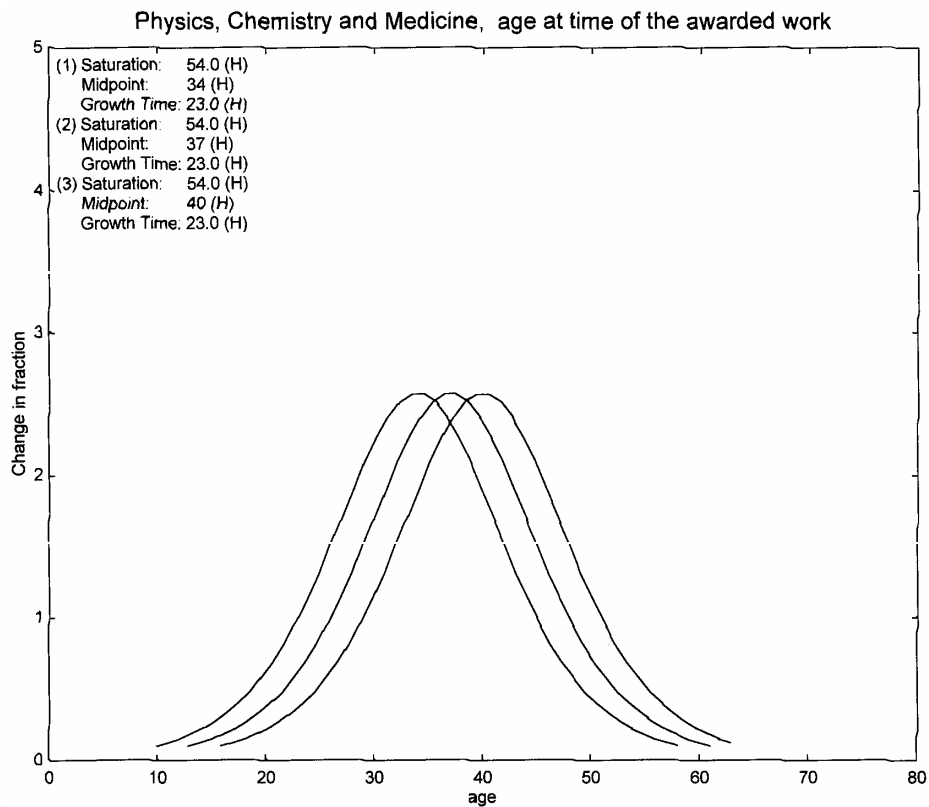


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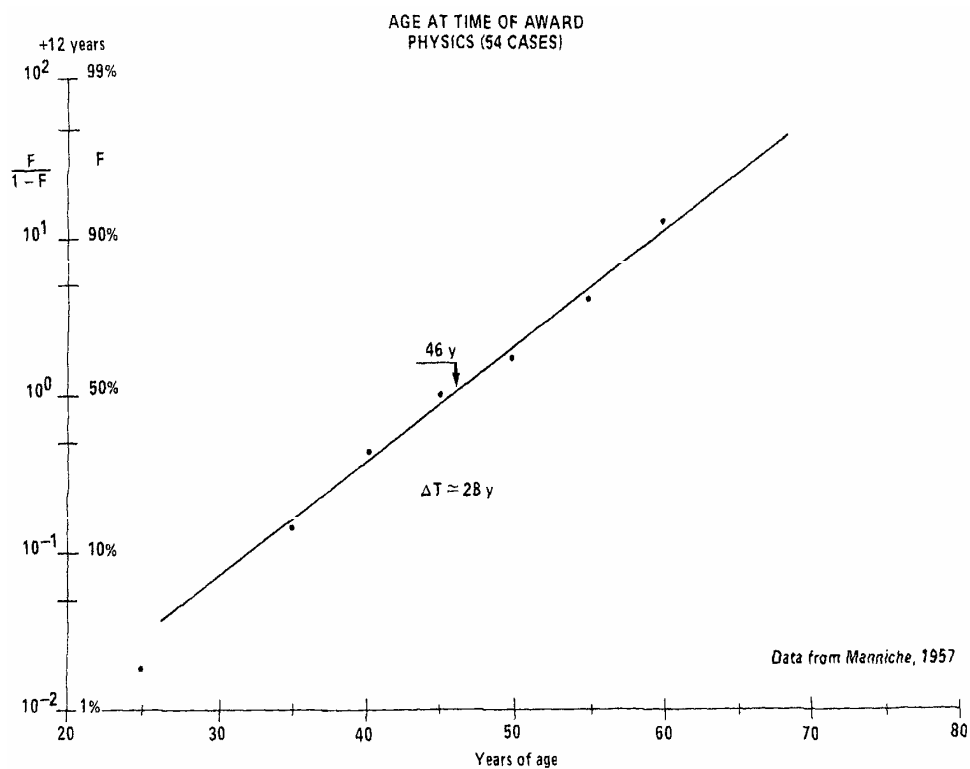


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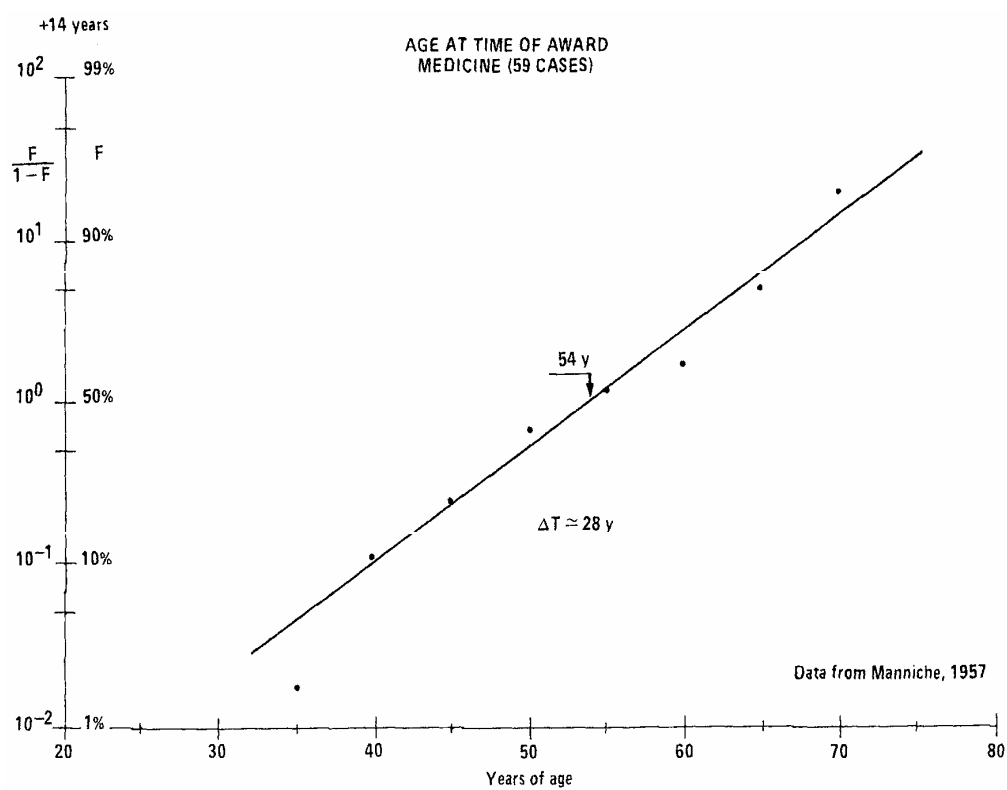


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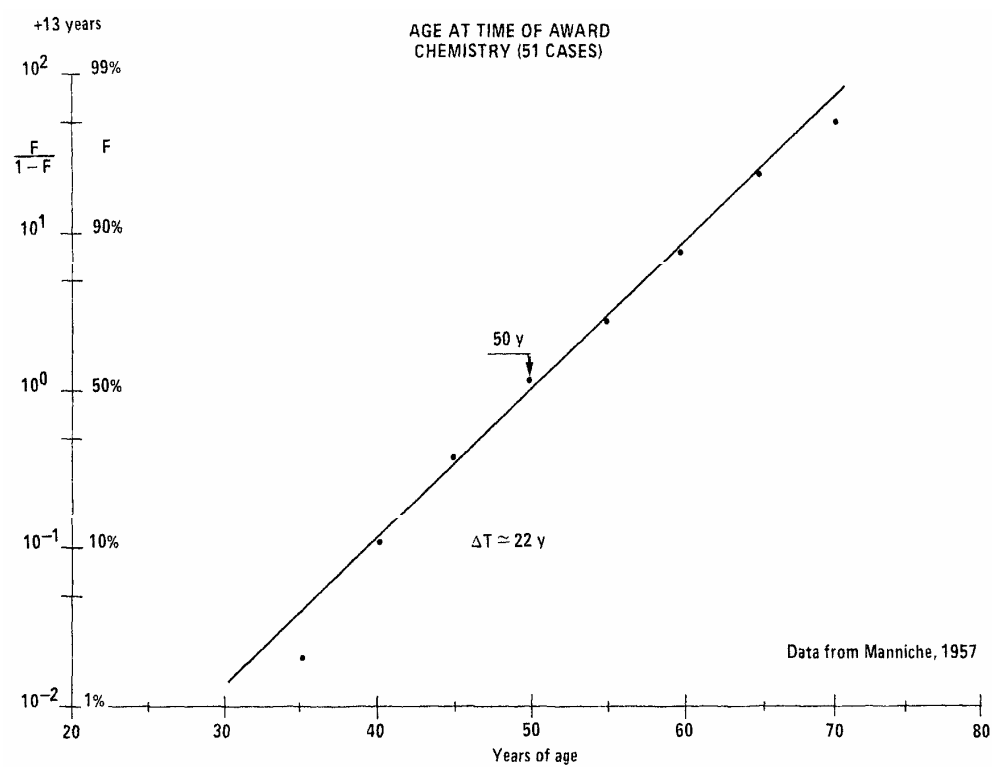
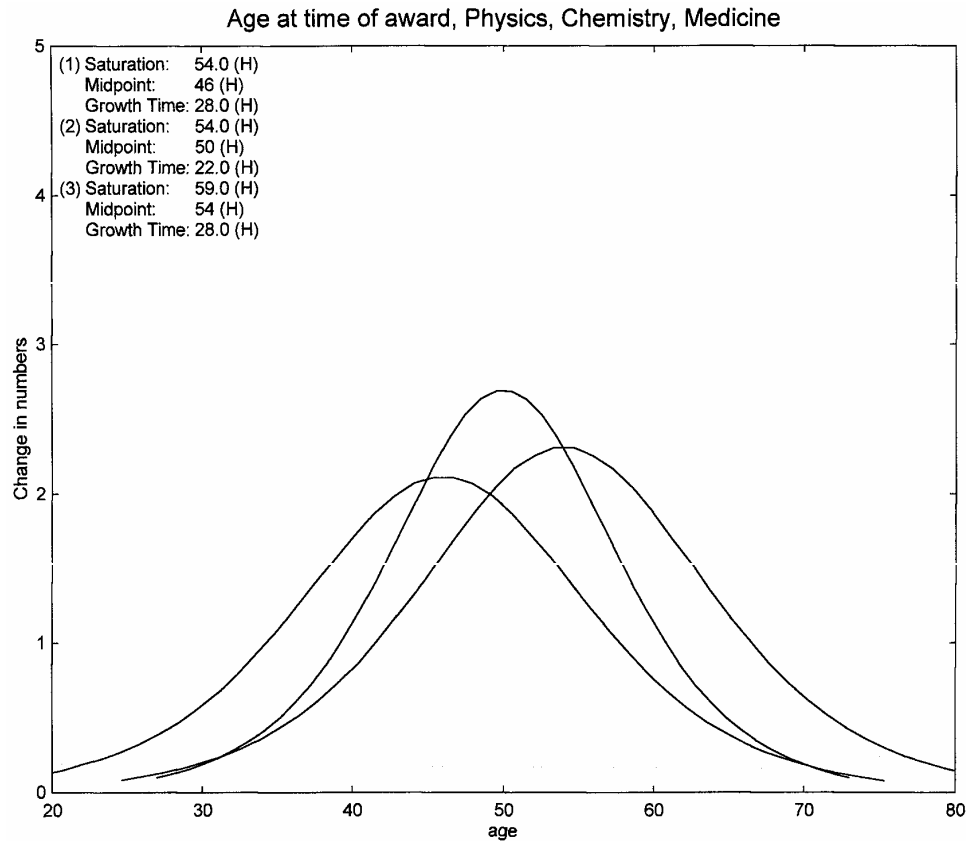


Figure 4.1.23



4.2. The film makers

Theater, of which film is the most modern technological version, has always been considered a very creative activity involving various artists: actors, authors, metteurs en scène, costumiers: a coacervation of creativity in every detail. The piece must be real and at the same time not real, but carrying a deep message on how reality works.

Film artists share the character of theater artists, often eccentric, obviously exhibitionists, emotional, and fundamentally irregular in their personal and professional life. At least this is the cliché we find in literature and in daily gossip.

Having struck gold in our search for information on film people and correlated artists such as writers, we made an extensive analysis of their productivity as a function of age and found their behavior strikingly regular, matching that of university professors and Nobel Prize winners. As many women are active in the film business, we were also able to explore the gender issue, which is much more difficult in the other two categories where women are a minority. The results are as “normal” as one could expect: the logistics patterns are dutifully filled, and the only way to distinguish them is the high percentage of them having a double equation. The only gender issue therefore seems to be linked to the pretty, sexy and young roles that women usually have to play.

The double pulse is interesting although it does not seem to procure a double lifespan but just reports a peculiar organization of the life pattern with usually a large pulse of

activity at the young-mature age, followed by a small spurt at a higher age. The attached figures illustrate well the situation. The two pulses are in many ways reminiscent of those of Canadian and Egyptian males in terms of child production, although the ages are much younger in the latter case.

Another characteristic of film people is that, as is the case with very dedicated artists in other disciplines, they seem to never give up, sometimes stealing a last film before death by anticipating it with respect to the “logistic program,” as in the case of John Huston. His last film, anticipated by a couple of years, is suitably titled “The Dead.” This appears clearly in the charts, but although logistics fit the ups and downs of an individual’s activity extraordinarily well, we cannot really guarantee such a deduction. In any case a relatively strong longitudinal noise, i.e., advancing or delaying an accomplishment, is current business and such shifts are possible.

The only point that film makers might not like at all from our analysis is that they seem to live automatically in an automatic world. Their extra large egos boost their extra important careers created overnight from nothing—as God did at the beginning if on a somewhat larger scale—to make them feel unique. The only arrow in their quiver really is that, for the time being, we are unable to calculate the second pulse from the characteristics of the first one (which we managed with other cases). So the exact course of their life doings remains just out of grasp.

Legend for the film makers

Film makers are said to be a colorful and very active bunch of creative people and we can find all sorts of productivity configurations in multiple roles such as actors or producers that can be easily separated and compared, and so on.

For our analysis we took the following individuals: Michelangelo Antonioni (b. 1912) as director, including a time distribution of his top-rated films to check the Simonton proposal that masterpieces are evenly distributed, as a percentage of all works, over the life of the creator; Steven Spielberg (b. 1940) to show the meshing of his three careers, as actor, as director, and as producer; Hans Dreier (b. 1885) operating during World War II and a very successful art director, with 450 films bagged; George Lucas (b. 1944) as producer and as writer; and Lina Wertmüller (b. 1926) as a representative of the feminine gender, perhaps. For the actresses we chose Jane Fonda (b. 1937) and Vanessa Redgrave (b. 1937), whose career is represented with a double pulse.

Michelangelo Antonioni has two pulses, centered at 40 and 78 years of age. His top-rated films have a logistic distribution centered around 1961 when he was aged 49. To compare we took a mean of the two centers weighted on the number of films in the pulse and we get 49 as a mean, which helps to give credibility to the Simonton hypothesis. Incidentally, Antonioni remarried at 74, in correlation with his second pulse.

Steven Spielberg is a multifaceted artist to say the least, and his different tasks may help to understand how much is natural and how much is contextual. In fact a producer and an actor have very different contexts. The central age for the actor is 48, for the producer 46, and for the director, weighted, is 48. It seems clear that nature runs the show, so to speak, as in the case of Bach. The same check for George Lucas shows 43 years for the producer and a weighted 44 years for the film writer.

Hans Dreier was very productive and his career can be wrapped up in a single smooth logistic. A fact to observe is the late center point, at 55 years, somehow in the ballpark of Nobelists in economics. Lina Wertmueller also shares this characteristic, with a center point at 56 years.

Coming to the actresses, Jane Fonda has a single pulse centered at 46, and Vanessa Redgrave a weighted center at 51.

Figure 4.2.1a

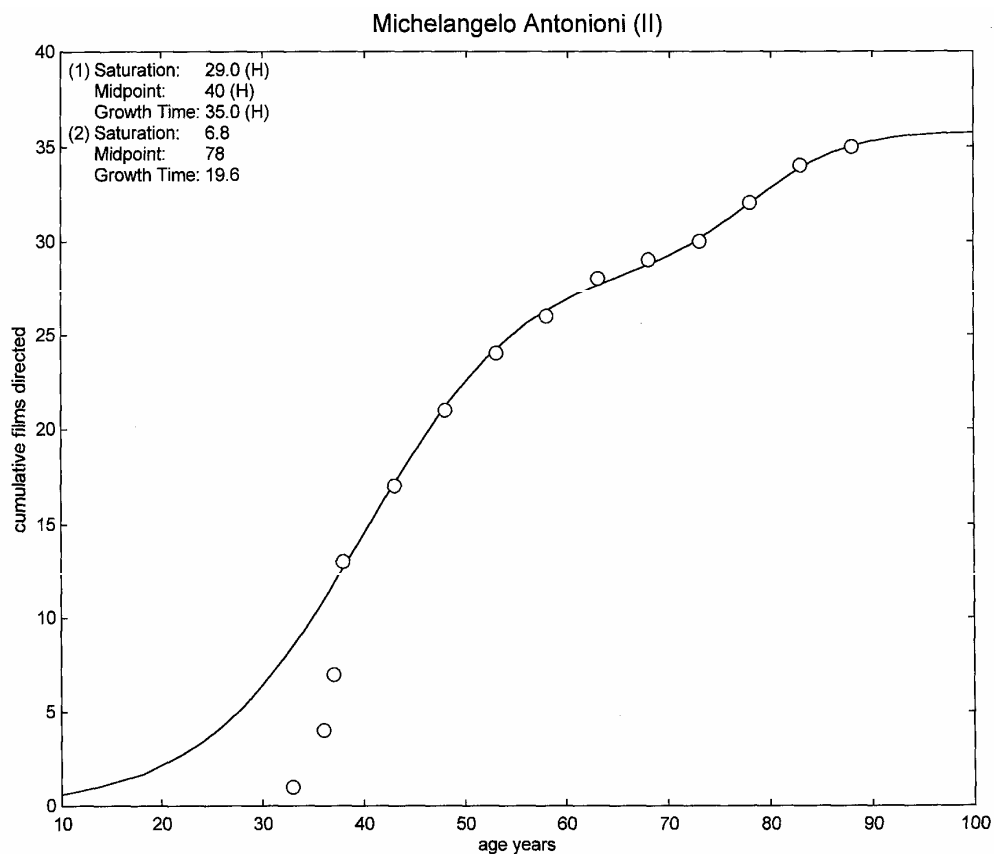


Figure 4.2.1b

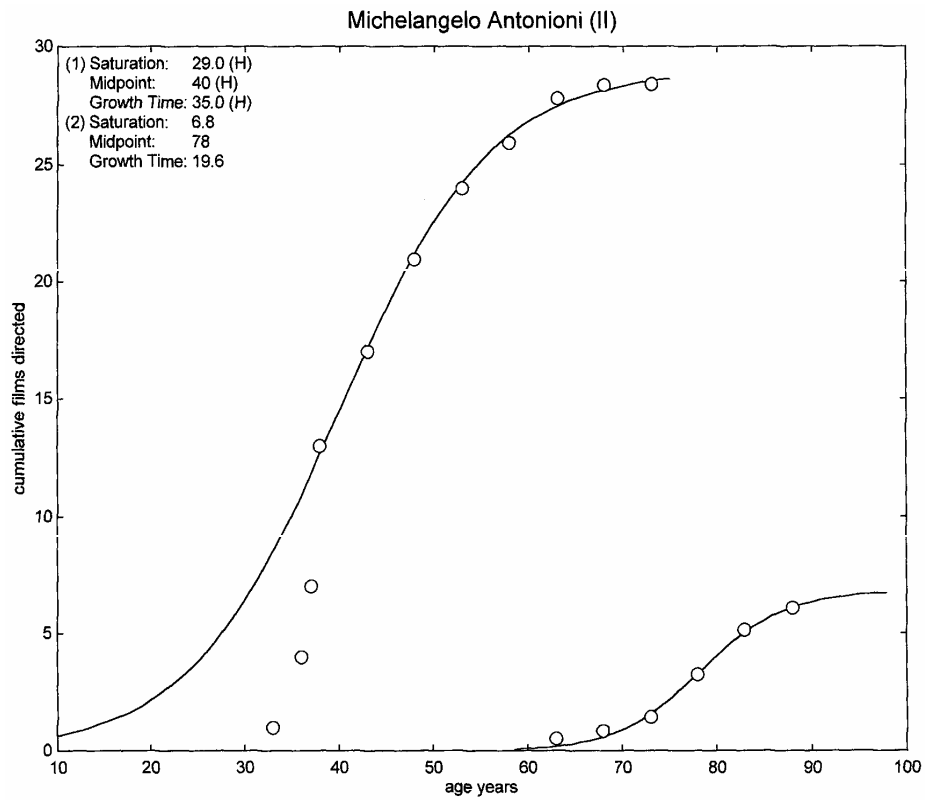


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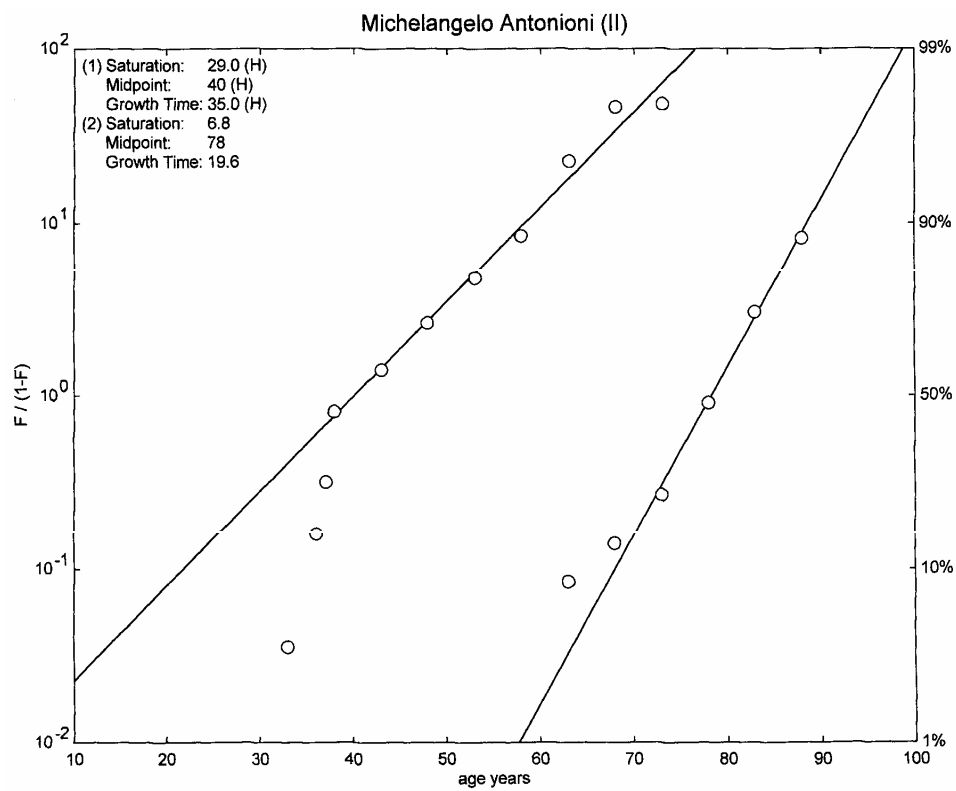


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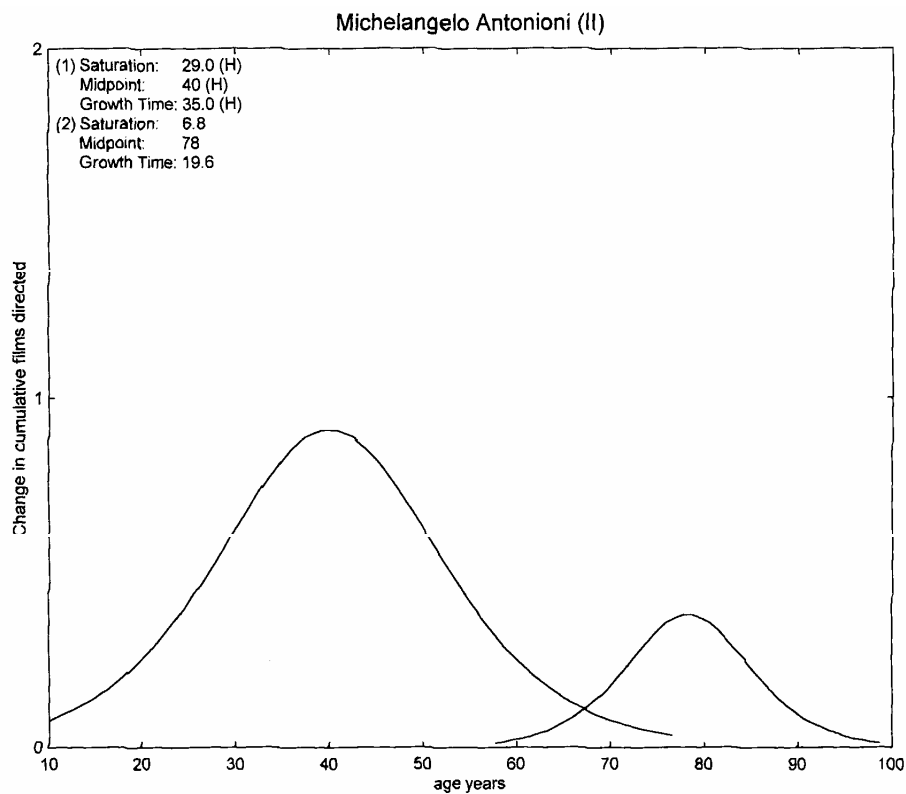


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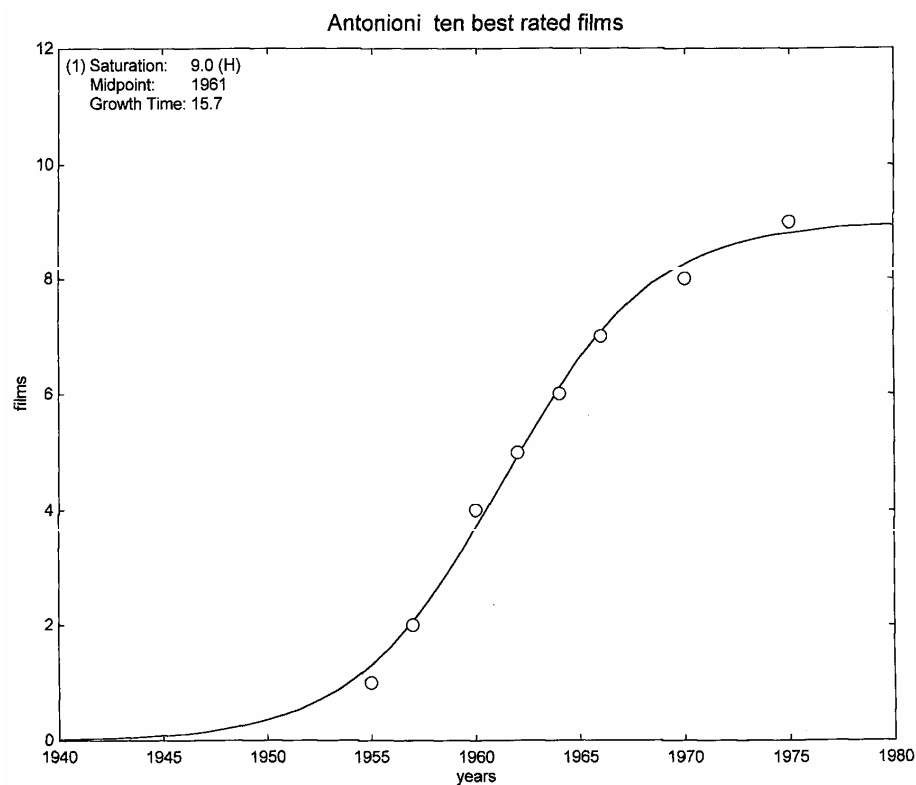


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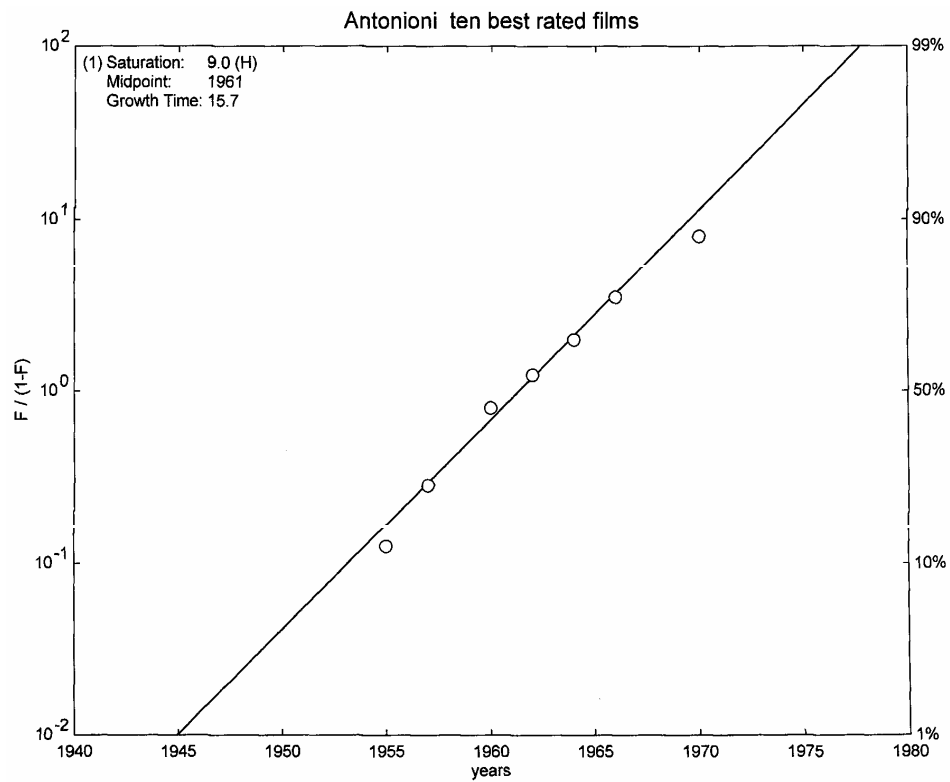


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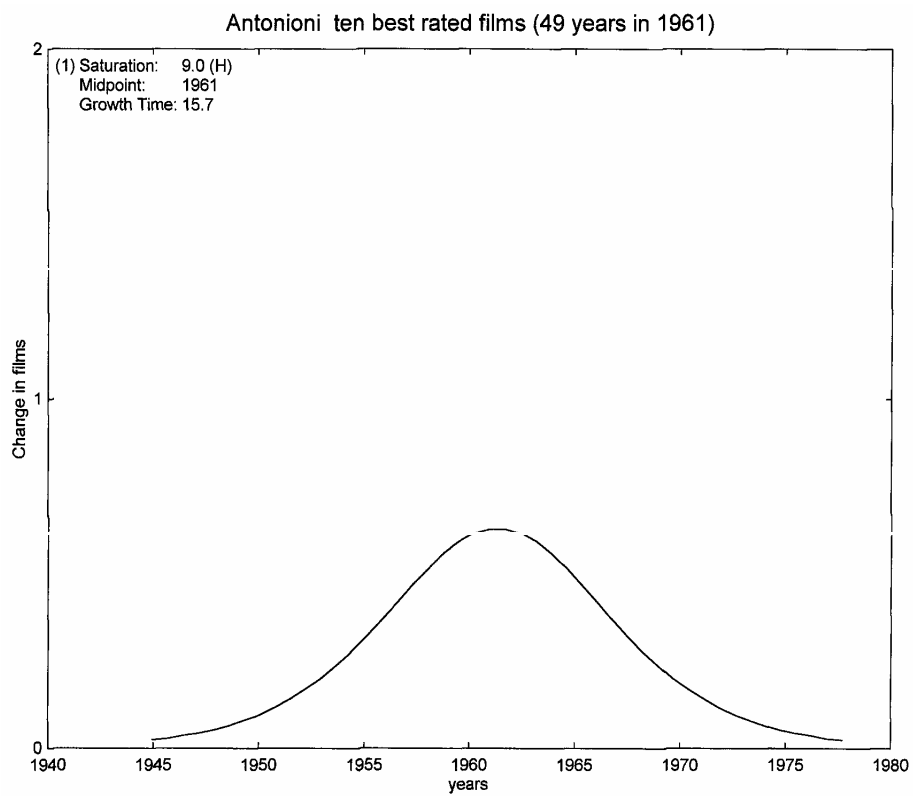


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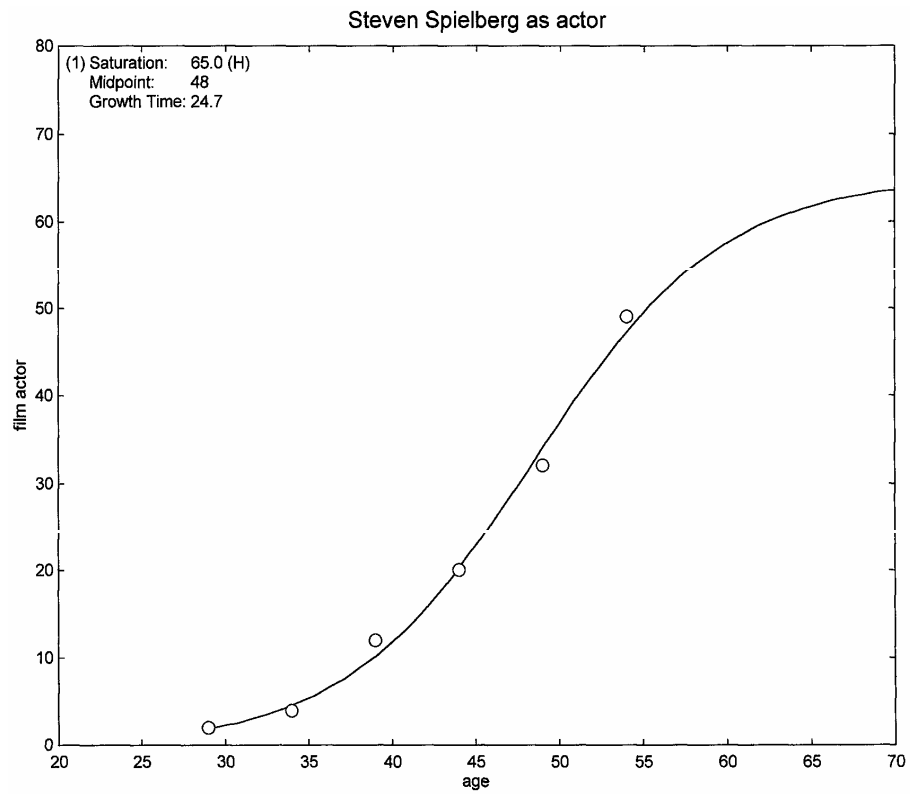


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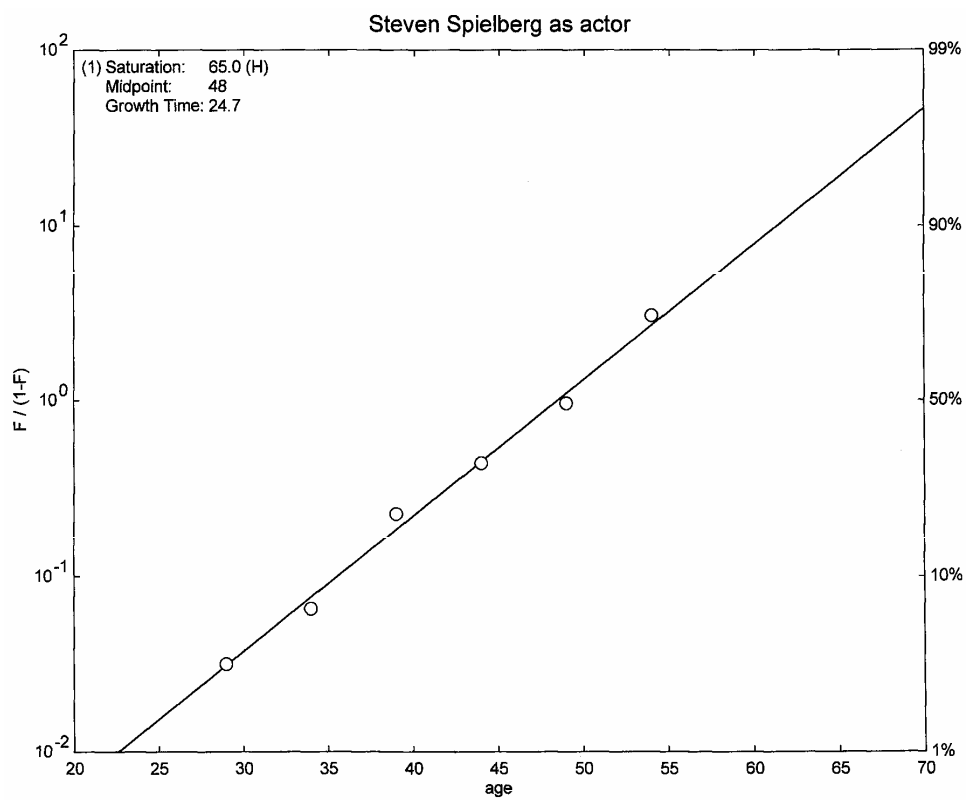


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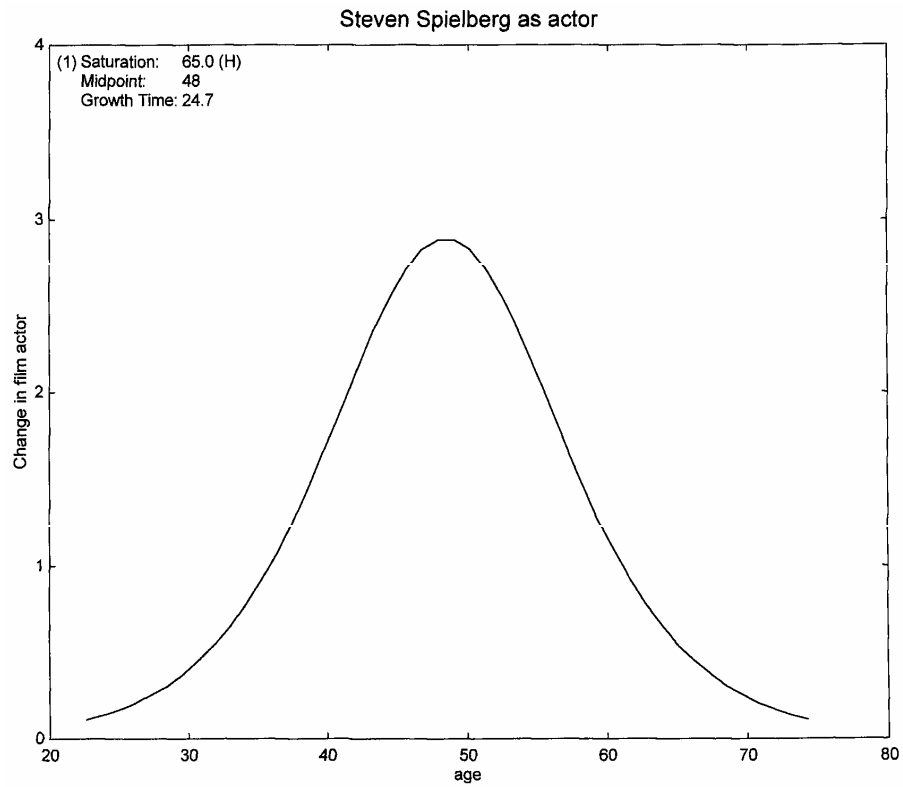


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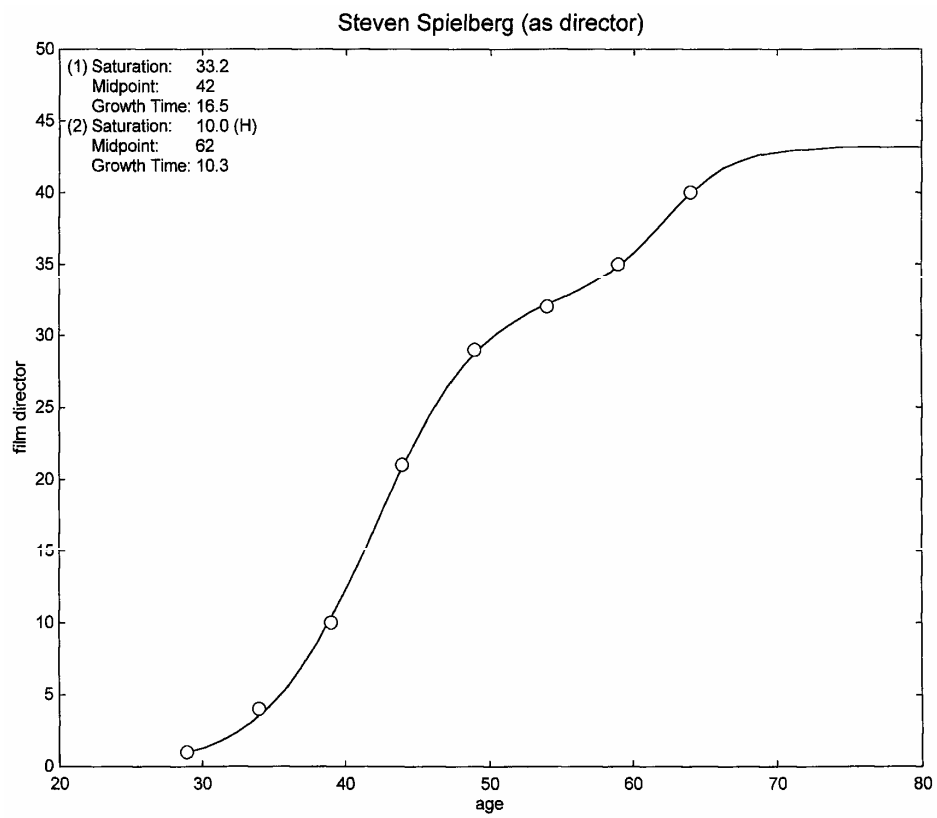


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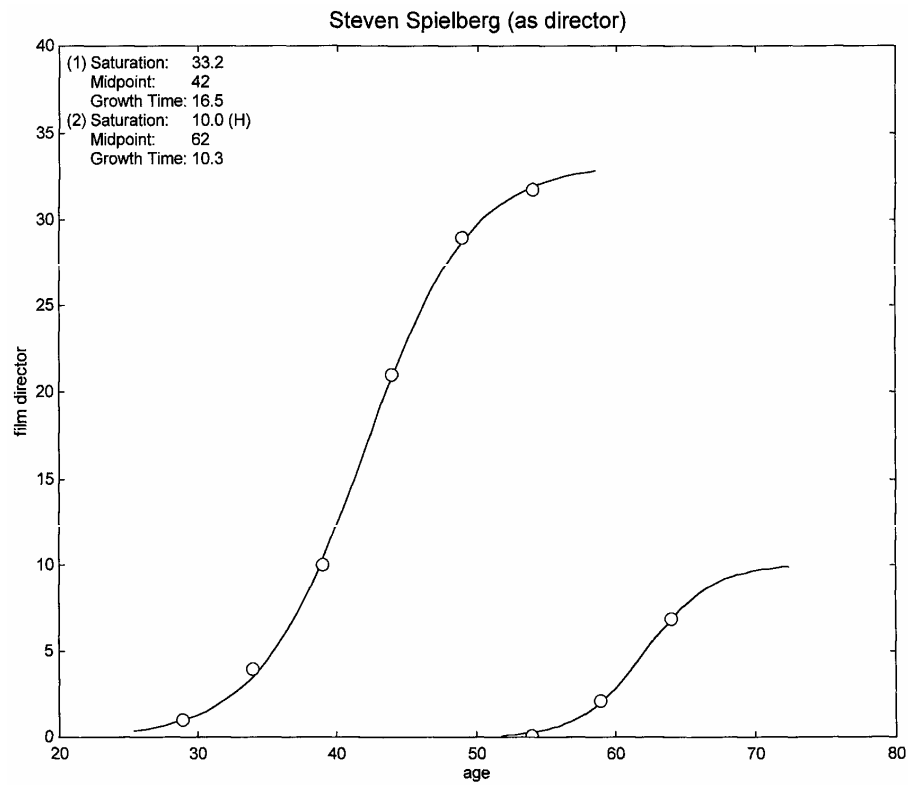


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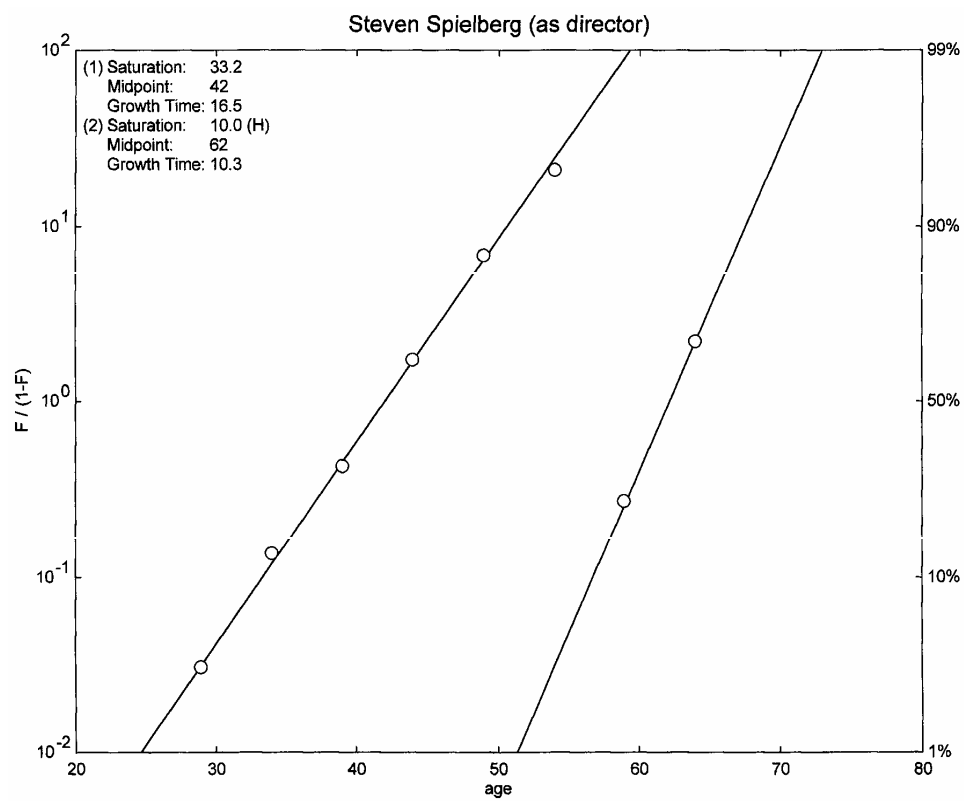


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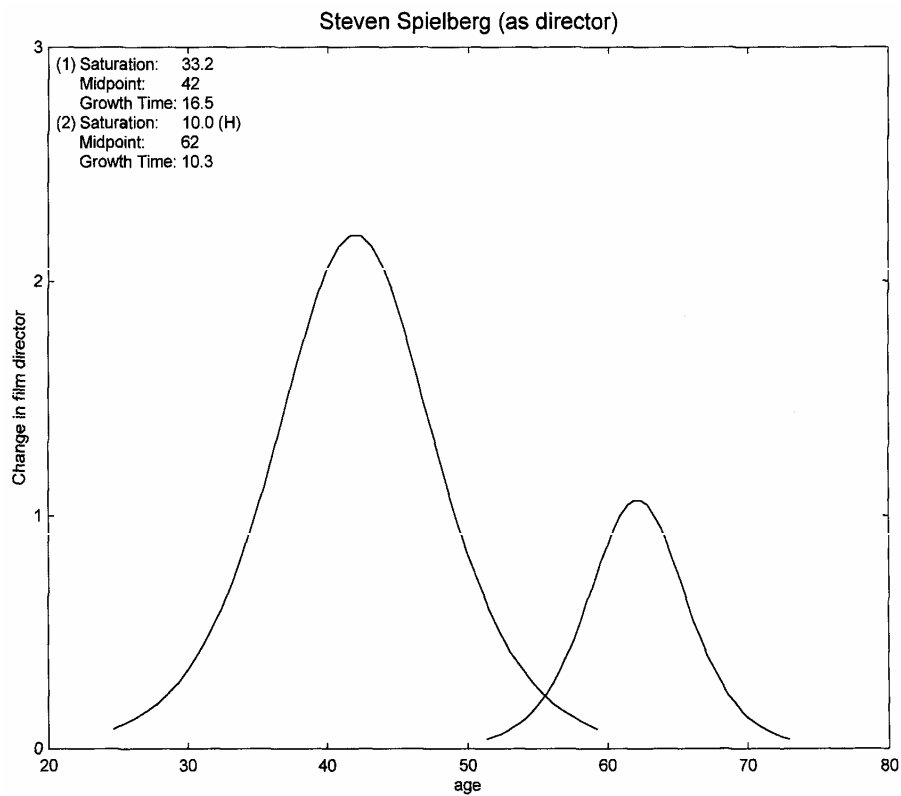


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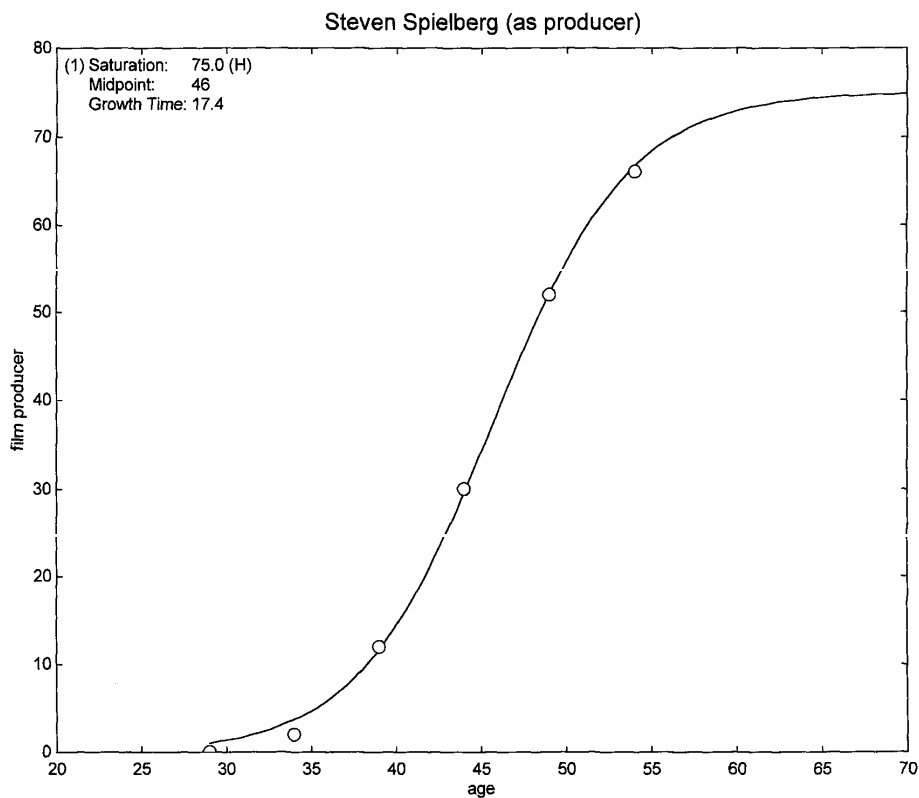


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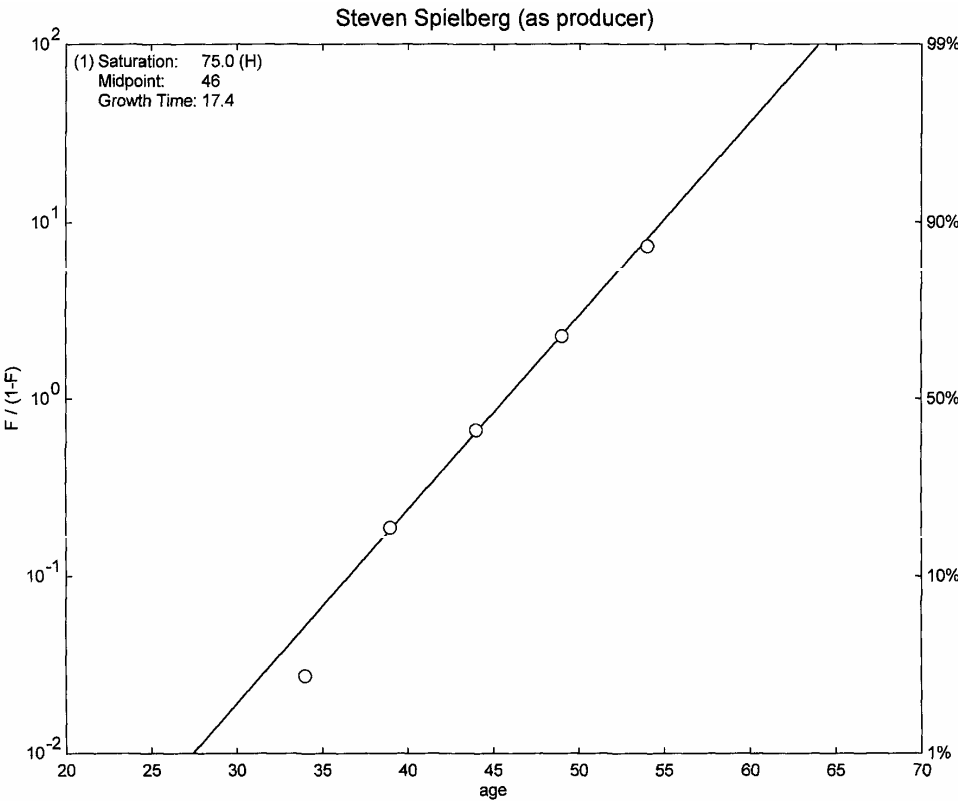


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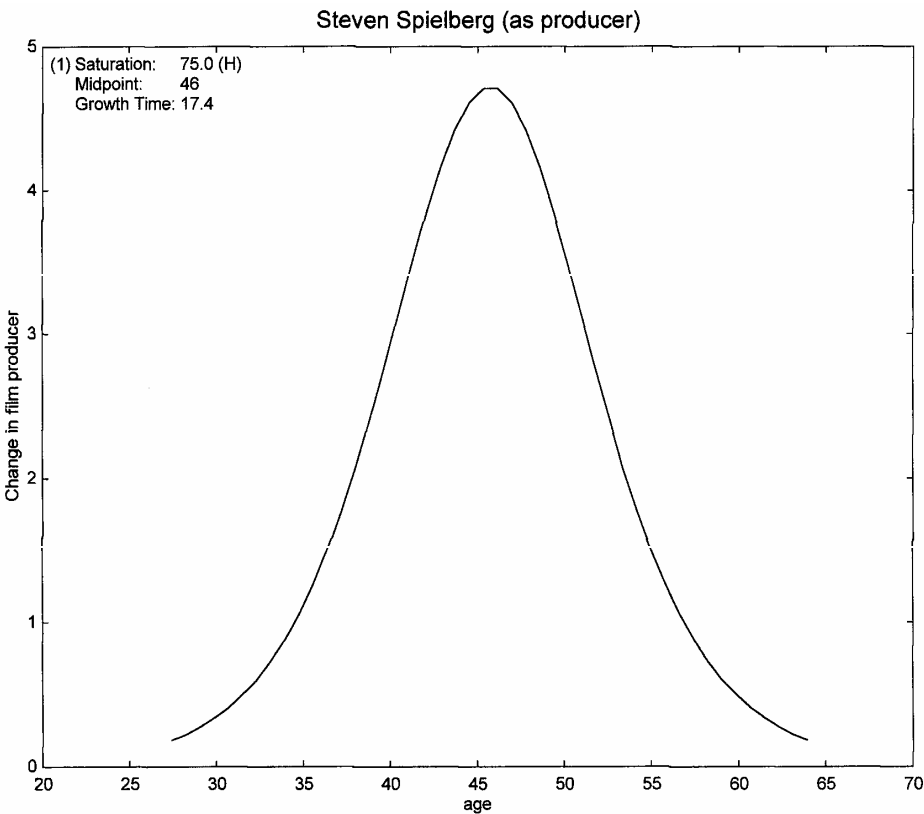


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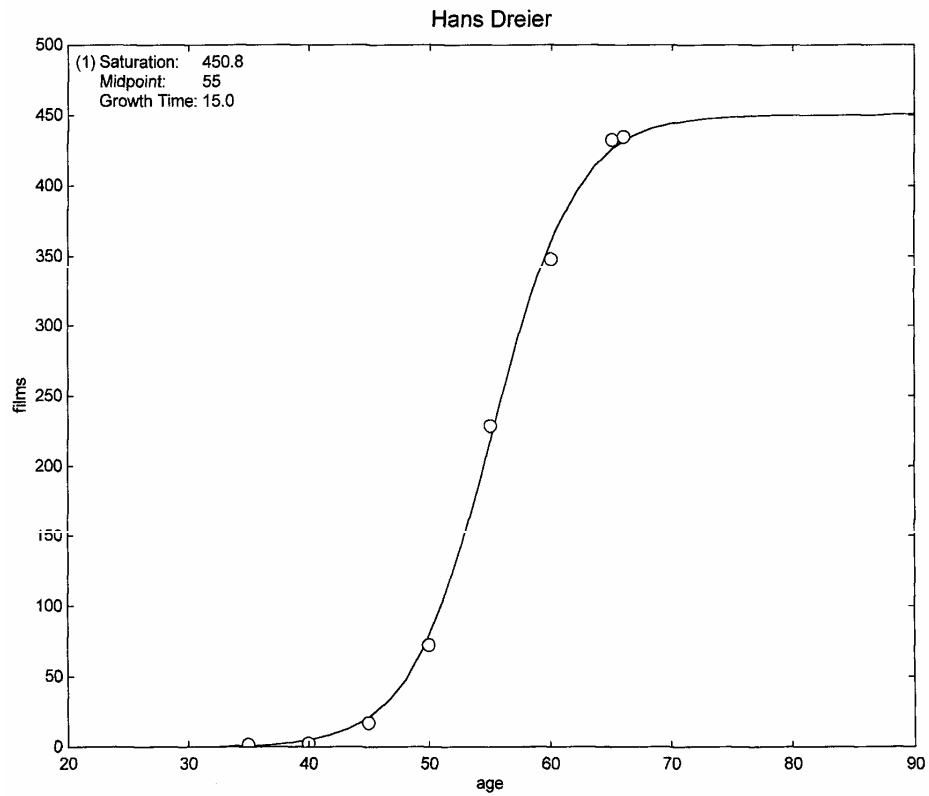


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Figure 4.2.6c

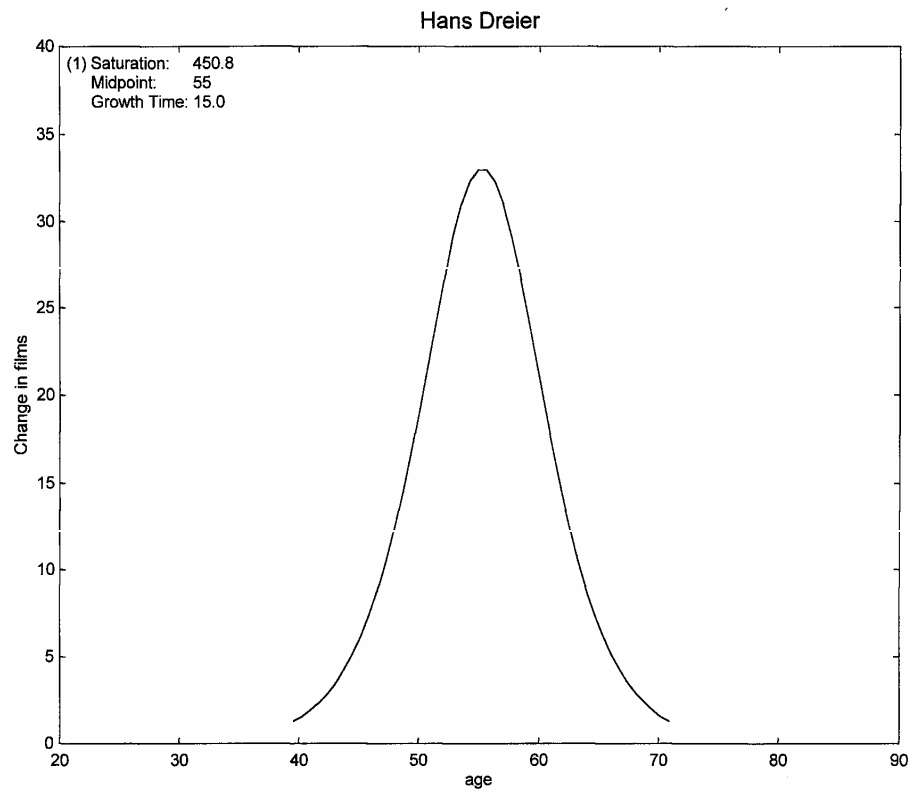


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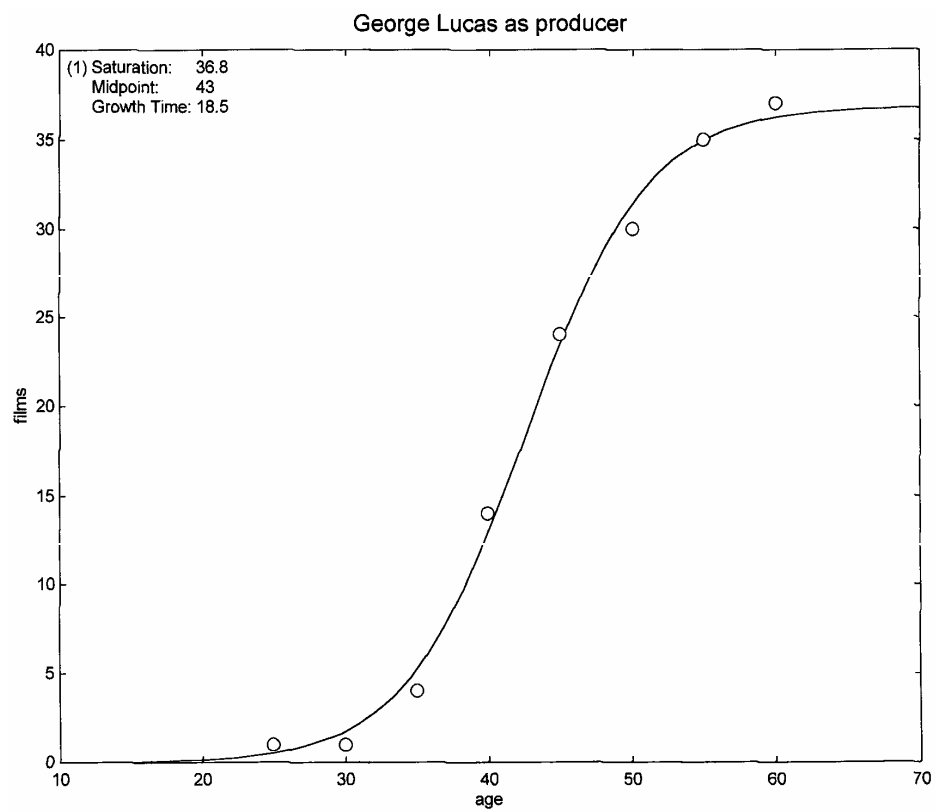


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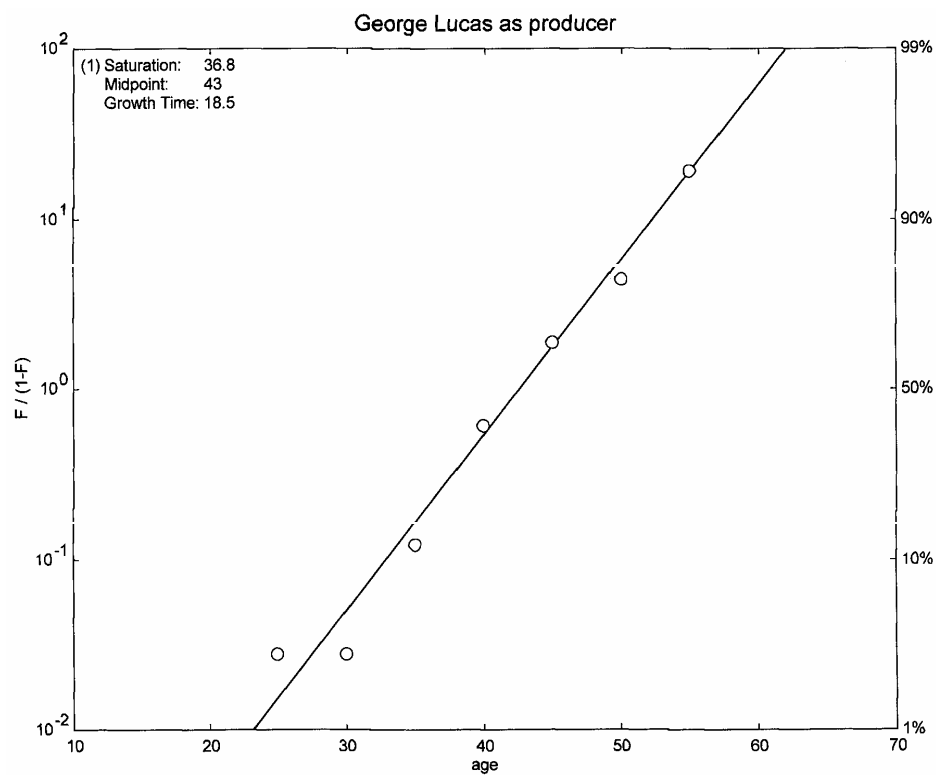


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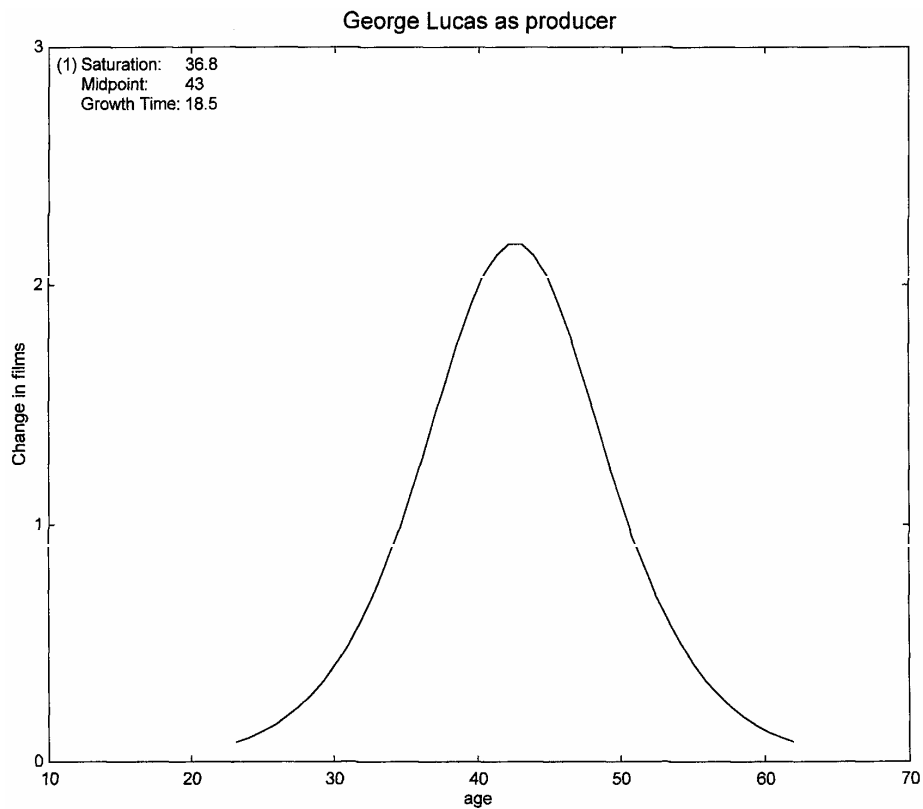


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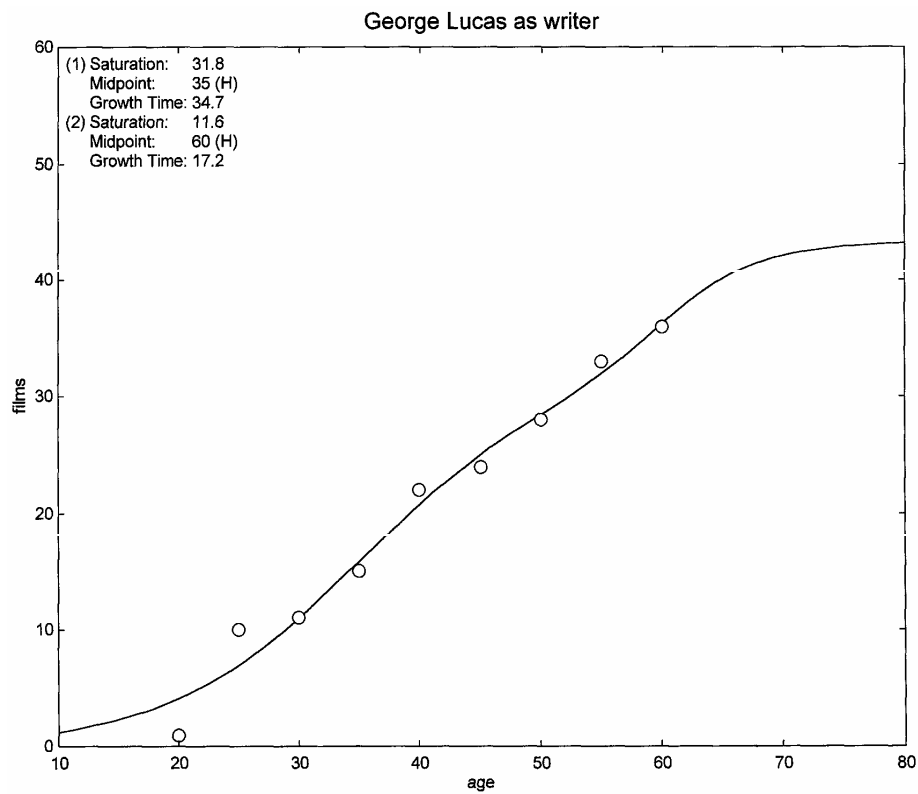


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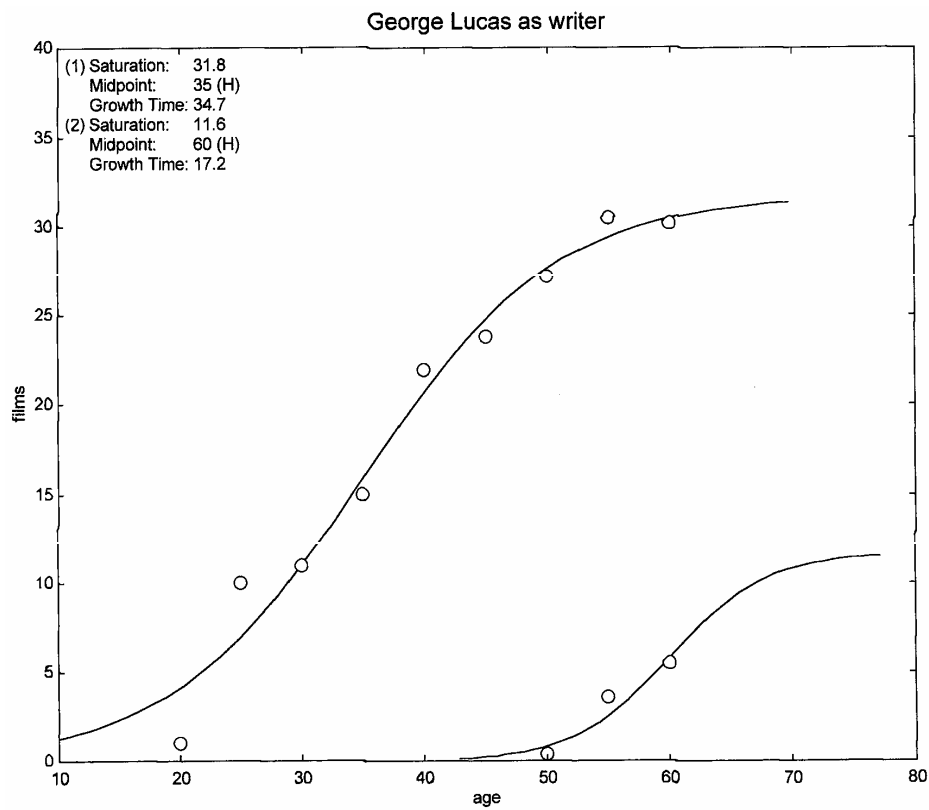


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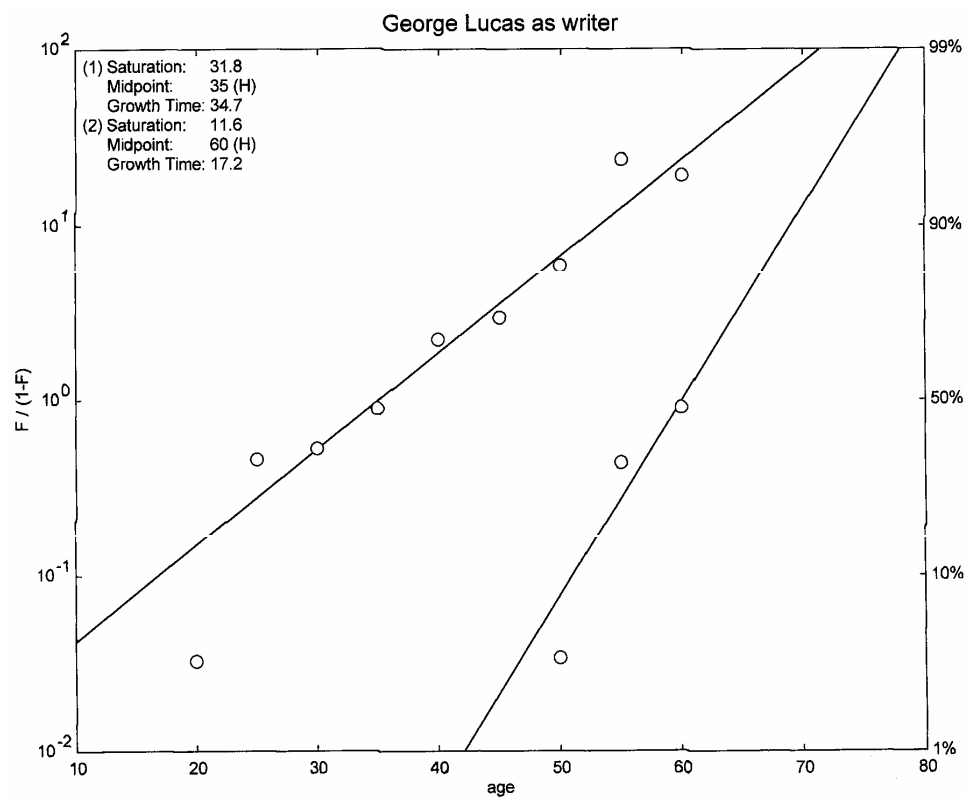


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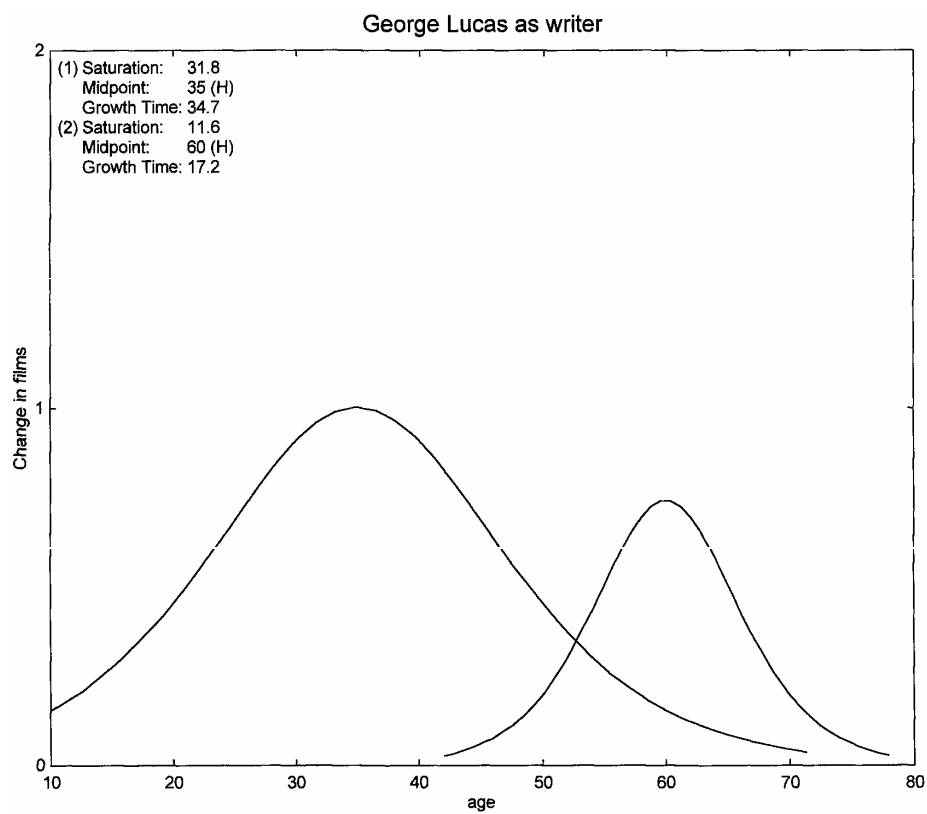


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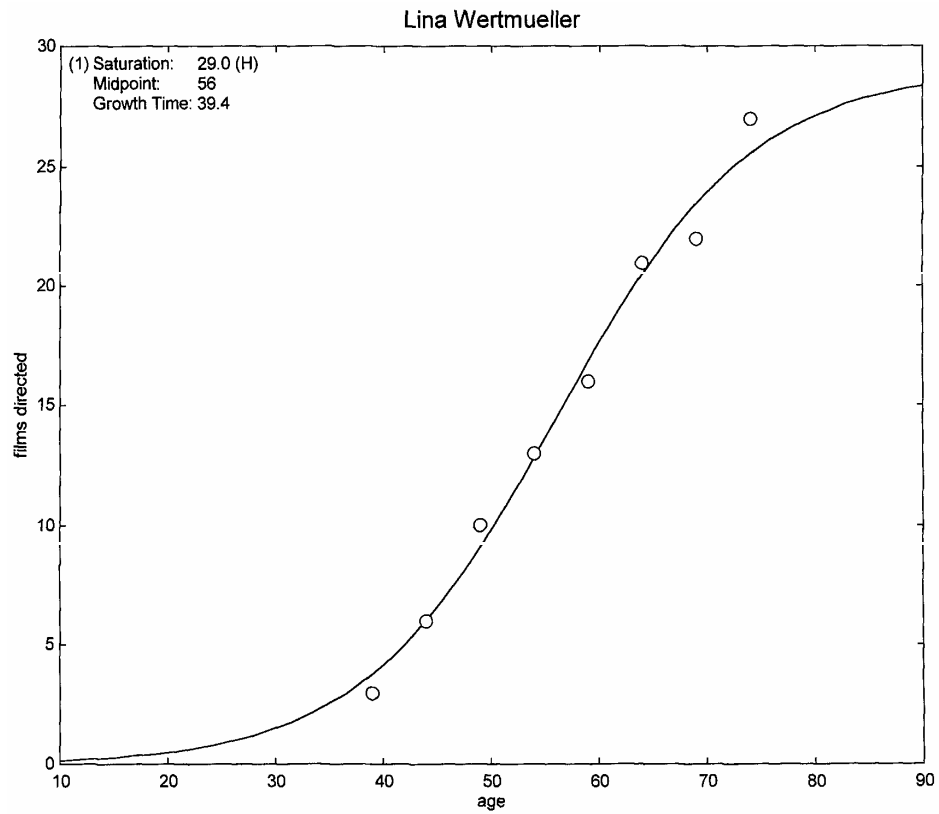


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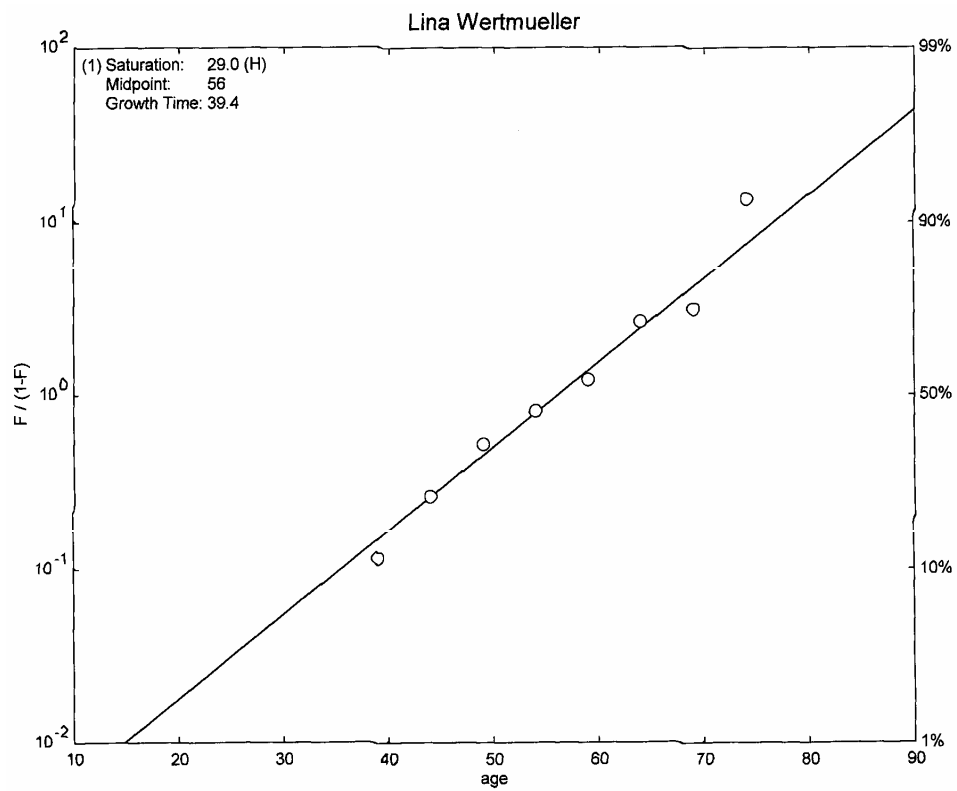


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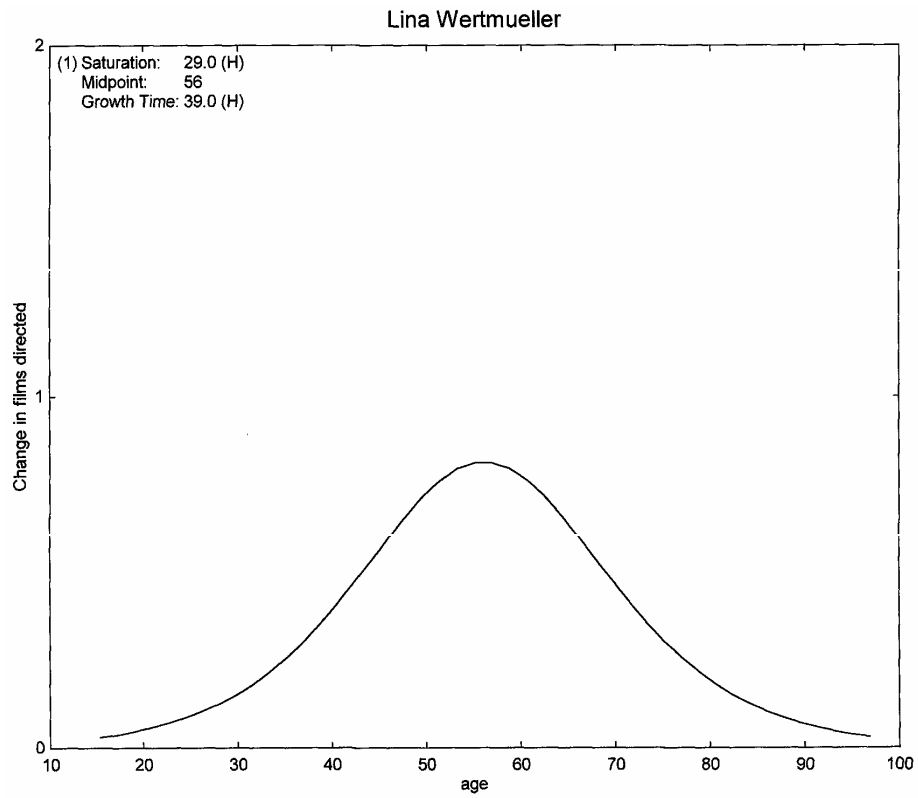


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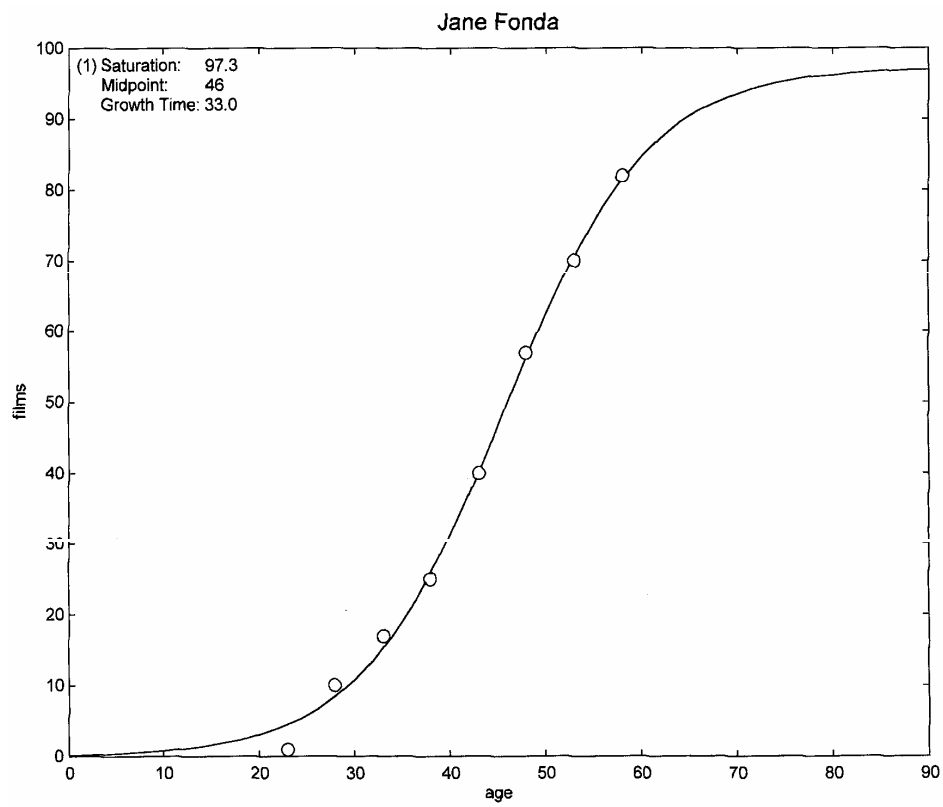


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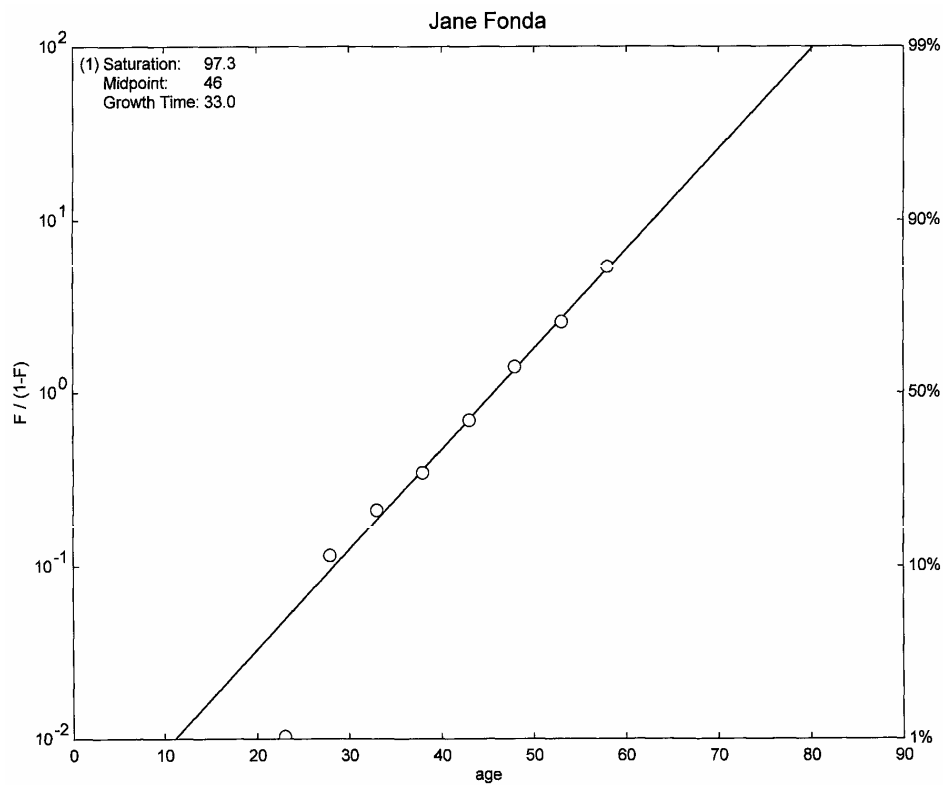


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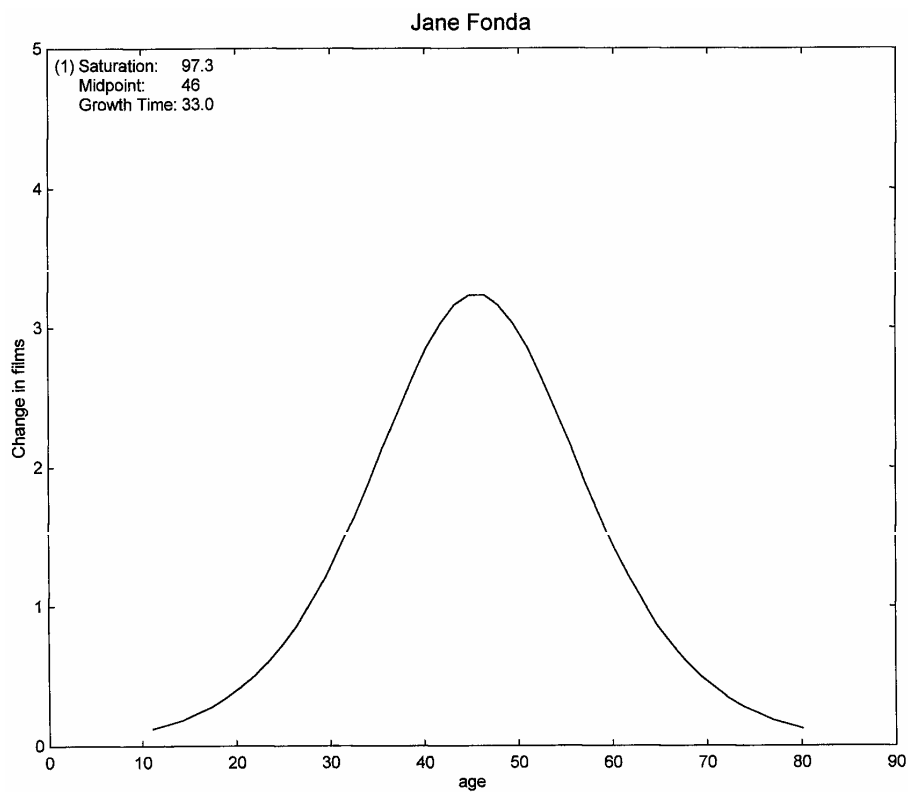


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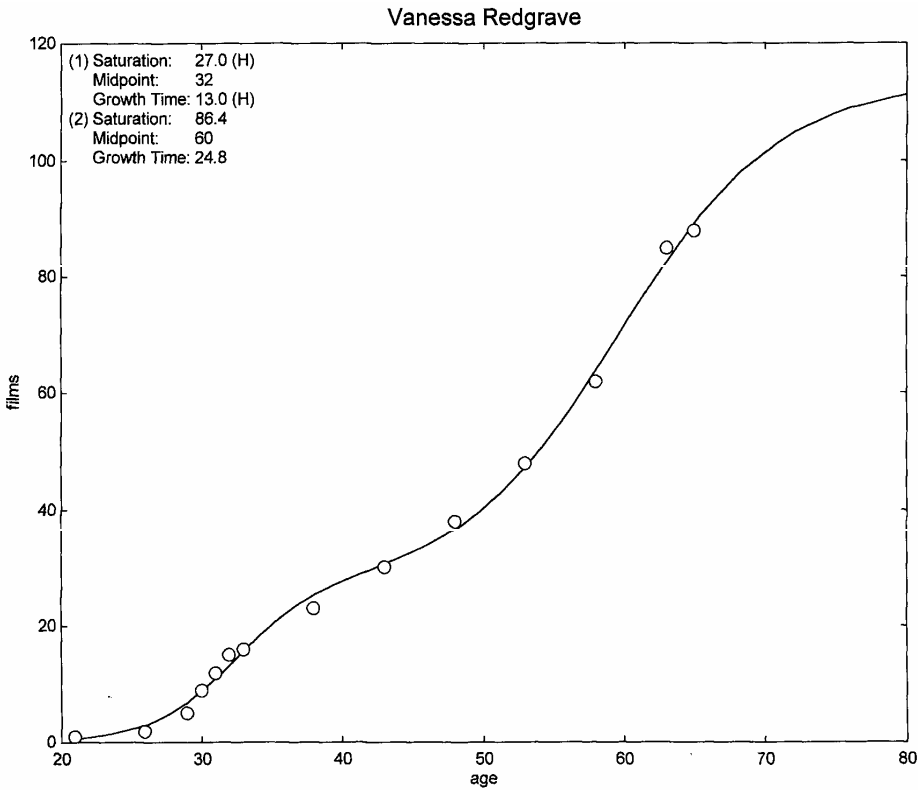


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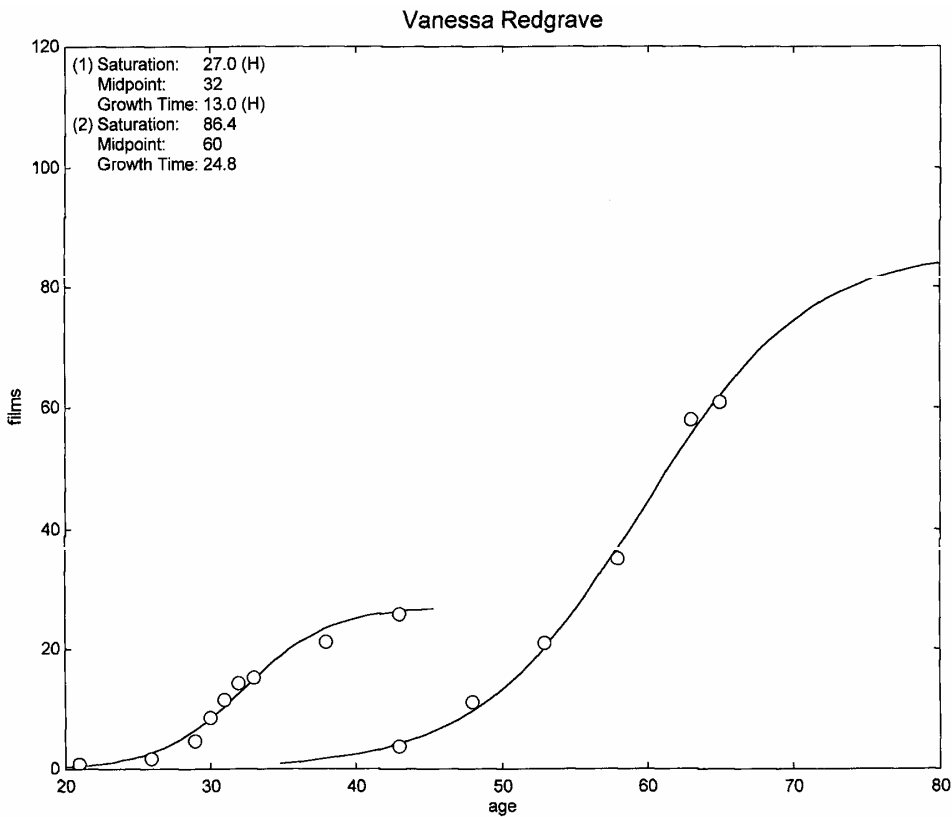


Figure 4.2.11c

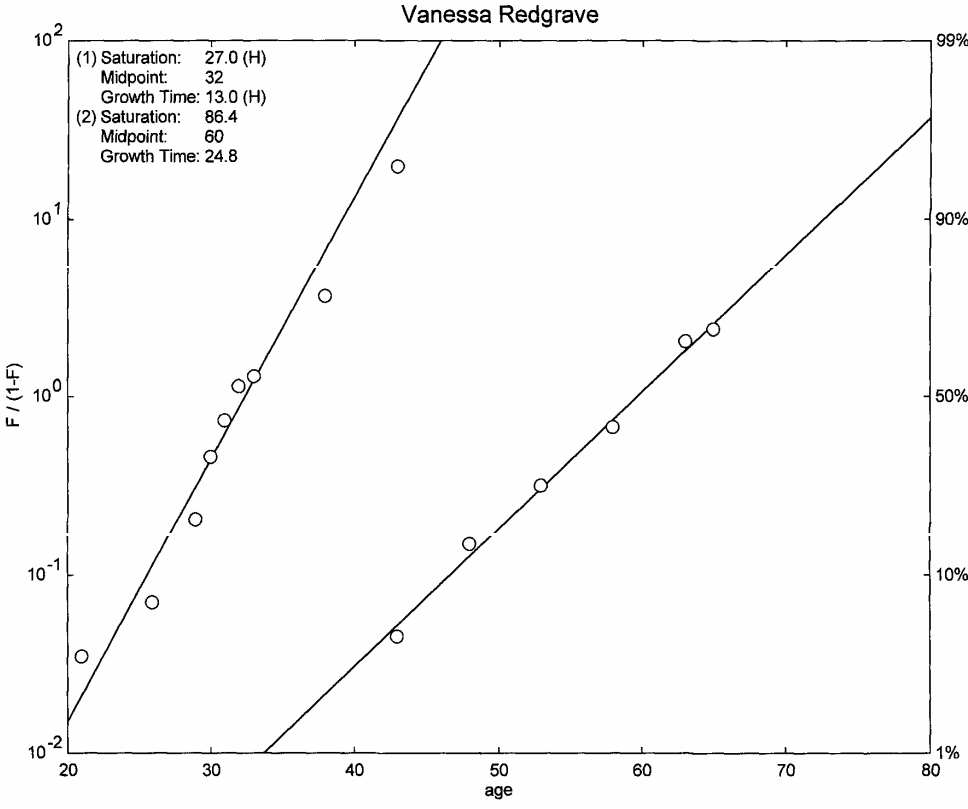
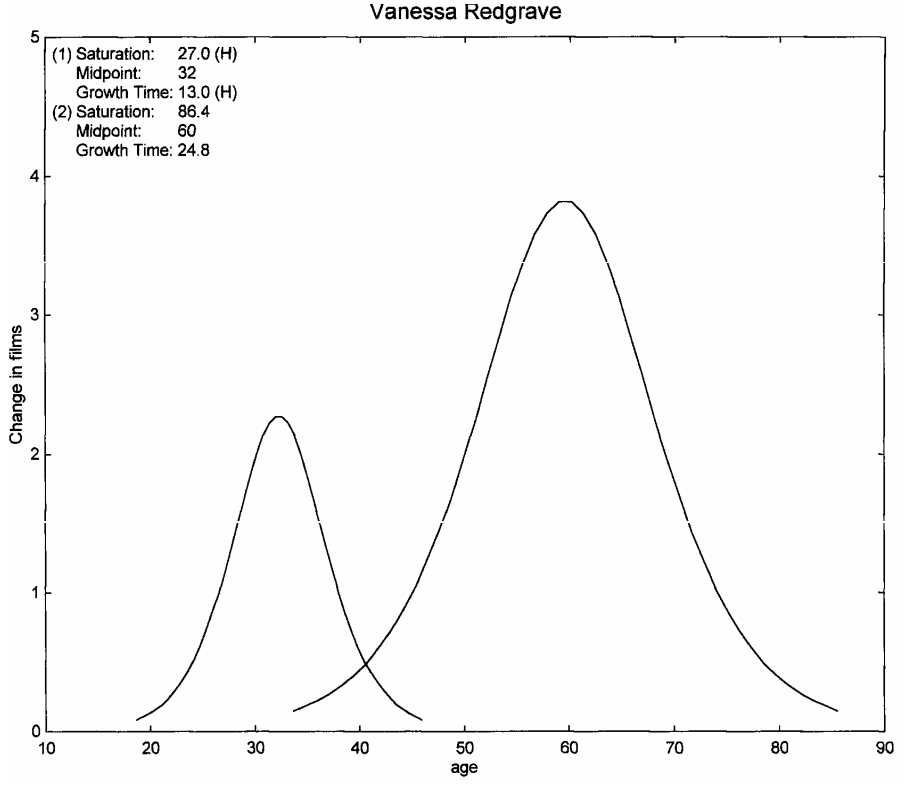


Figure 4.2.11d



4.3. The criminals

Criminals represent a large professional category in society. They not only constitute a great nuisance for the citizen in general, but they stimulate vast economic activity in terms of police, judicial systems, prisons, weapons, locks, and safes. The citizen, on top of being the primary victim of criminal actions, also has to pay in terms of taxes for the maintenance of all the above system, with zero advantages for him as we shall see.

The logistic model applies very well to one criminal person, and permits us to see his activity in an holistic way over his lifespan. What comes out is that punishments have zero effect on criminal activity. Certainly time spent in prison isolates the criminal from his job, so to speak. However, following release from prison, the criminal dutifully commits the crimes that he would have committed had he been free. I do not see really any moral stigma on that. The criminal is geared to do what he does in the same manner as the Nobel Prize winner pursues his research, regardless of the great *mise en scène* of the containment system. In this light it does not seem correct to punish the criminal as he cannot avoid doing what he is doing. The data on which we base such ponderous statements is thin, however, because all our attempts to gather evidence of criminal activity on a personal basis were refused for various reasons, primarily privacy. We suspect that everybody in the business knows the painful truth, about which nobody outside should know.

Historical analysis of criminal treatment shows that people have been conscious of this situation: apart from the death penalty, isolation without taking basic freedoms away, as in the case of exile, was widely practiced. According to legend, Rome was founded by a bunch of criminals whose original communities had exiled to the pestiferous marshes of the Paludi Pontine. This may explain the need to procure women with the “Ratto delle sabine”, and the great skill of Romans to establish a simple and effective system of laws. In our case there might be a line of attack worth special research. The few cases we were able to analyze show that criminality seems to be mainly restricted to the younger age groups. By analyzing criminal activity from the beginning, one can fix the relative logistic and try to forecast its approximate length and ending phase of this activity. Consequently one could define the period of ostracism. The ostracism should not be meant to punish the criminals, which is useless, but rather to protect fellow citizens.

One interesting sideline of our criminal analysis is that the crimes committed by a criminal organization fit the logistic, showing again the biological overtones of a social organization just as if it were a multi-cellular organism fitting the cellular rules. We have undertaken various analyses on these organizations, both named, like the Red Brigades, or more gaseous ones, like those attacking embassies in the 1980s. The match is perfect, and to give a hint of the meaning of these results, the killing of Aldo Moro, representing the peak of the Red Brigades’ violence, took place at exactly the flex of their logistic.

Legend for the criminals

In the following, we report on four anonymous criminal careers coming from the Institute of Criminology of Cambridge, UK. The numbers of crimes at saturation are

relatively limited, from 14 to 20. This may explain why the bell charts extend to such early ages. In the first tract there are no crimes, or mathematically, less than one per year. The bell charts may be taken as indicators of criminal attraction, which starts very early. The ages can be identified in the charts.

The fifth case refers to Michele Greco, a famous mafia boss and head of the “cupola,” the center of power of the Mafia organization. The homicides recorded were not carried out by Greco personally, but represent an executive expression of his will. There were 80 homicides in total, a rather large number concentrated in such a short lapse of time.

The last chart is a testimony to our thesis on the futility of punishing criminals. The chart is built from the statistics on homicide rates in London over a period of 63 years, from 1858 to 1921, when capital punishment was still in force. Execution was a deterrent of some sort, but the effect was only to introduce some longitudinal noise. The homicides not committed around the week of the execution were dutifully performed in the following month.

Figure 4.3.1a

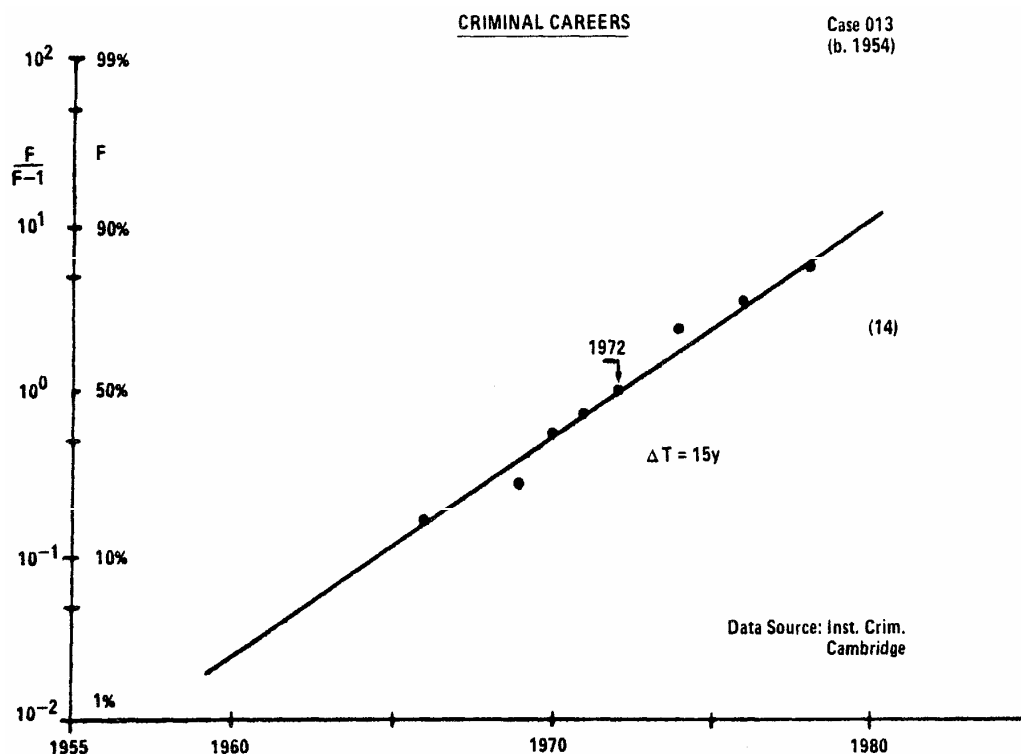


Figure 4.3.1b

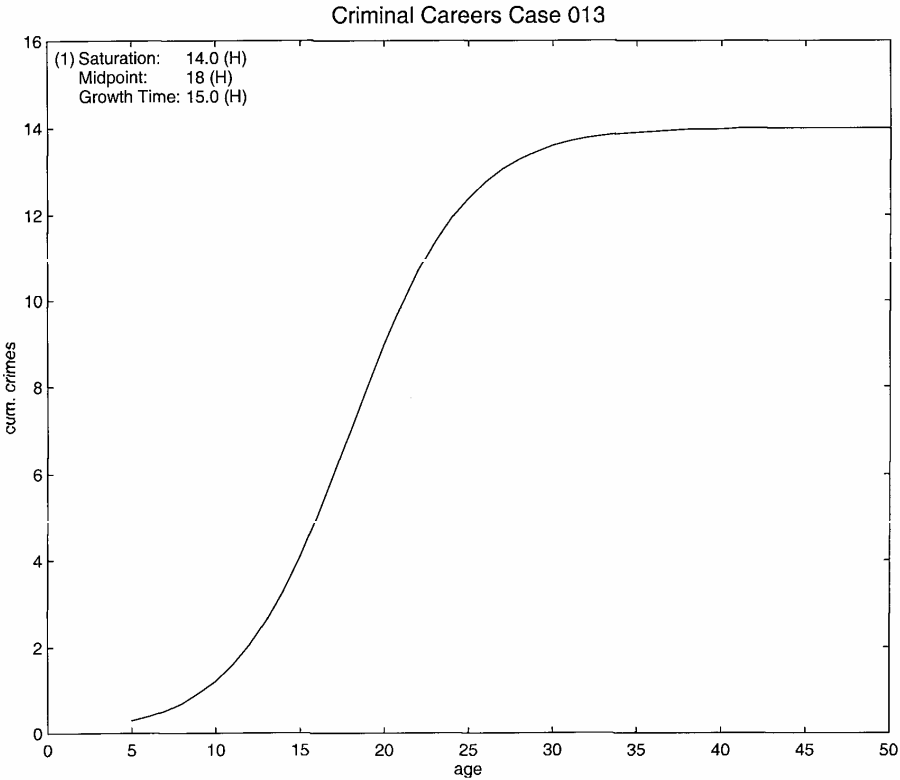


Figure 4.3.1c

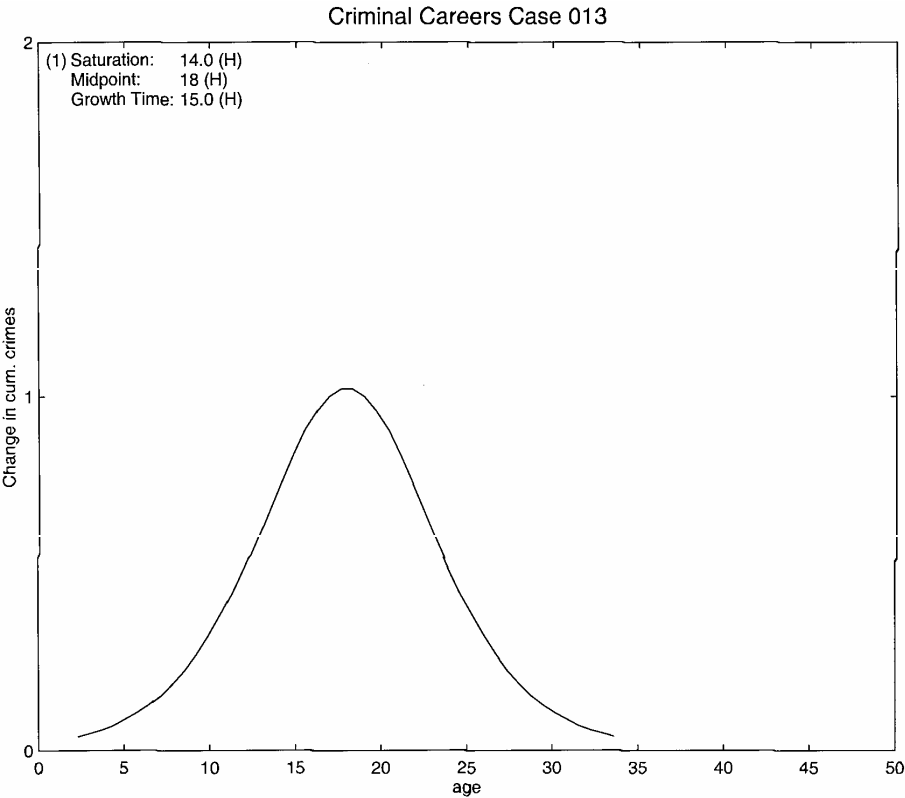


Figure 4.3.2a

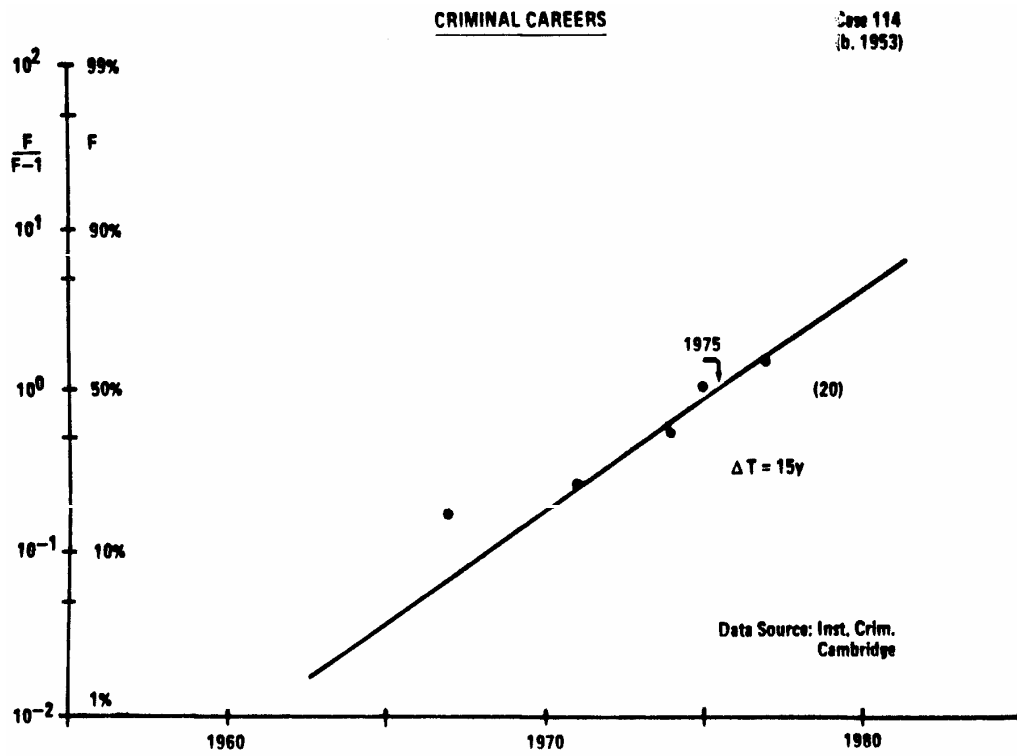


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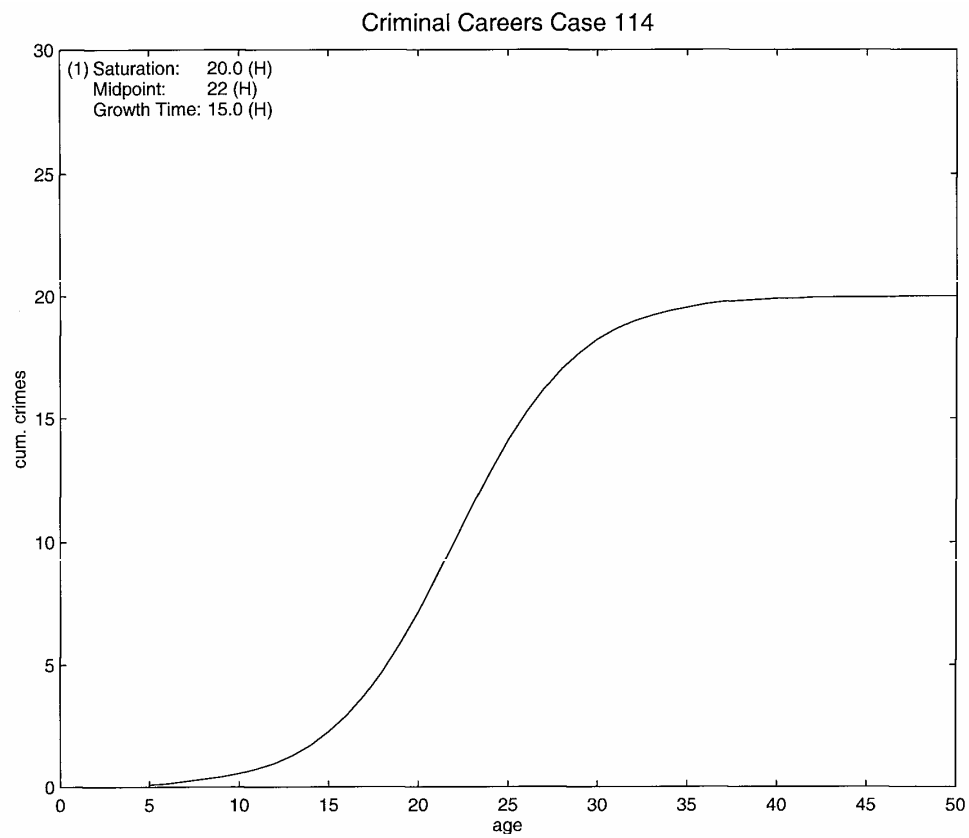


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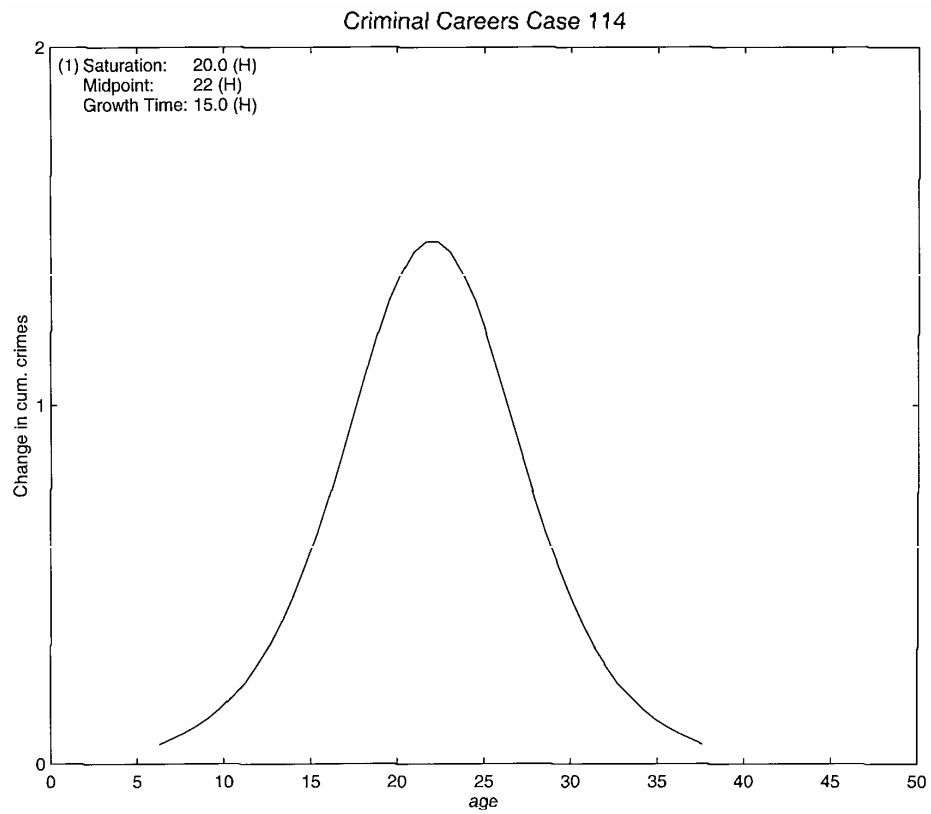


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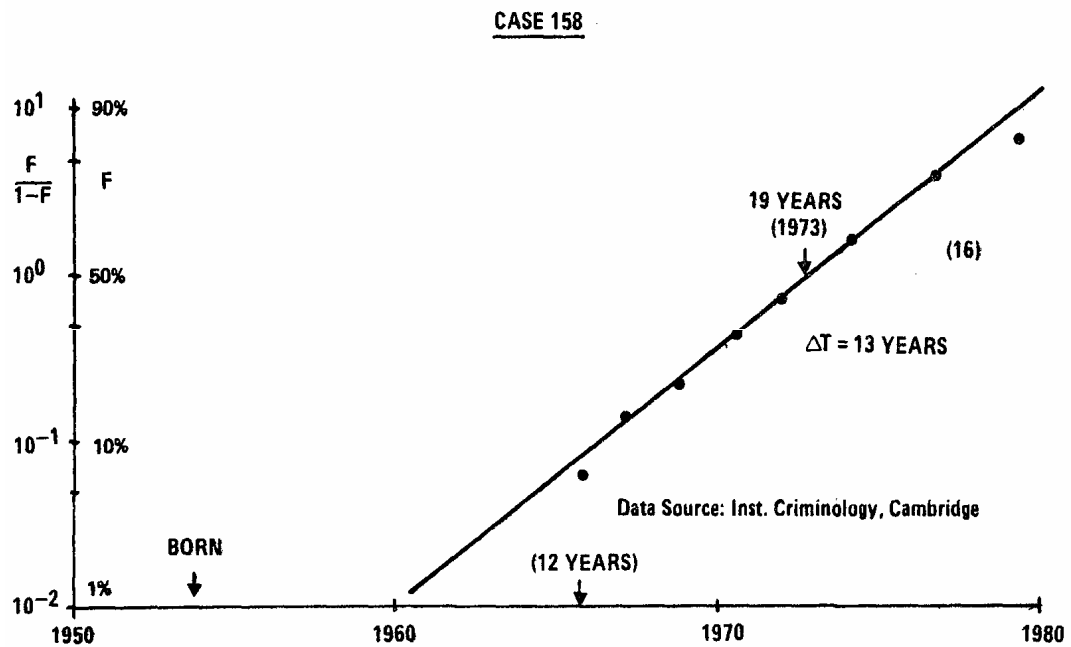


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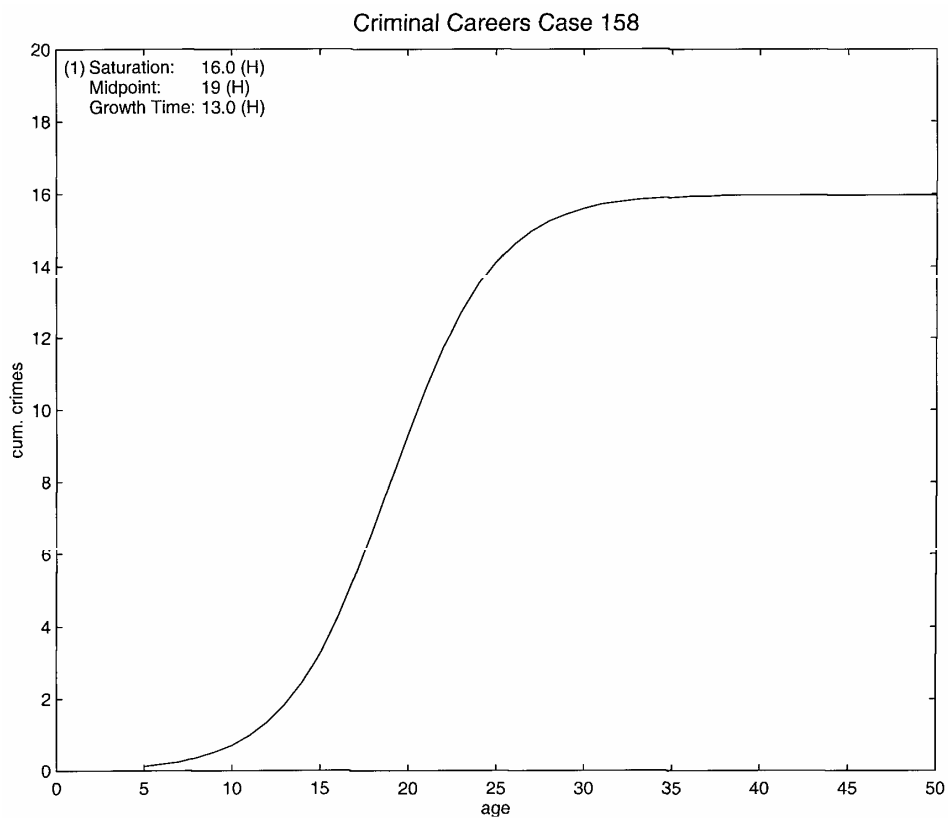


Figure 4.3.3c

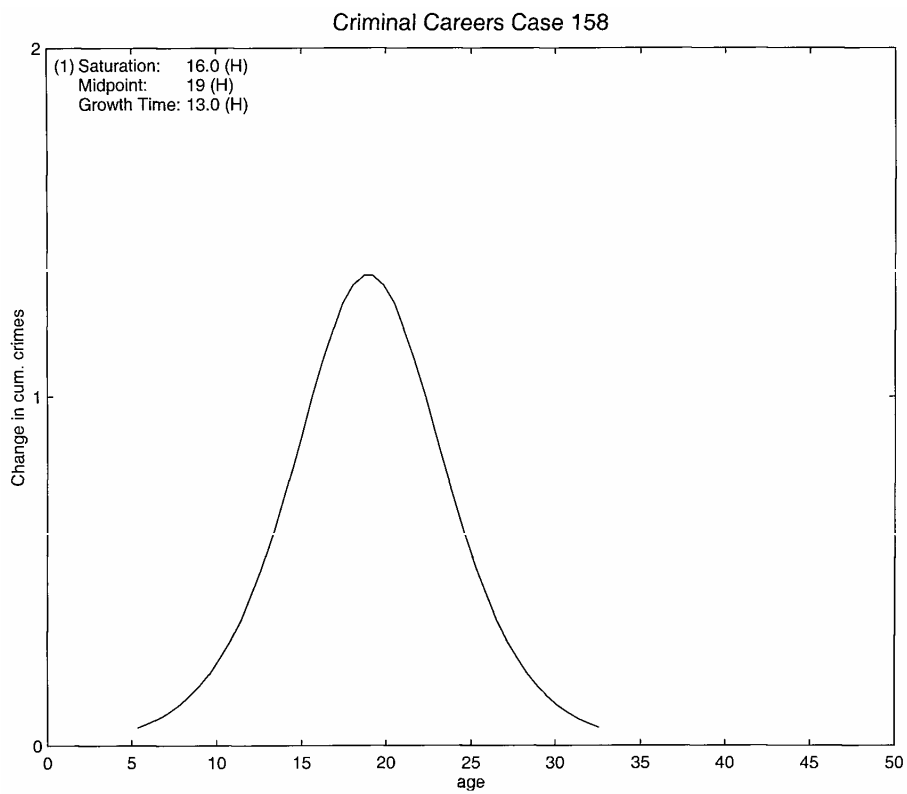


Figure 4.3.4a

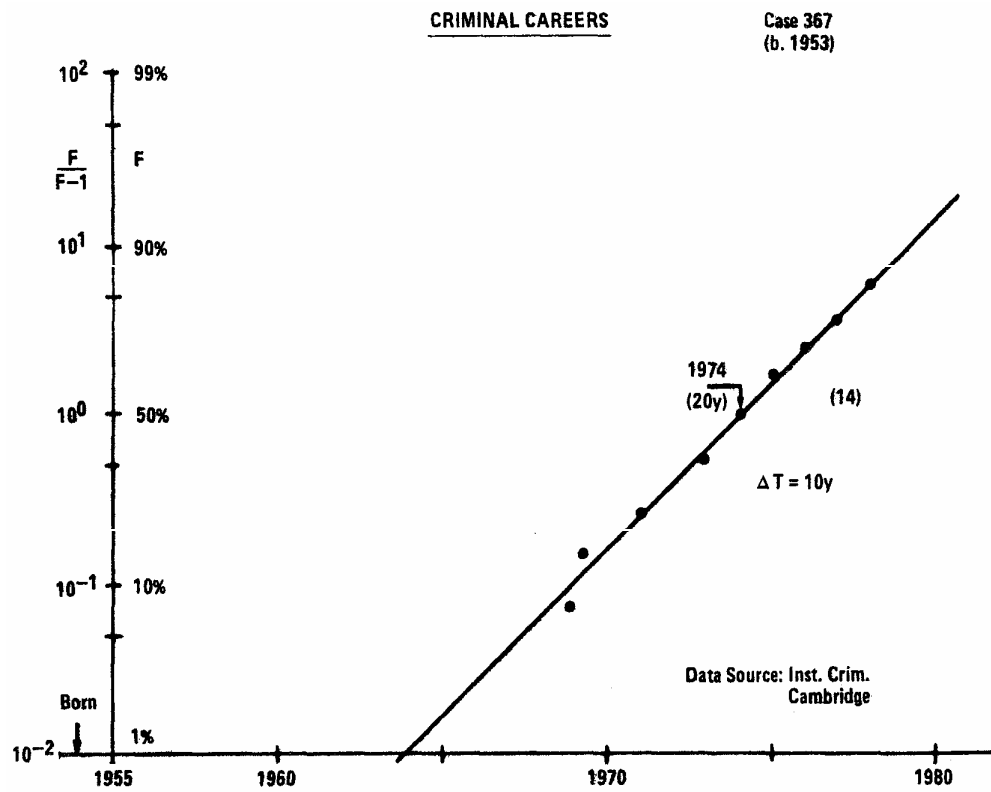


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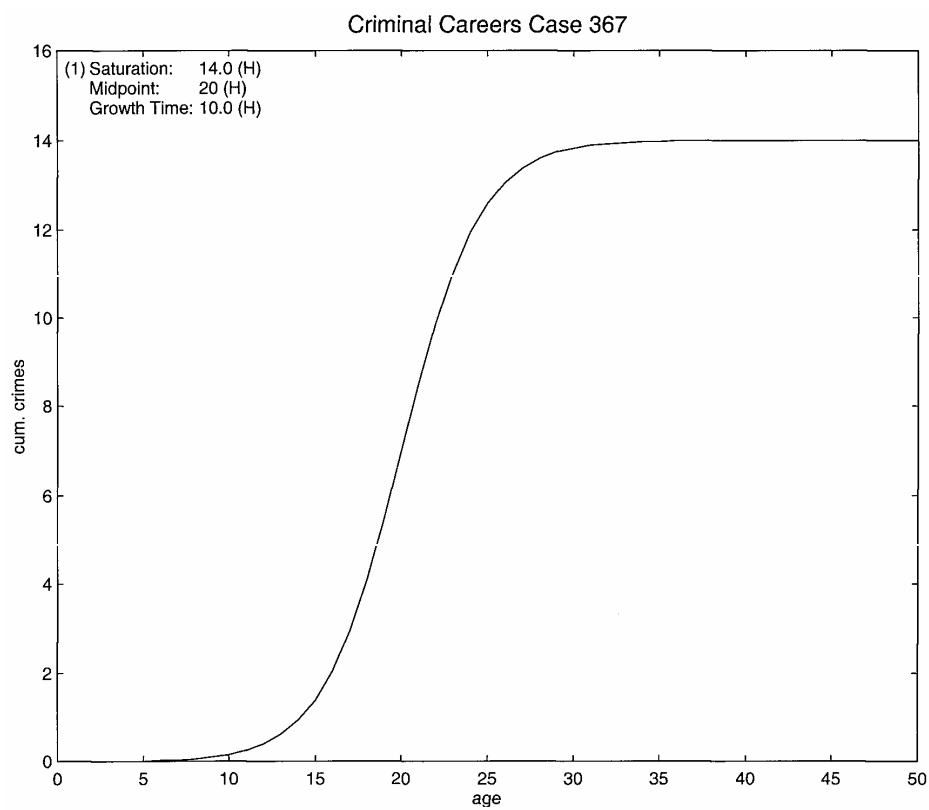


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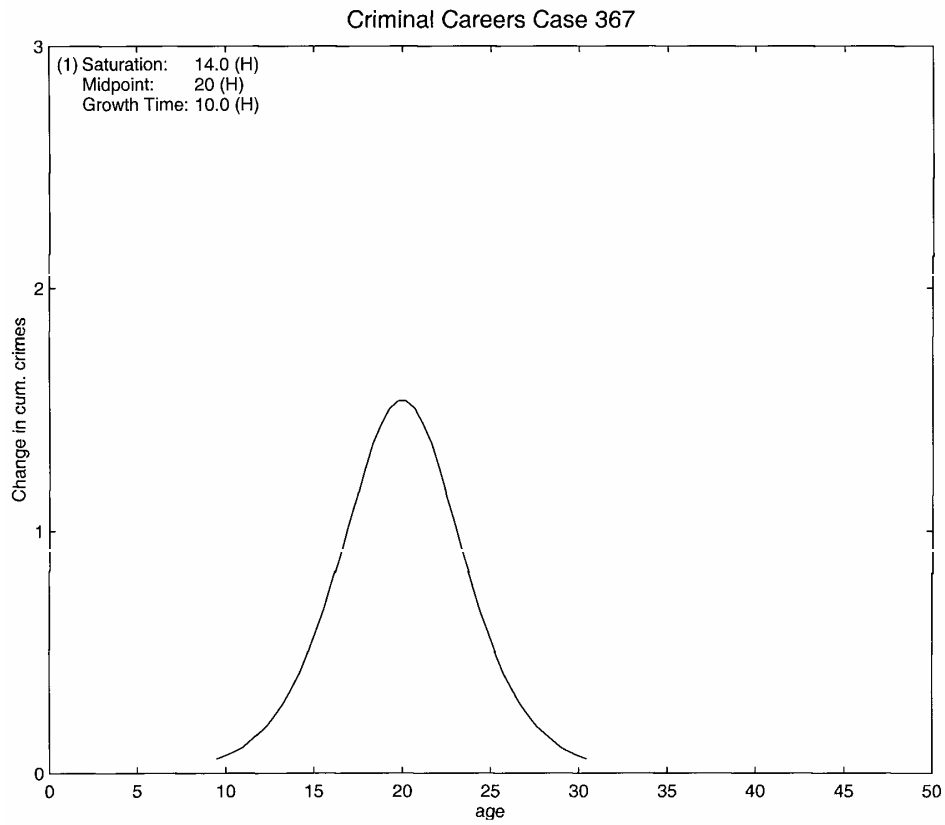


Figure 4.3.5a

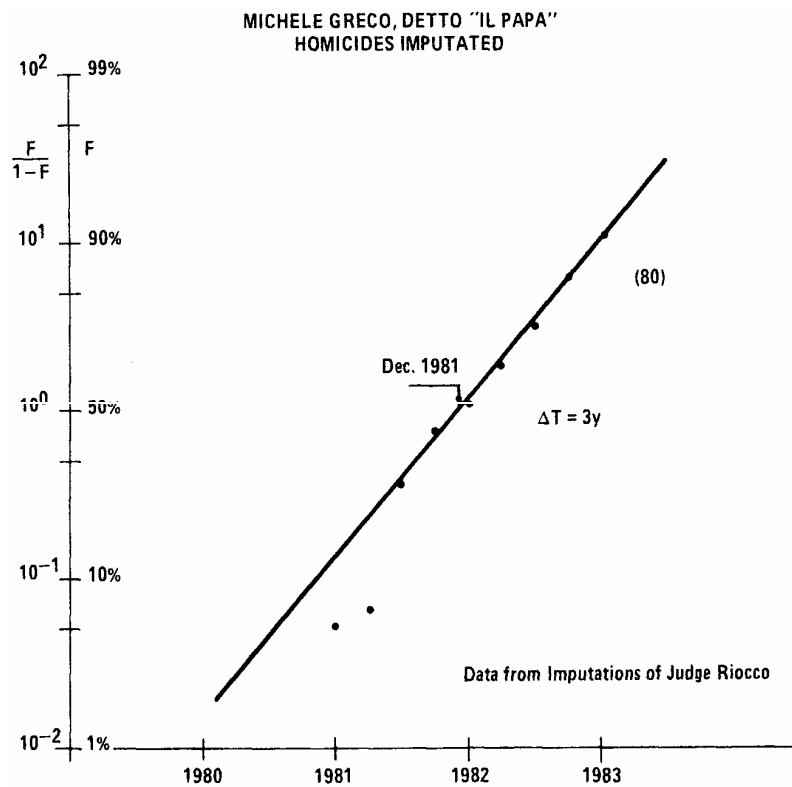


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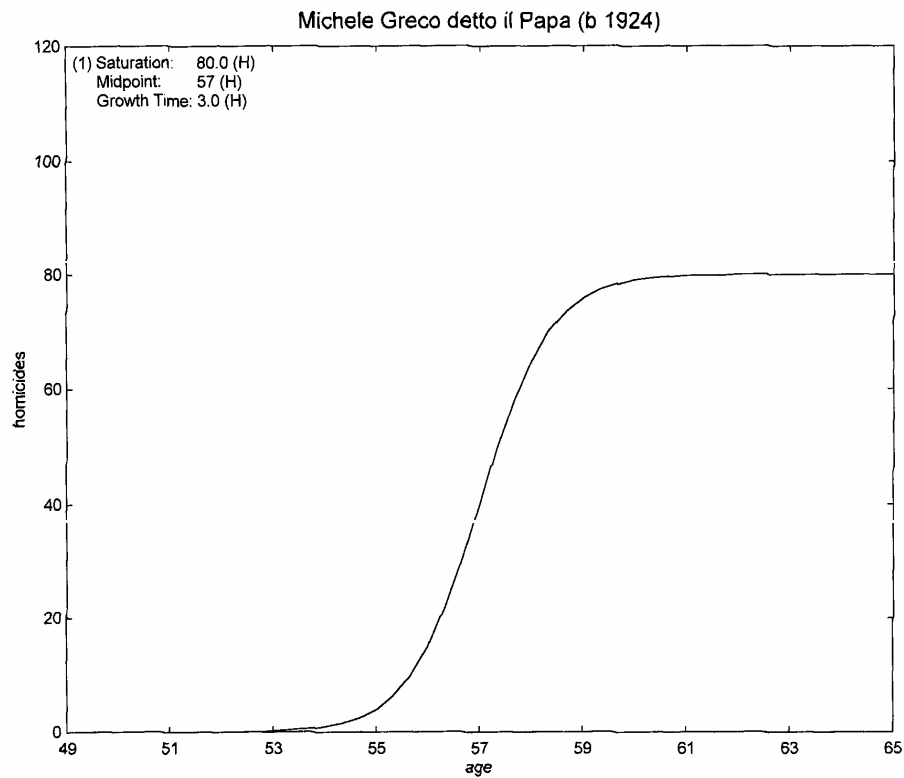


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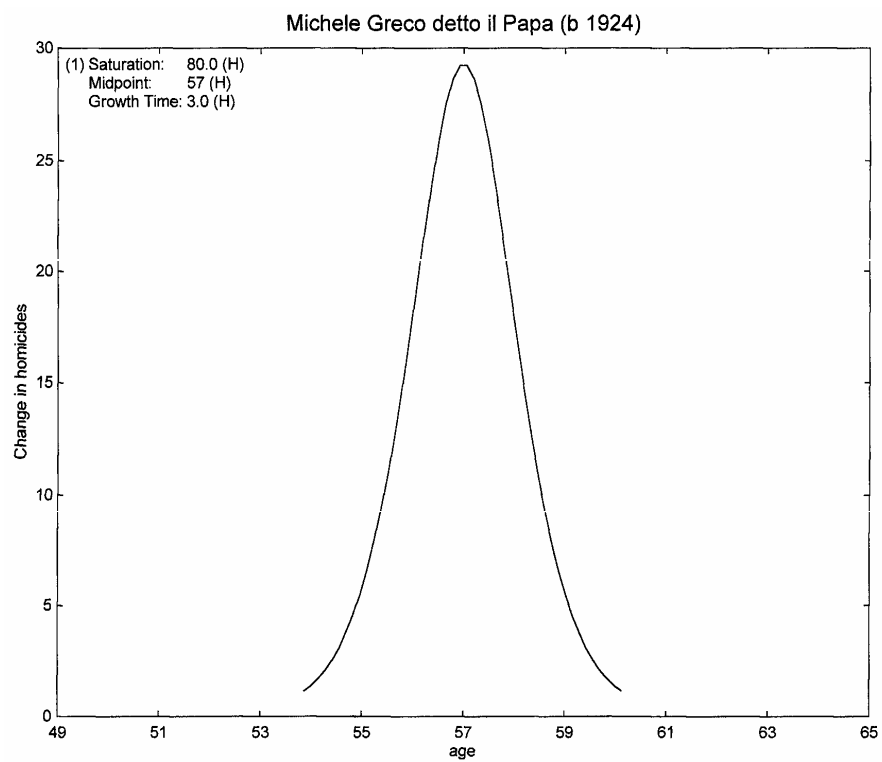
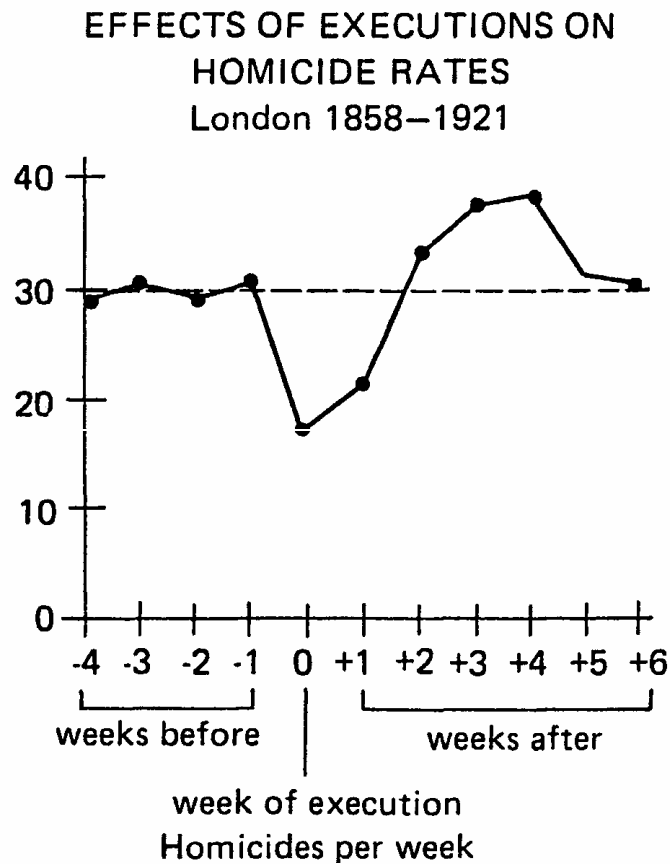


Figure 4.3.6



Legend for criminal organizations

As mentioned previously, we discovered that organizations behave as individuals with their appropriate logistic, even in the case of cultural waves, where there is no formal organization as such but rather an informal connection, such as for fans in a stadium.

In this subsection we report four cases, each interesting in itself. We begin with the famous Italian Red Brigades that terrorized Italy around 1980. A very violent but fairly short-term phenomenon, it lasted 12 years. We focus our attention on the high quality of the fitting and the fact that the kidnapping and killing of a top politician, Aldo Moro, occurred exactly at the flex of the equation, when the rate of growth is at a maximum.

The second case is that of the Anonima Sequestri, probably comprising various bands kidnapping for ransom. The number of kidnappings is incredible, 670 at saturation point. It was in fact a fully fledged industry.

The third case refers to embassy storming by terrorists, a sport popular in the 1970s, but relatively short-lived, with a time constant of only four years. Although probably the work of various organizations, their correlation is remarkable.

The fourth case is very actual, even if it refers to events that happened 30 years ago, reporting on attacks with casualties of terrorists in Israel.

Figure 4.3.7a

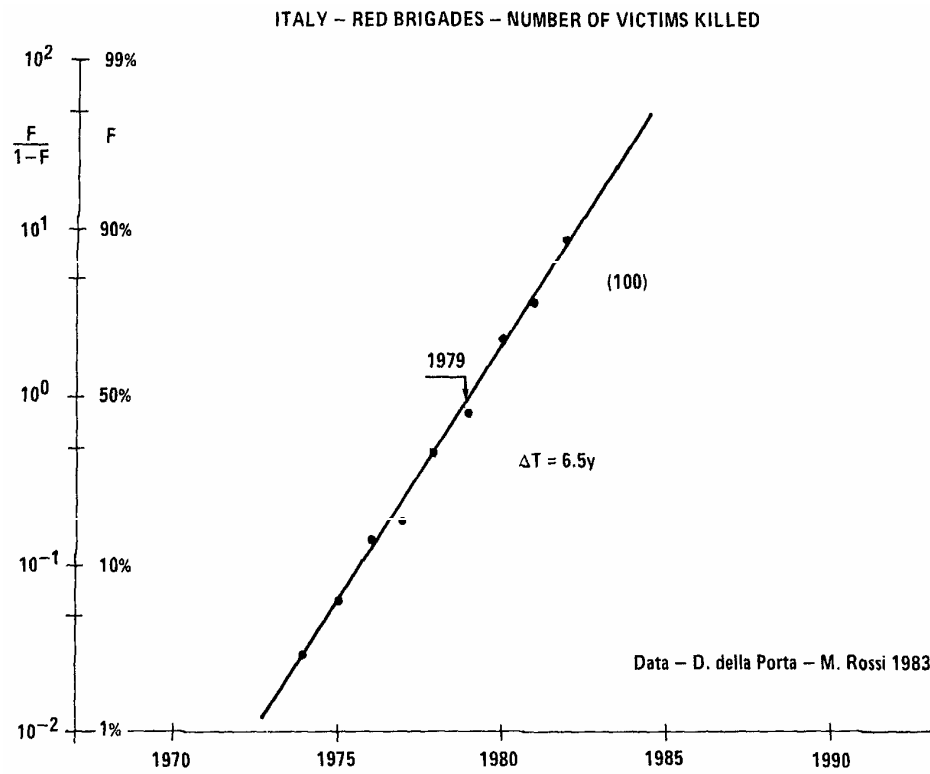


Figure 4.3.7b

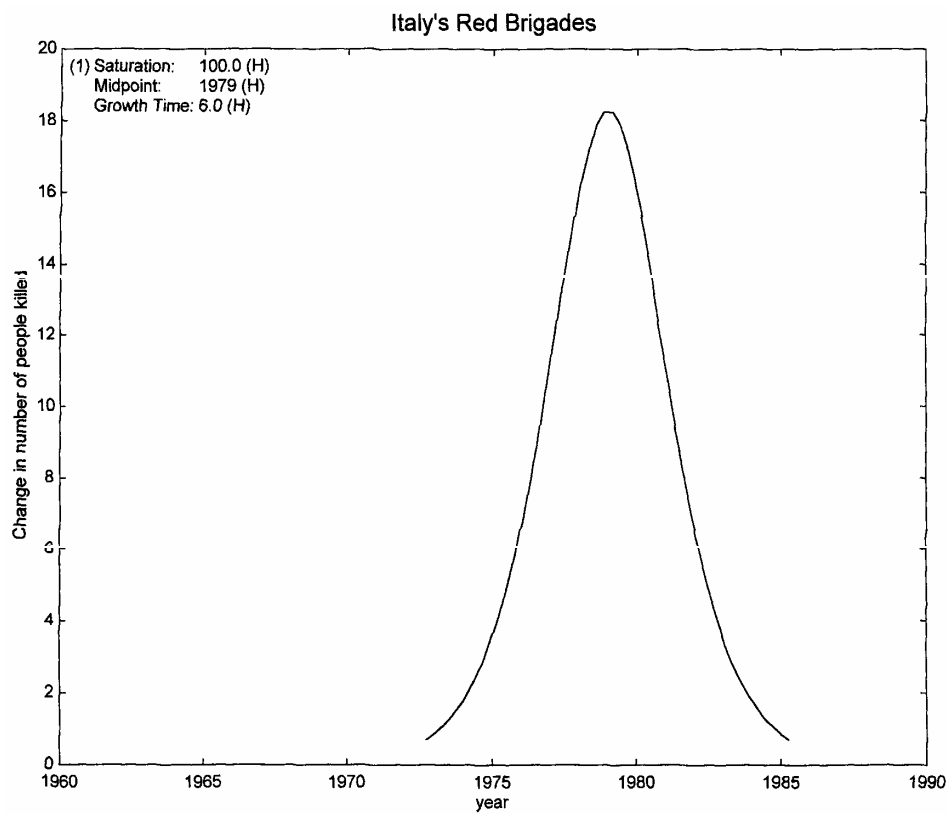


Figure 4.3.8a

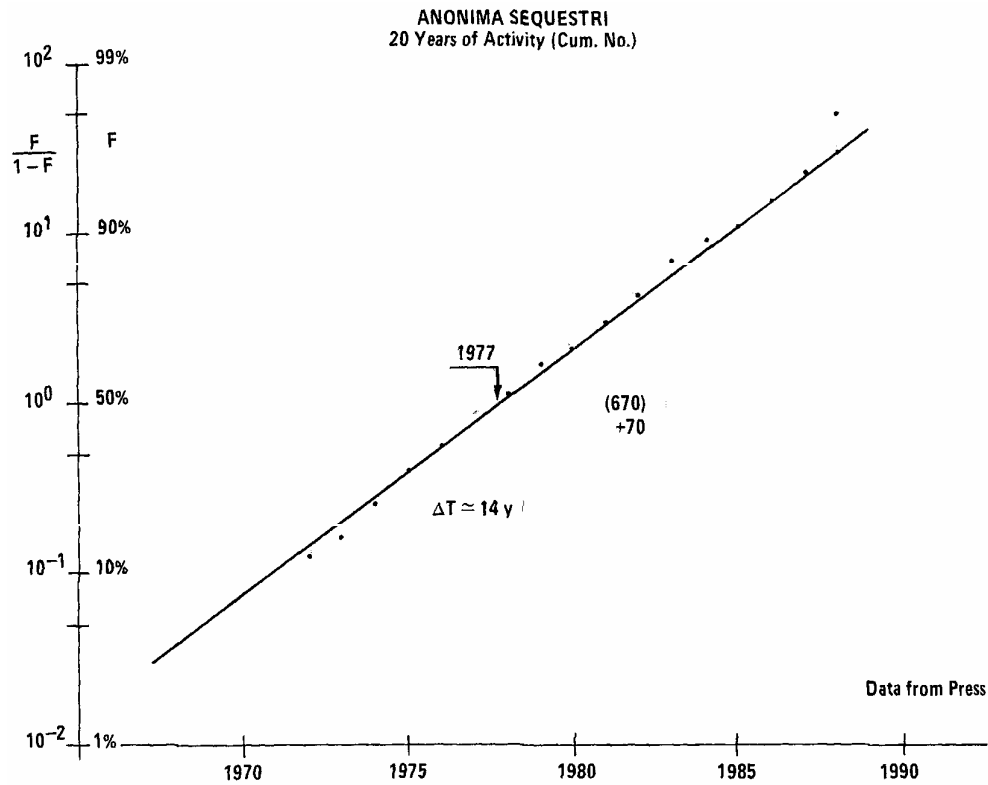


Figure 4.3.8b

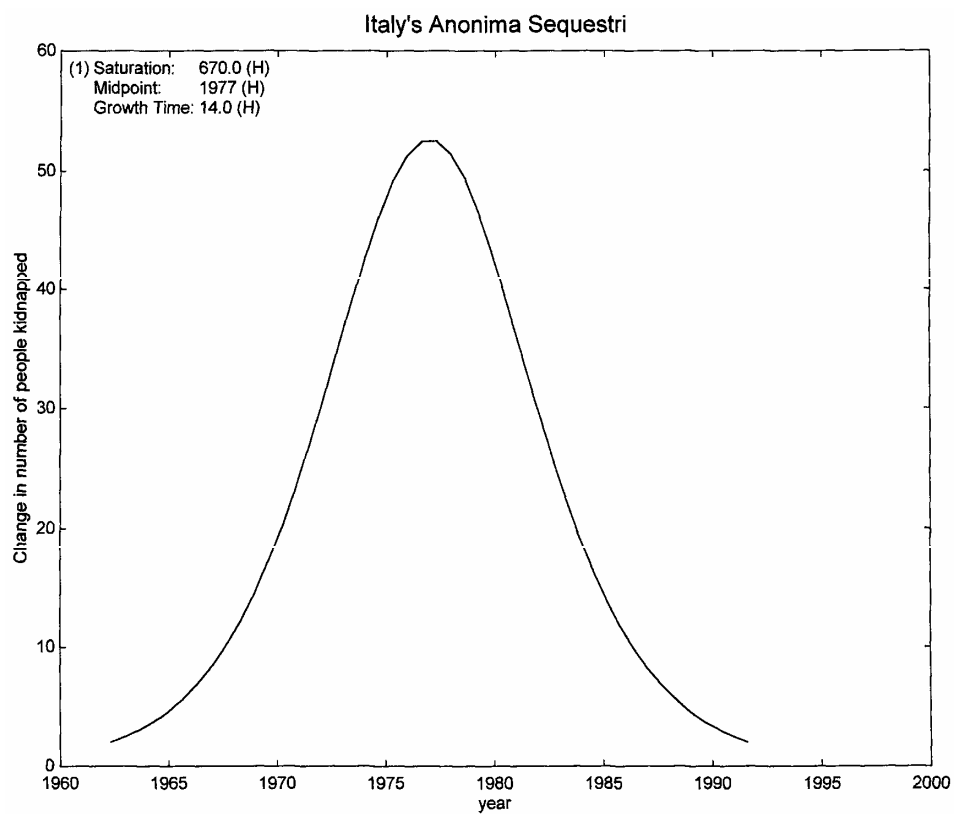


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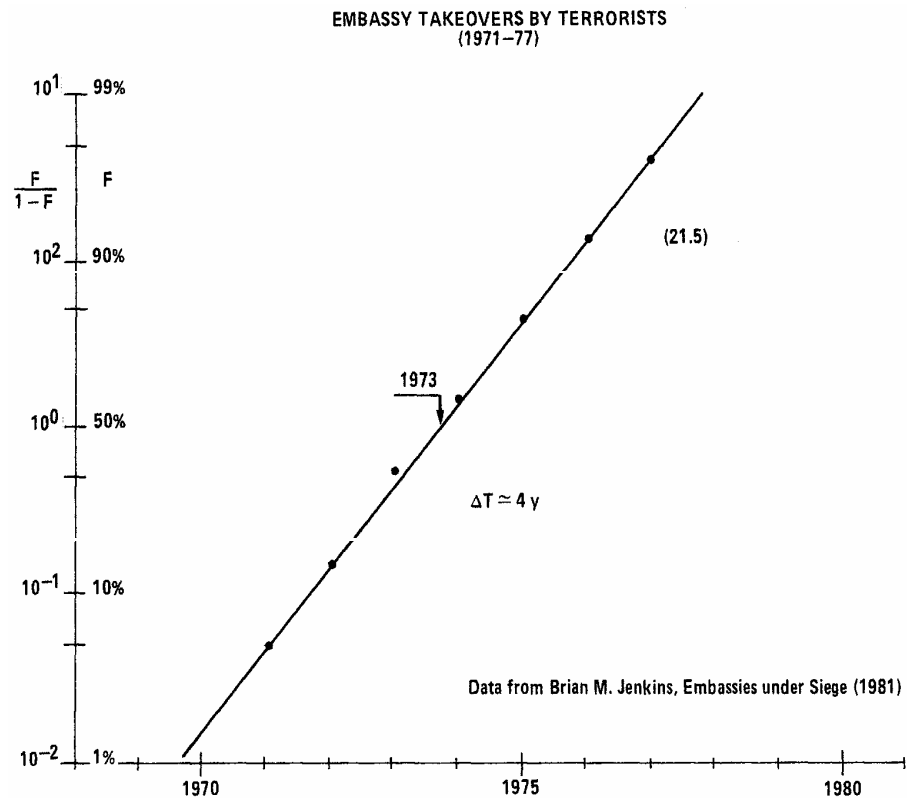


Figure 4.3.9b

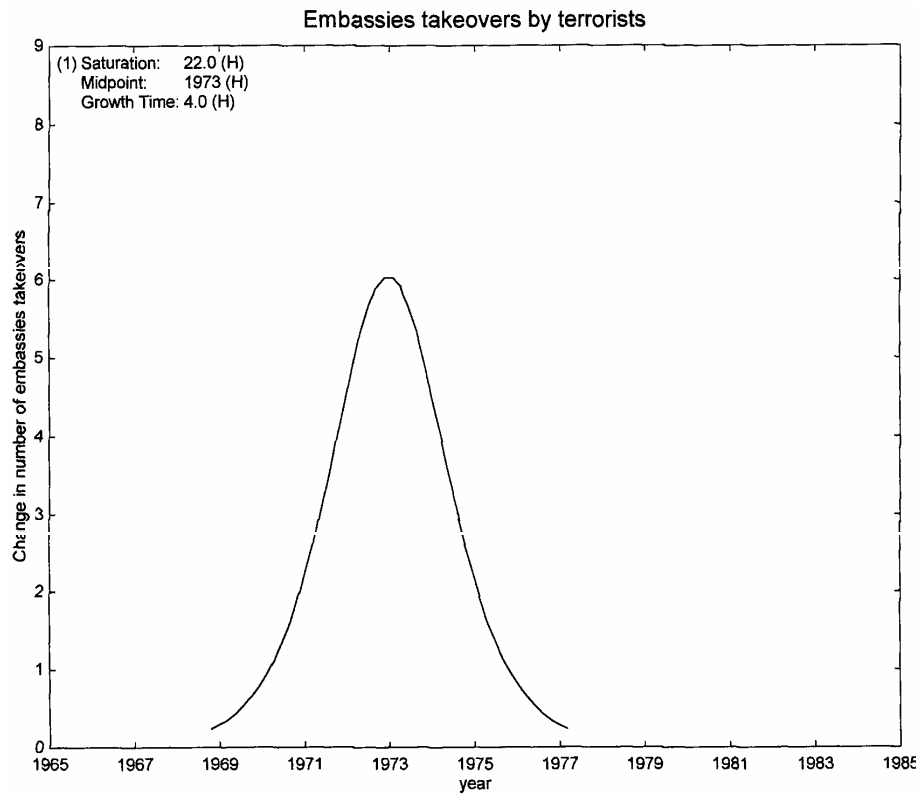


Figure 4.3.10a

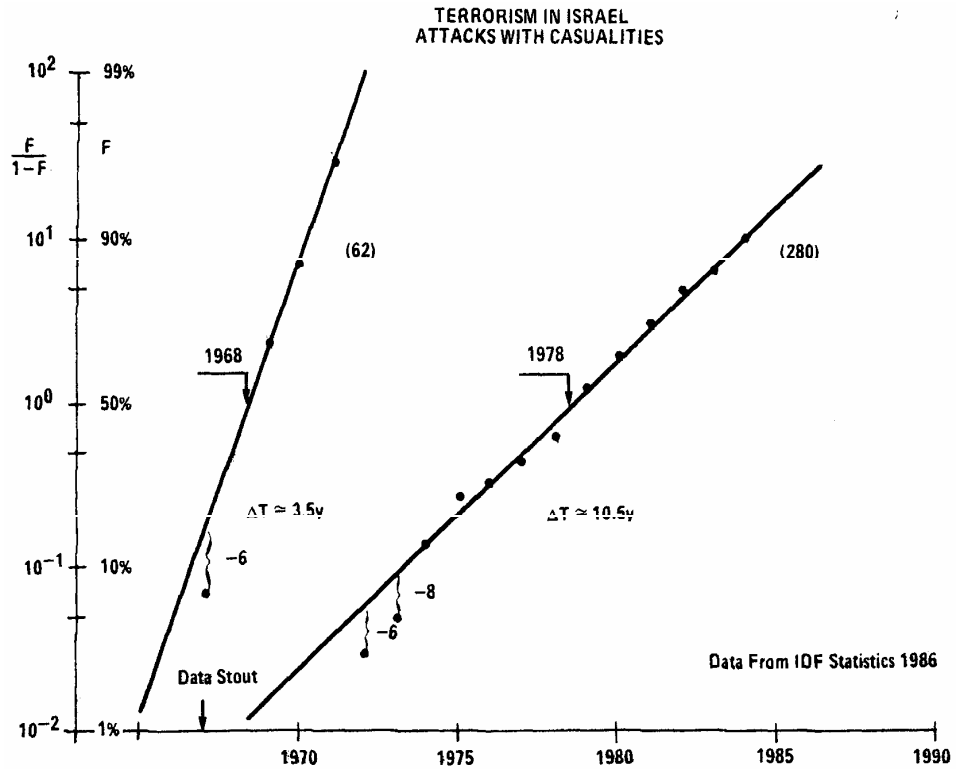
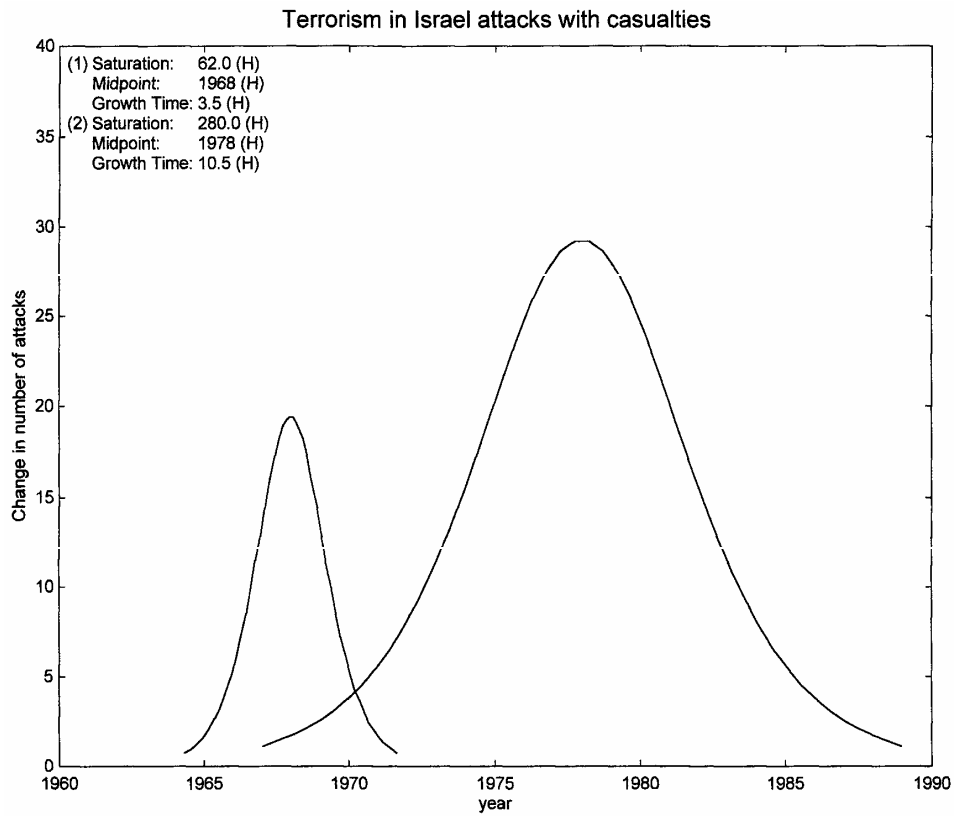


Figure 4.3.10b



4.4. The athletes

It is well known that athletic prowess is characterized by young age: from a professional point of view most athletes are “old” already in their thirties. If we look at charts of the quality indicators of our physiology, we seem to start degrading just after puberty.

Athletic performance (we may also call it productivity) is determined, if not limited, by the capacity of the human system to bring oxygen to the muscles, which seems to be the main bottleneck to performance and endurance. Actually “marathon” animals that can easily escape their predators if they can survive their initial sprint have large lungs, powerful hearts, and broad arteries. The muscles are wiry but not very developed in size. A high concentration of red cells, i.e., of hemoglobin, helps them in some cases.

In the case of athletes, we see a rapid increase in performance with age starting at perhaps ten years, peaking at various ages depending on the specialty, and inexorably decreasing after 40 if, against expectations, fairly slowly. The first chart refers to the best performances versus age for various categories of runners. The data do not, therefore, refer to a person or to the mean of a group, but to the best in the field. Logistics also seem to perform their duty well here by mapping the performance up and down. In resistance sport, such as marathon-running or mountain climbing, performance decreases quite slowly with age. Here, the effort is distributed over a long period of time, so that oxygen supply may not be as important as stamina.

We also have here a good example of gender. When women compete in the various specialties, their performance falls behind that of men of the same age.

Qualitatively one can interpret the difference as a consequence of the role of females in more primitive human communities, where the male was more dominant, and fought and concentrated on hunting, while the females concentrated on gathering. The man had more opportunity to chase and to flee, where speed is at a premium and also to wrestle, where breath is again at a premium.

What is difficult to understand in Darwinian logic is why performance degradation starts so early. Cui prodest? One should also say that actual fertility, i.e., the number of children produced by a cohort of women as a function of age, peaks around 30 years. In both cases rapid degradation may be the adjustment to a very abrasive environment, where reaching 50 was a lost bet.

The aim of our research being the individual, we found an inexhaustible source of data in the “Baseball Encyclopedia,” where the life careers of hundreds of players are reported. We assumed that the “hits” are the center object of the game and took them as an indicator of the inclusive fitness of the player. We used the hits to check a logistic fit on the player’s integrals. With surprise we found that they worked. Again, one man, one career, three numbers. The logistic is obviously centered on fairly young ages, e.g., Ben Oglivie has a center point at 31 years and a time constant of about 11 years. He left the job at 36 years of age when he dropped to about 40% of his top performance. We note in passing that this curve has much in common with that of the actual fertility of females, at least as far as the central point is concerned, but the bell-shaped curve representing actual performance is narrower. Both activities require inclusive fitness,

but making children appears to be a more relaxed sport. This is yet another connection in the hyper connected system of human sociality and biology.

Legend for the athletes

The productivity of an athlete can be measured by his performance, and we take that as the indicator when clearly identified as a number, such as speed or hits. The best performances for running the 200 meters, the 400 meters, the 800 meters, and the marathon for men and women are taken from a paper by Dan H. Moore (1975) of Laurence Livermore Laboratory. They report the age records for 1974.

We took as an exercise the analysis of the men's 400 meters, and found that the cumulative can be nicely split as the sum of two logistics, one centered at 22 years and one unexpectedly at 55 years of age. Actually, as can be seen from the chart, performance decreases quite slowly with age, and the current intuitive supposition is that stamina compensates for shortness of breath. One could interpret the two logistics, or better the sum of their derivatives that give the actual performance, as "Oxygenation" and "Stamination." In the following charts we analyzed the famous javelin thrower, Matti Jarvinen, and found again that the cumulative of his best throws can be split into two logistics whose derivatives show the contributions to his throwing power from two different sources, presumably again oxygen and stamina.

We seem to be the first to have struck such a refined quantitative analysis of the performance of an athlete, pending explanations that the reader will provide. We looked at the case of a longevous baseball player, Pete Rose, where the stamina effects may well emerge. The original analysis with a single logistic appears quite good if perceptibly wobbly. With two logistics the fitting is visually perfect, but perhaps not worth the effort. However, on reflection, the two bell-shaped curves, one centered at 26 years of age and the other at 35, could well be dubbed oxygen and stamina, the second one giving the largest contribution to the longevity, so to speak, of the athlete. Ben Oglivie looks good with one go. But we persisted with our fine spectroscopy and found again something that may be interesting and lead to further research. The important point in our opinion is that the center point of the two bell-shaped curves occur at an age very similar to that of Pete Rose, suggesting a real phenomenon.

Figure 4.4.1

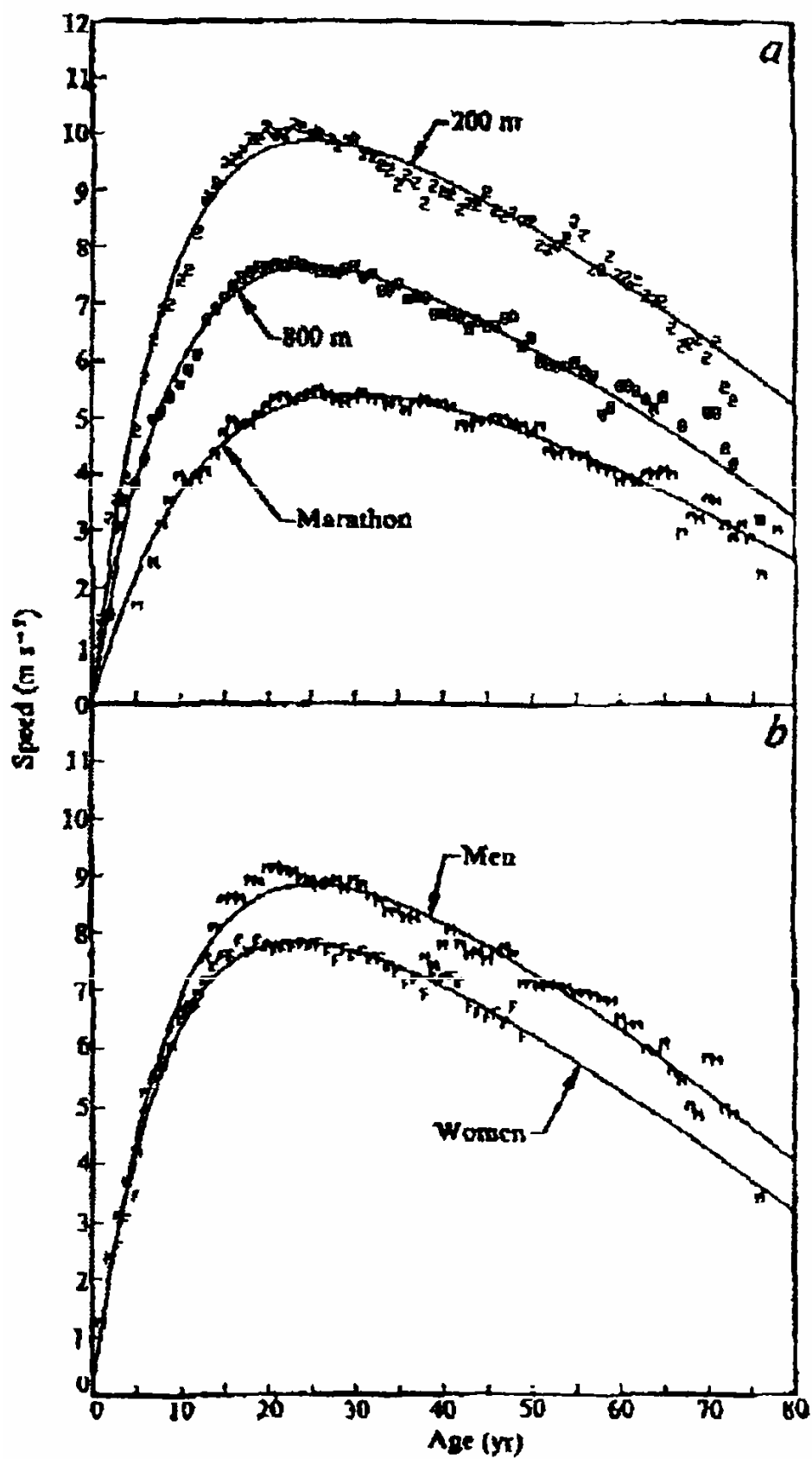


Figure 4.4.2a

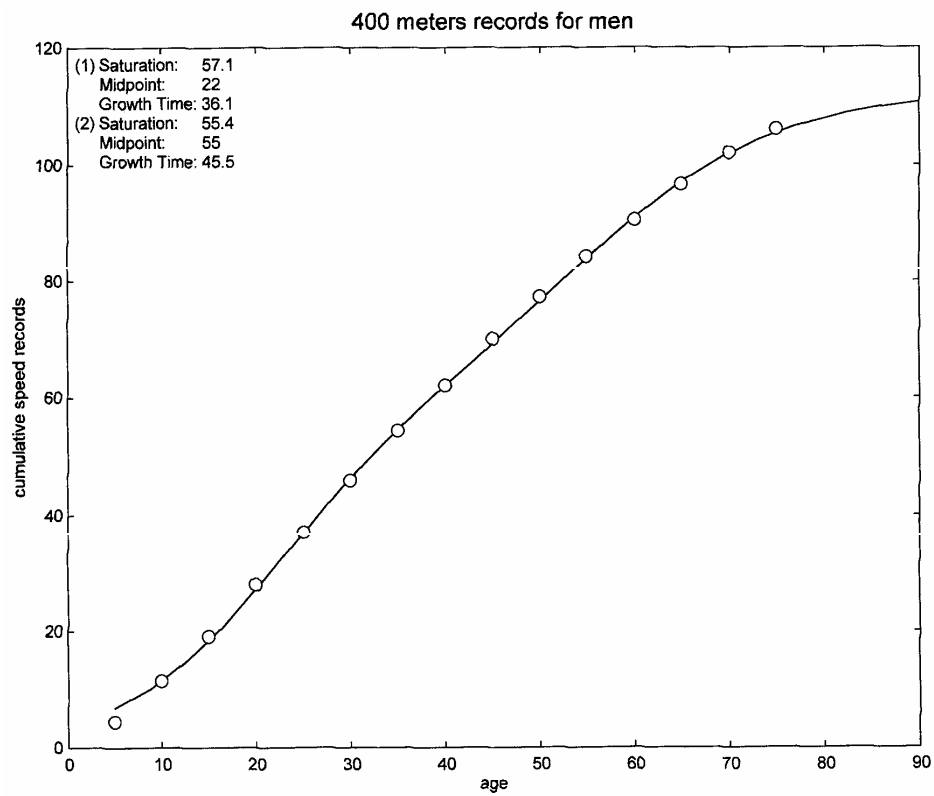


Figure 4.4.2b

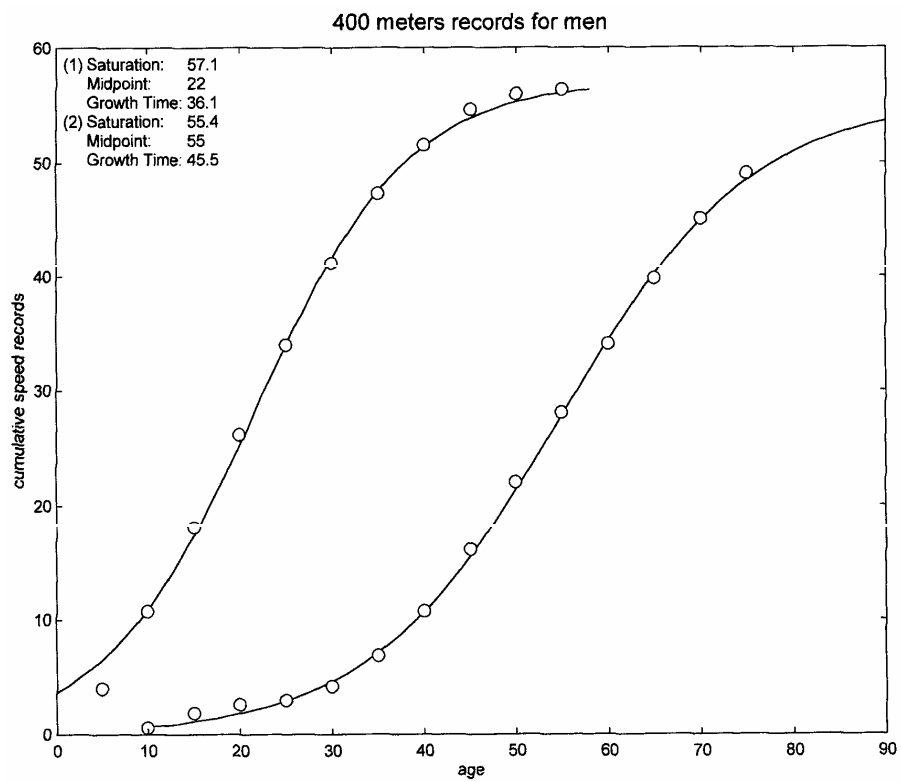


Figure 4.4.2c

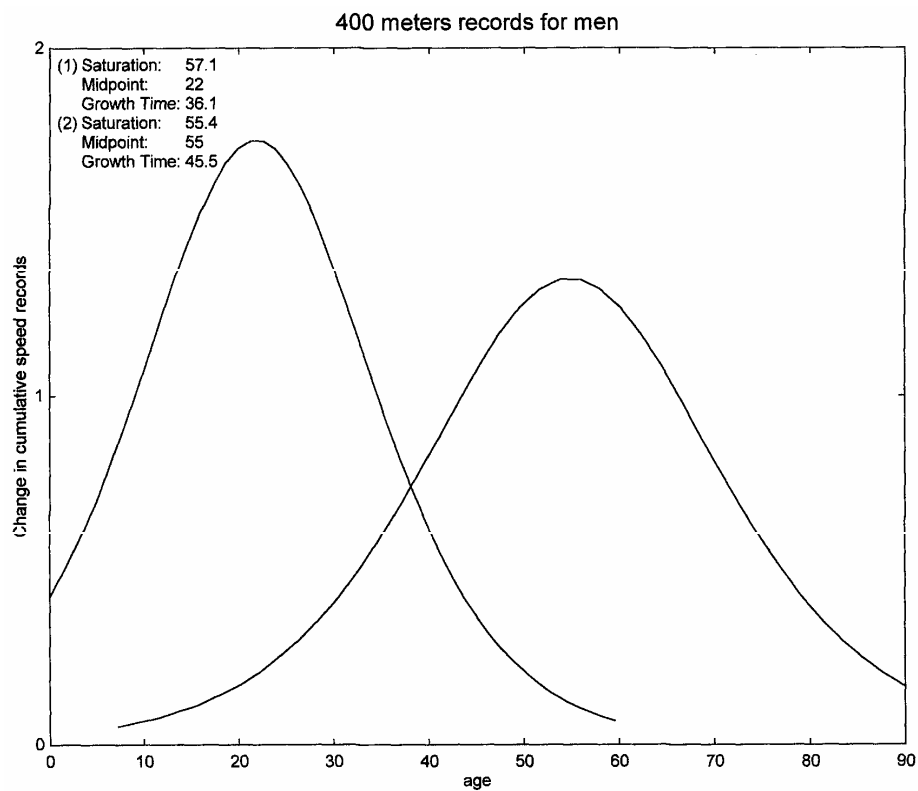


Figure 4.4.3a

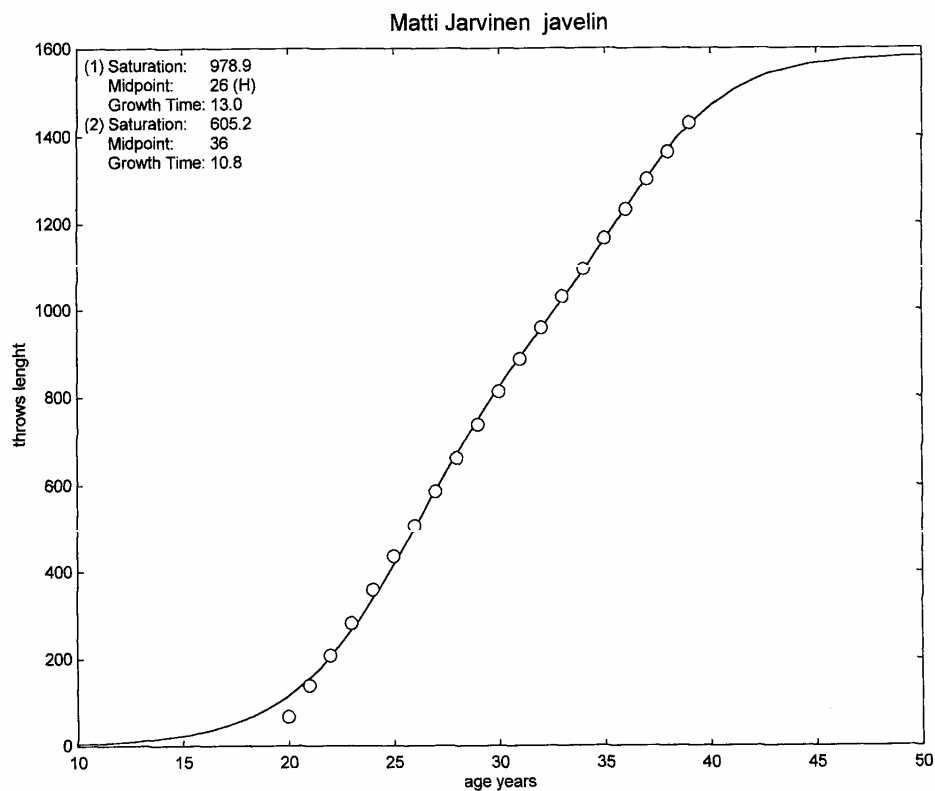


Figure 4.4.3b

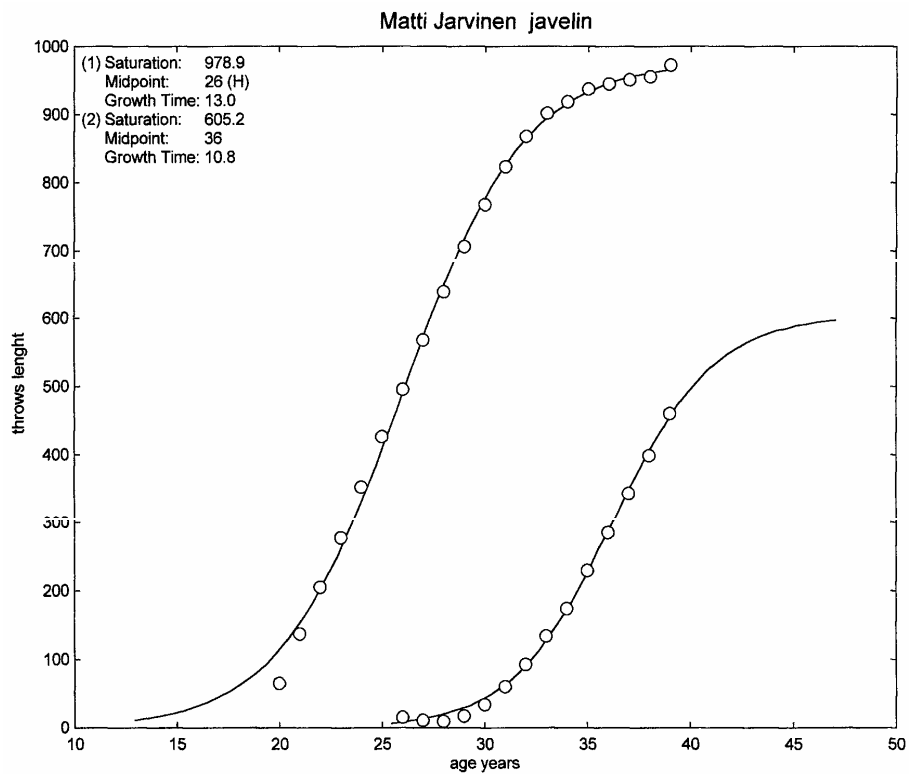


Figure 4.4.3c

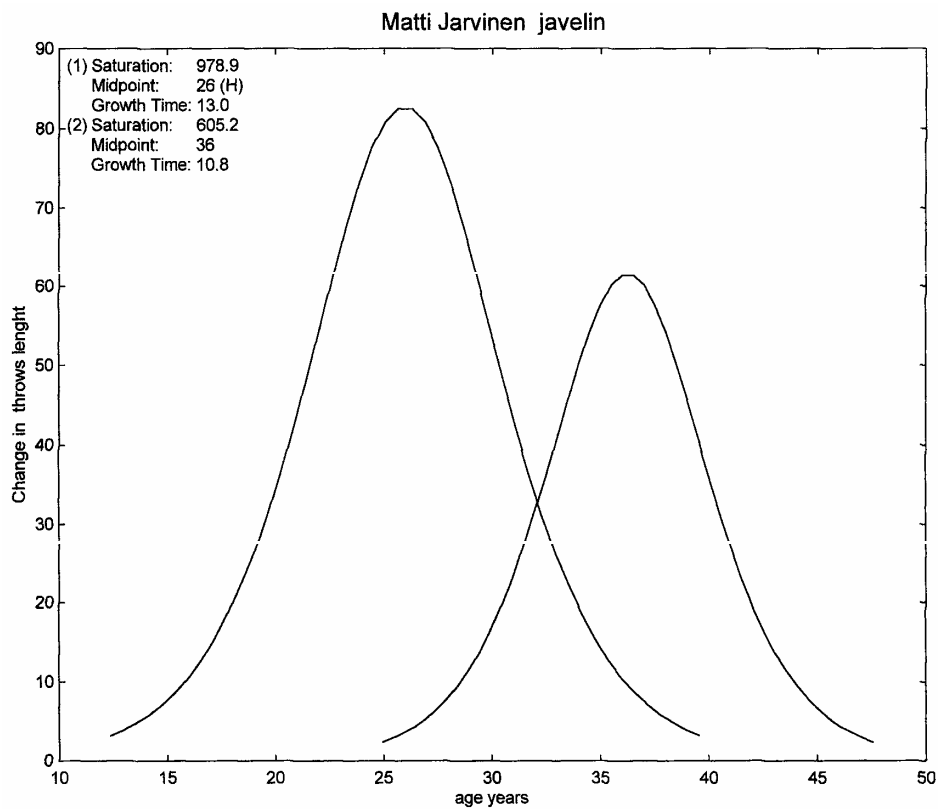


Figure 4.4.4a

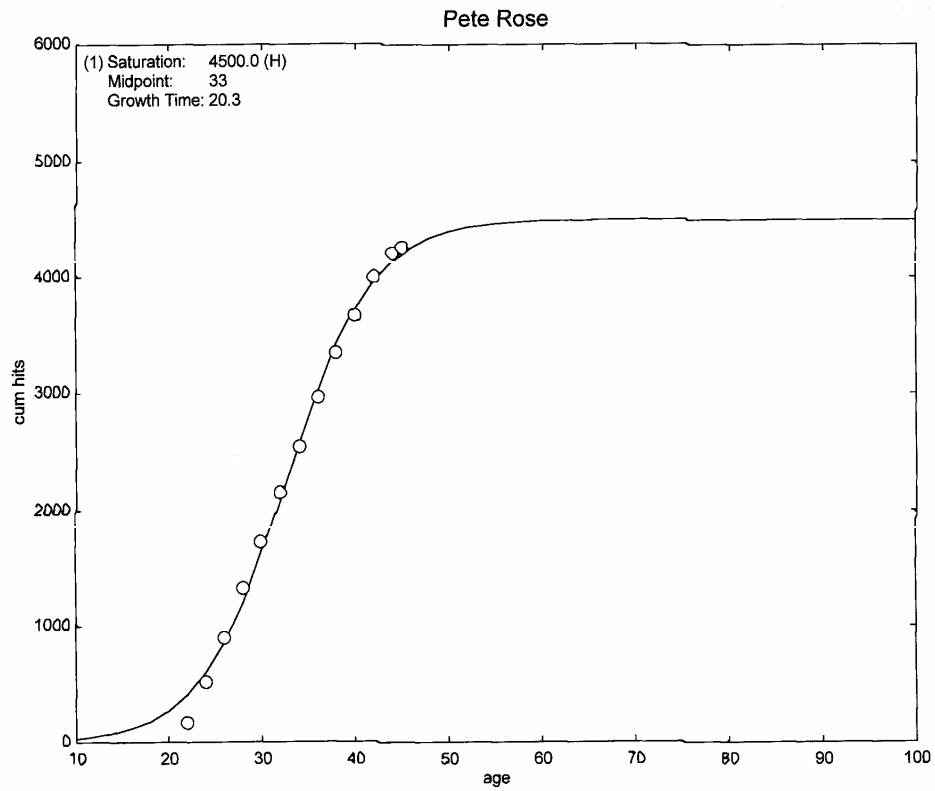


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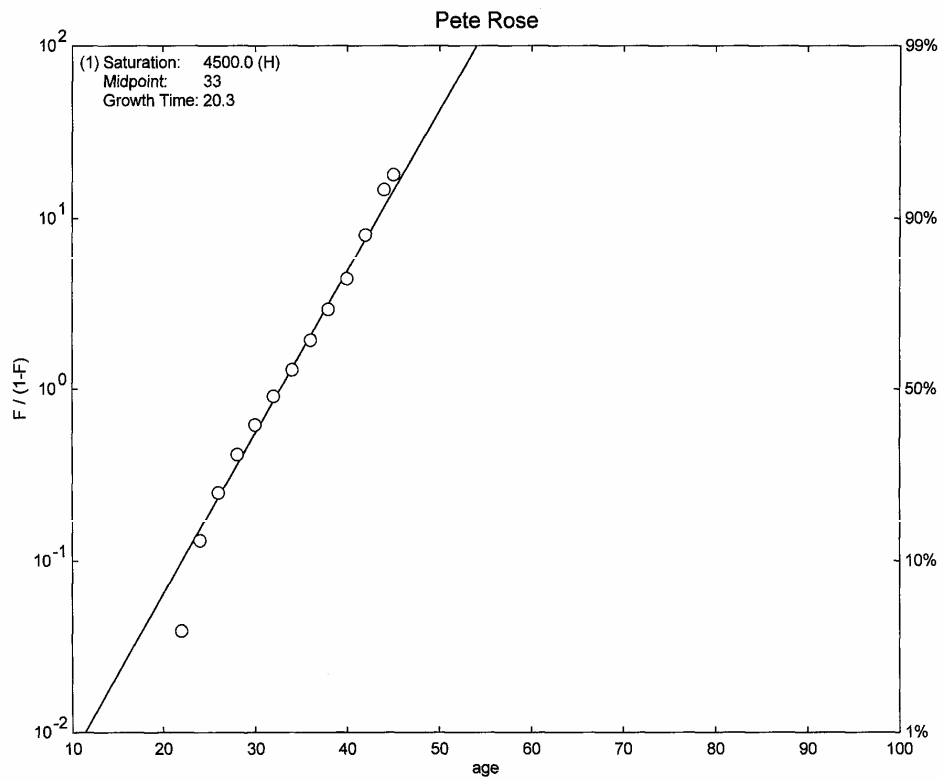


Figure 4.4.4c

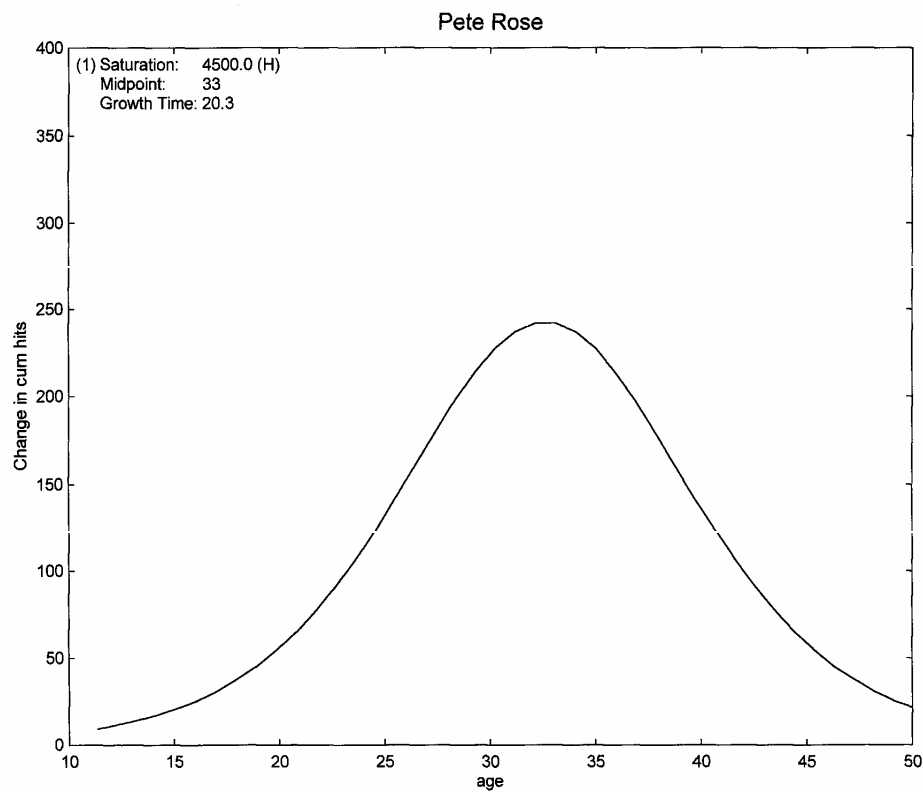


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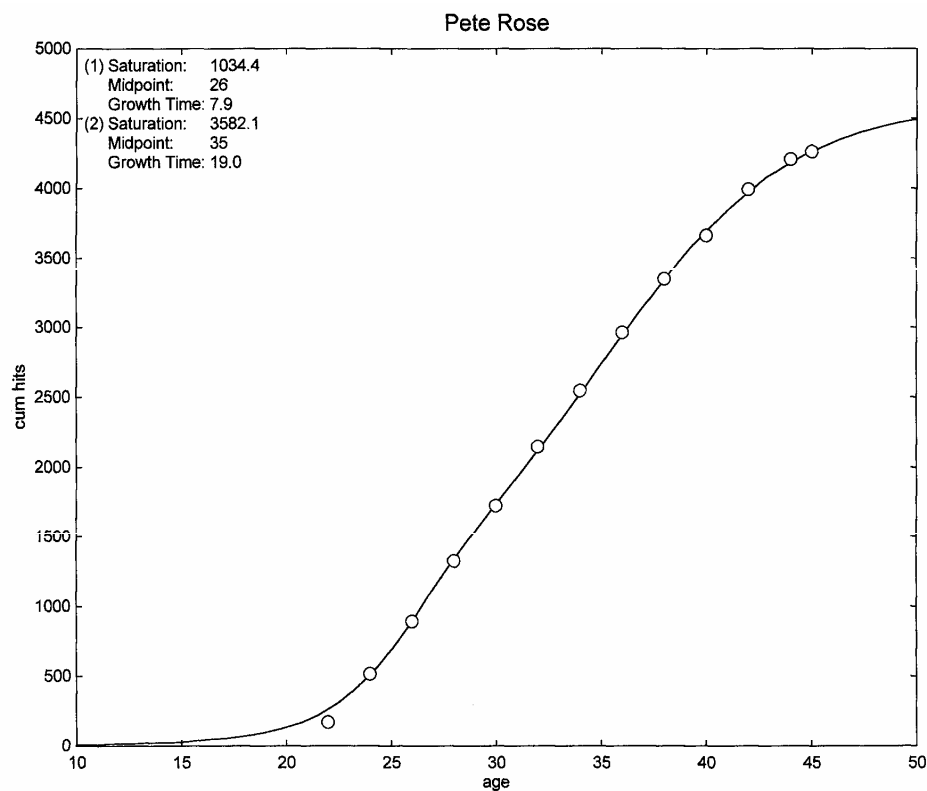


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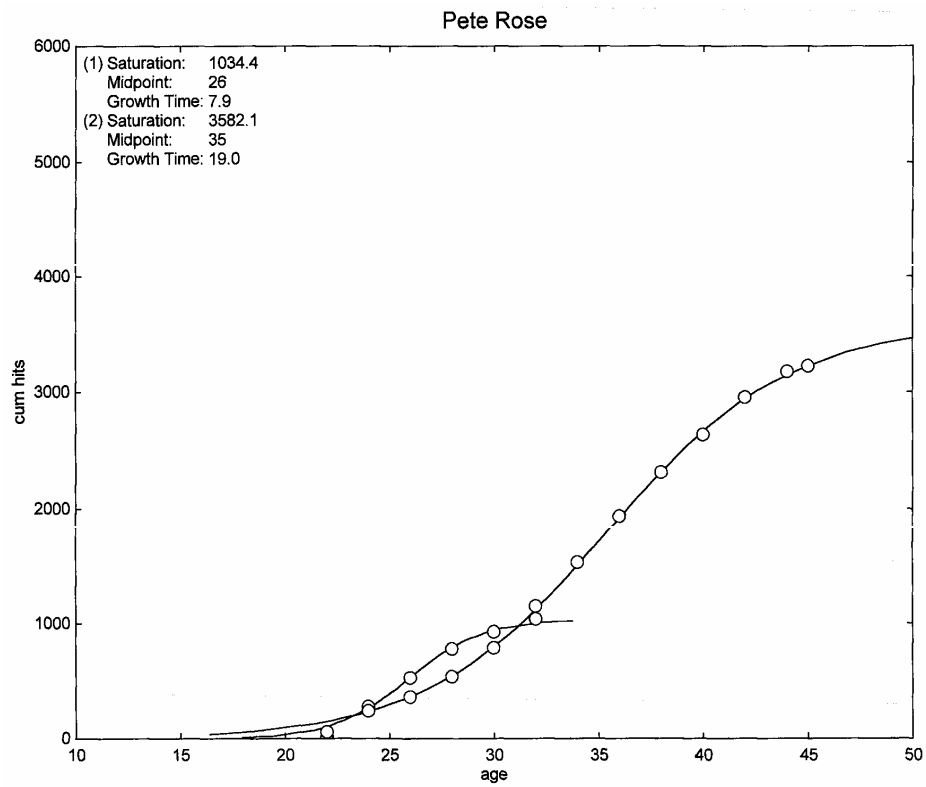


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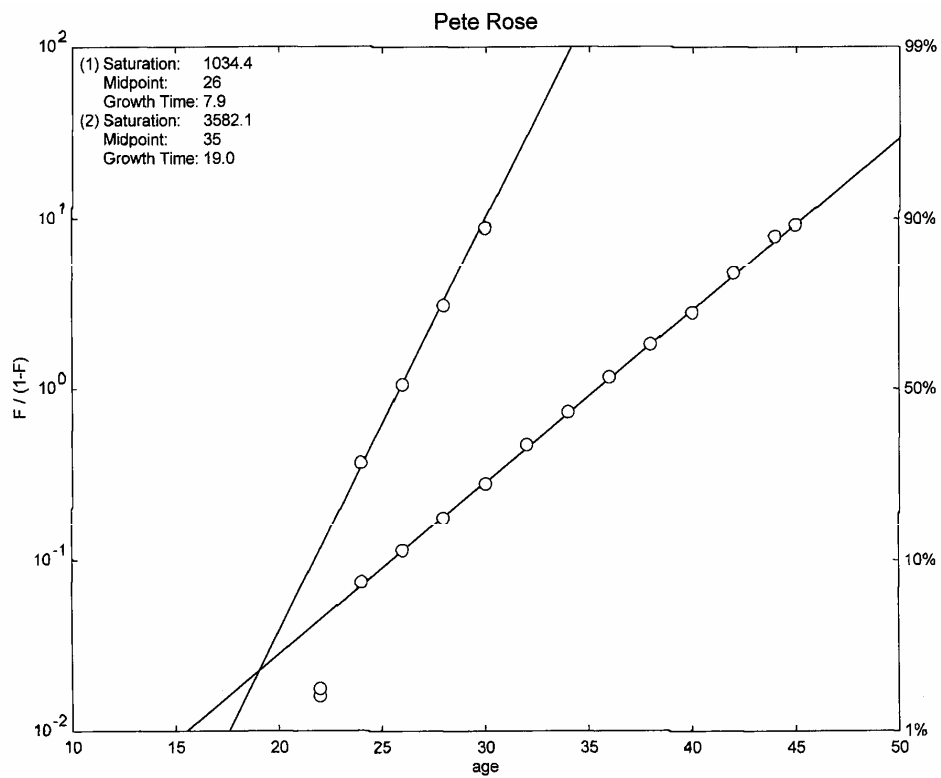


Figure 4.4.4g

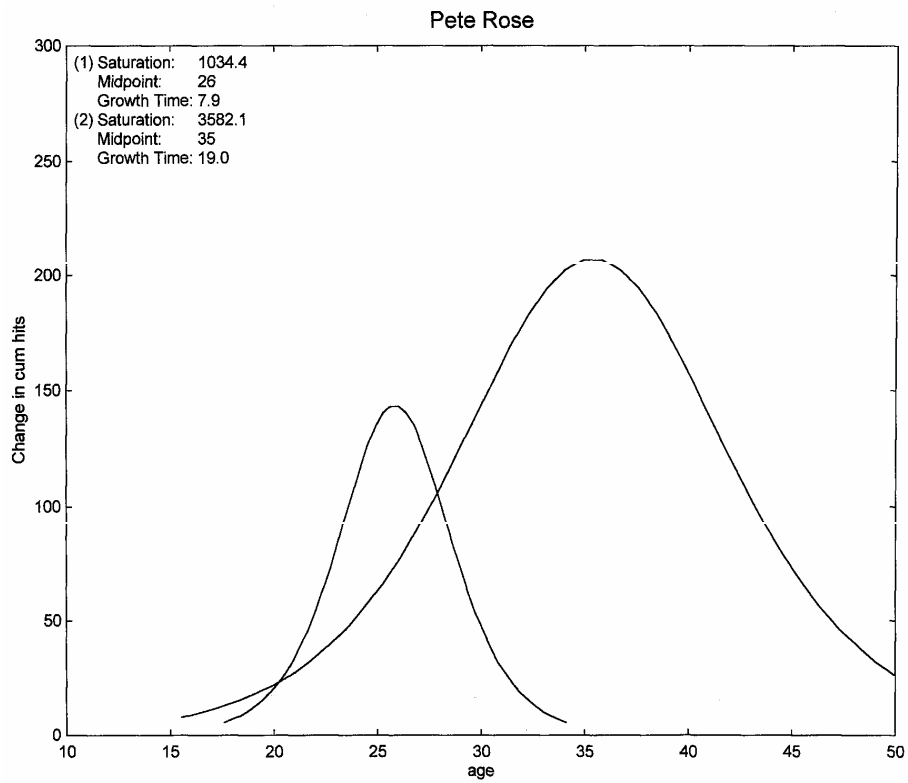


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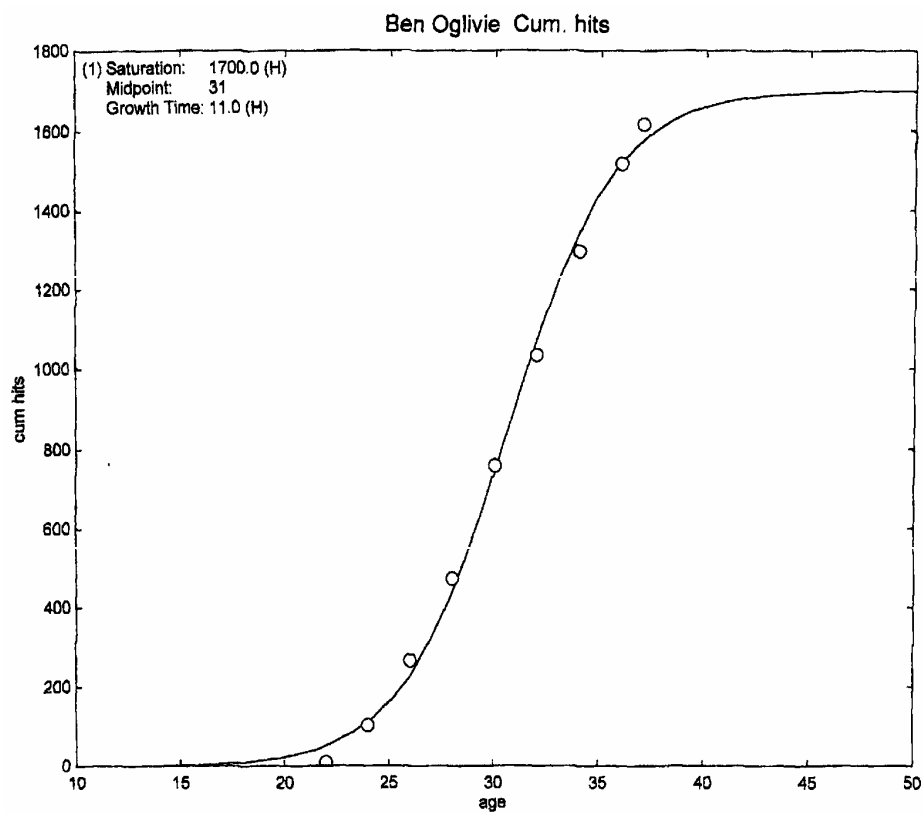


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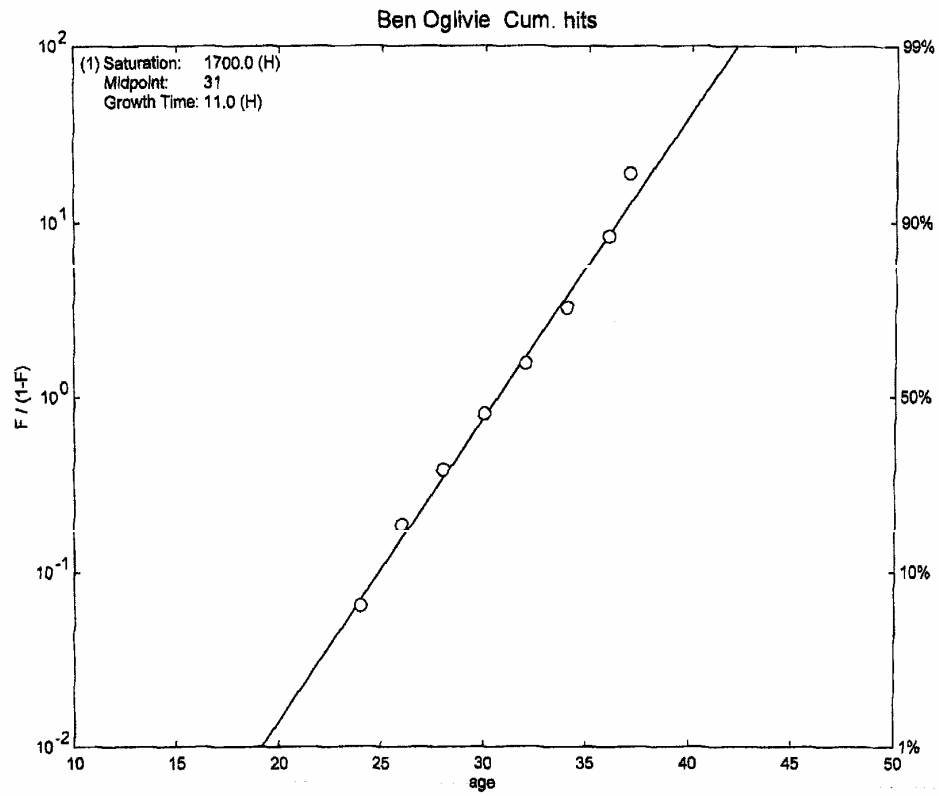


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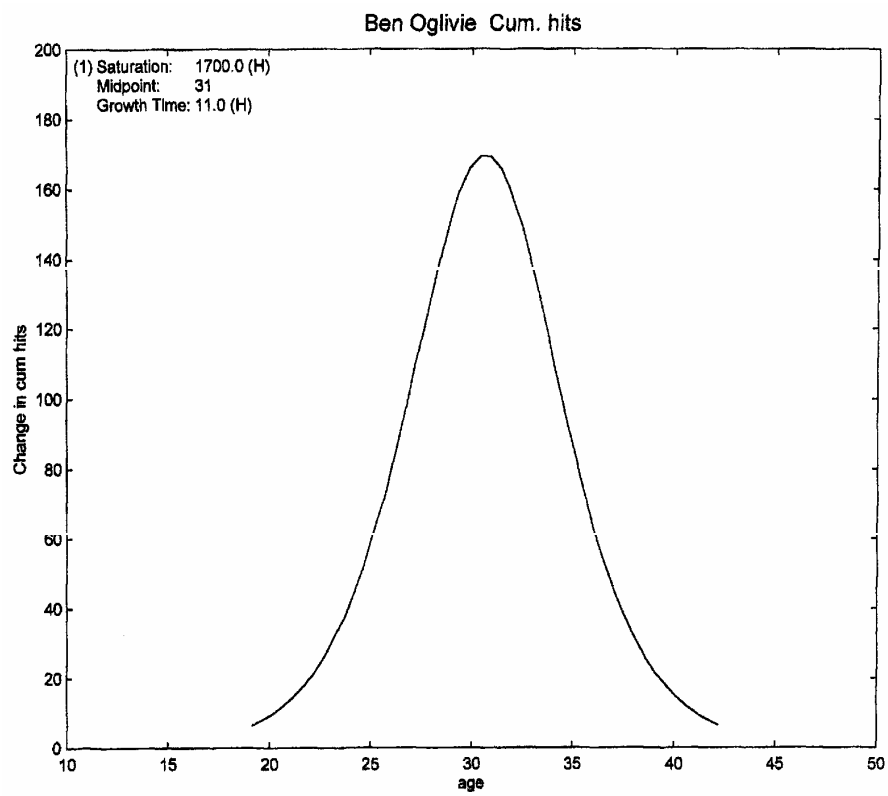


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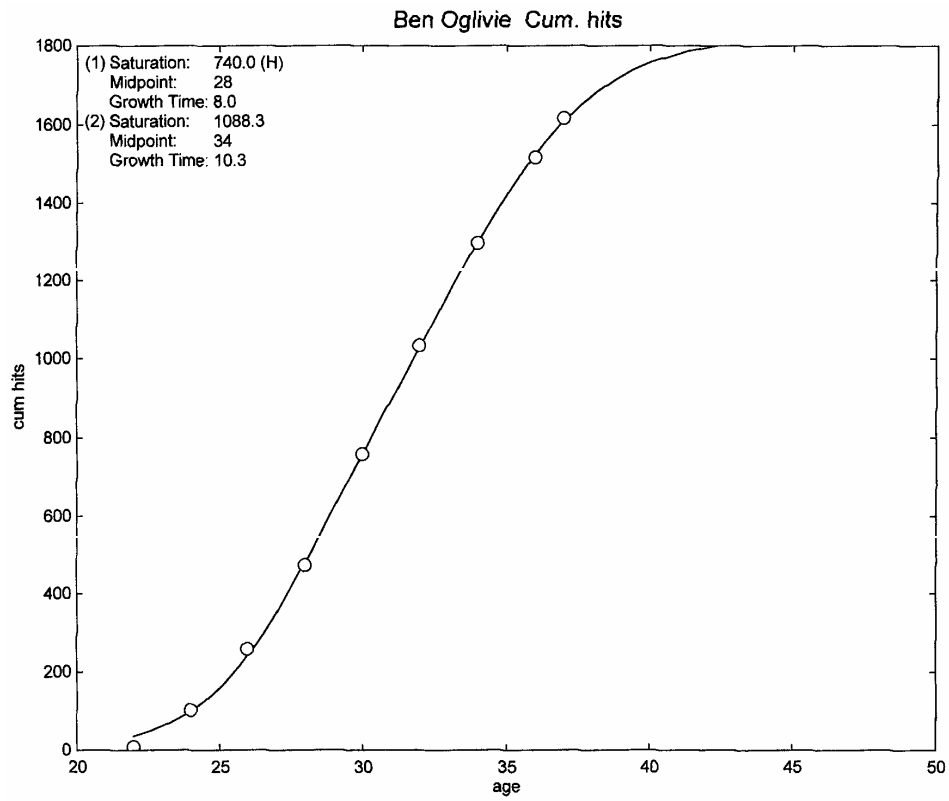


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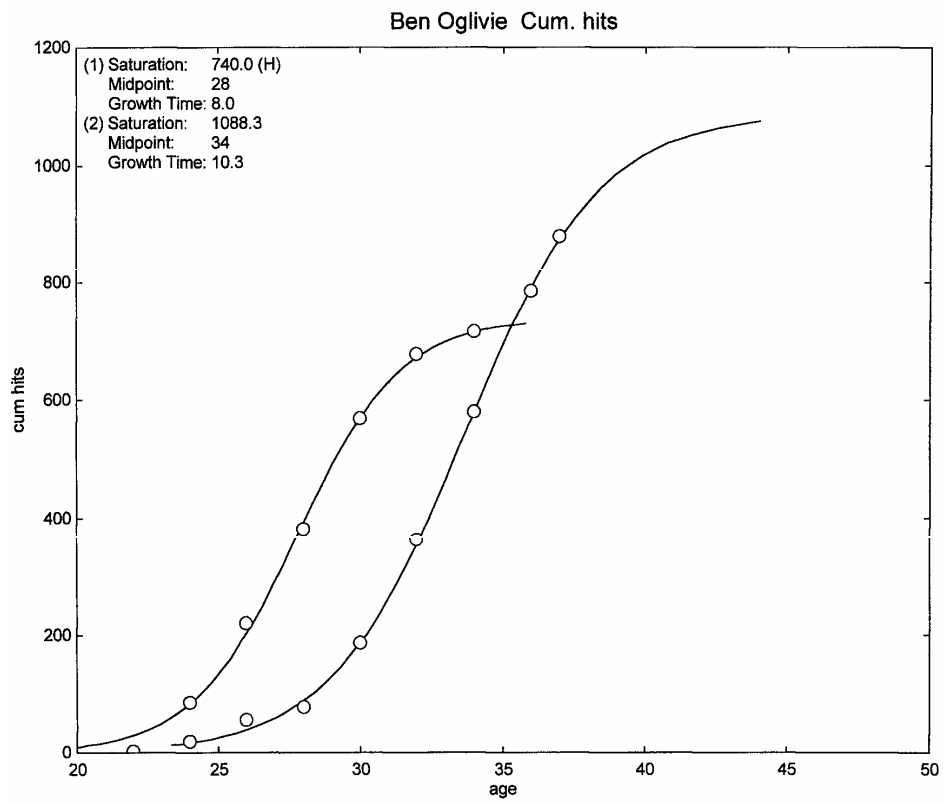


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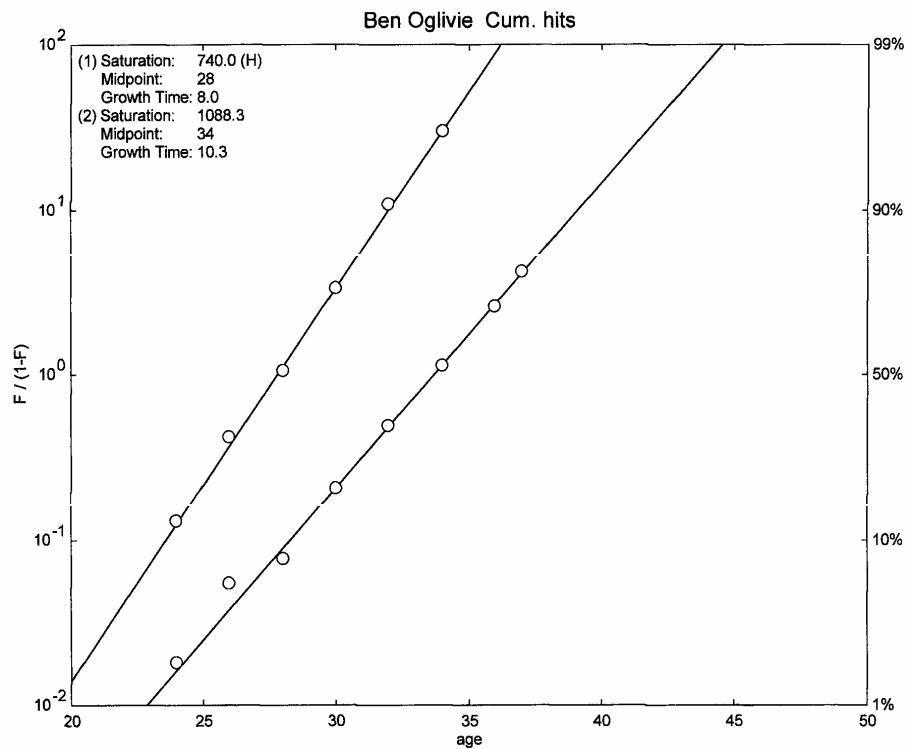
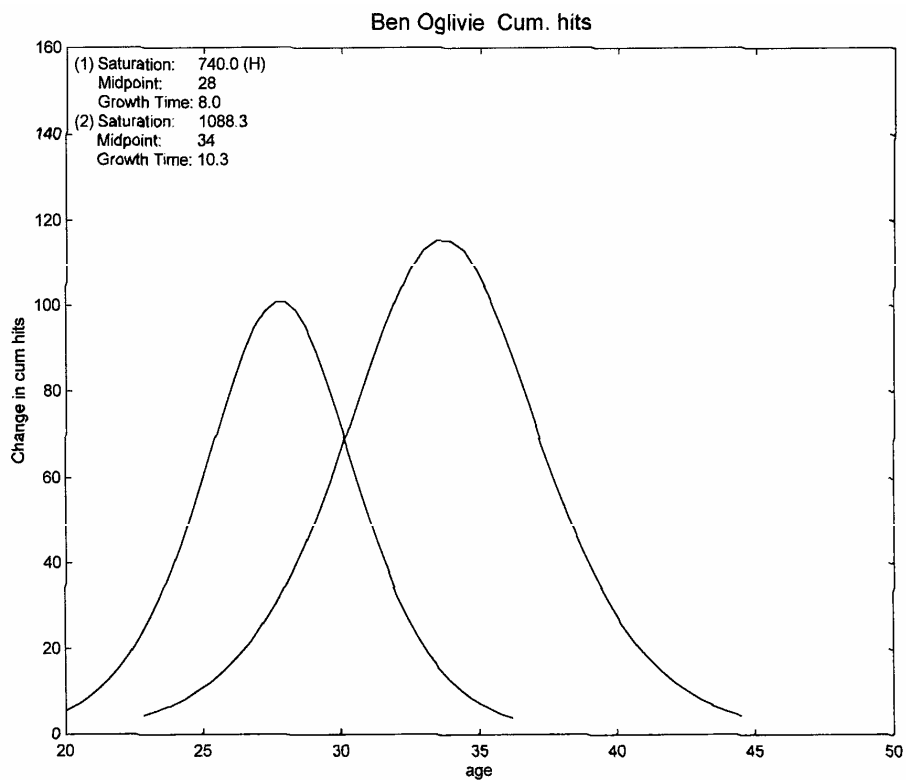


Figure 4.4.5g



4.5. The artists

We have already examined the film industry, where artists on and off stage perform with a maximum of visibility. We will deal here with other categories of artist, namely painters, musicians, and writers who are at times less visible but usually endowed with greater durability. One should make clear from the start that ultimately all behave more or less in the same way, but this has to be proved by our analysis, which being basically an empirical one, has to rely on an extended database of cases analyzed.

Artists are by definition creative and, as our analysis shows, dedicated people. Spurred on by their passions they usually continue to produce till death, and generally speaking die when their logistic saturates. This is not related to the number of objects they produce—there are redundant natures producing 1,000 paintings and stingy ones producing 20—nor to the quality of the objects produced. This drive to produce is in a sense an independent variable or function, and predates action. It looks like one of the subconscious operators nested in the limbic brain that was explored by Freud. As mentioned previously, we named these drives in an abstract form as “action pulses” without reference to the objective of the action itself. They appear so general that one should consider them as a basic cog in the human works and in that of human society too, as these pulses seem to reappear at group activity level, as adumbrated by the cases of criminal organizations reported above.

We do not think this is belittling the human value of art, which is different in that it represents a way to code abstract ideas into sensible bodies with intense aesthetic stimulation. But perhaps we take away some of the mystery and strangeness surrounding the artistic drives to create. The muses are brought to earth, and why not, science does that all the time. The choice we present is somehow limited and skewed to represent more the problems than a general overview.

Legend for the artists

Mozart (b. 1756) is a symbol and a prototype, and is therefore considered first. He was not only extremely creative—we could not name a piece that is not of high quality—but was also extremely productive, with more than 600 pieces according to our count. The time display of this production, which started very early, is well represented by a logistic that approaches saturation (96%) when Mozart was 35 years old. Time to die perhaps for an extremely dedicated artist like him. But his creativity continued to evolve in refinement and complexity, as demonstrated by the Magic Flute or the Last Requiem, until the very end. But action pulses are just switches. Gioacchino Rossini (b. 1792) provides a counterexample, saturating at about 35 years but living till 76. As the bell-shaped curve shows, his career looks much like that of a 100-meter sprinter. Opera writers generally look odd in comparison to other artists, perhaps warranting an ad hoc search.

Our third case is Maurice Ravel, (b. 1875), considered somehow bizarre and perhaps slightly mad. However, his logistic is perfect: one man, one career, three numbers, and he died at the “right” time, at 62 years of age. Taking advantage of the opportunity given by this type of fine spectroscopy to peep into the life of somehow strange people, we also analyzed Schubert (b. 1797), who, because of schizophrenia,

had two different names for his split personalities. In fact his work splits very well into two logistics superposed most of the time and curiously with the same saturation point of 600 pieces. Also Schumann may have had problems, but his situation is closer to normal. His death anyway was “timely.”

The painters look to fall more into line. Botticelli (b. 1445) has a good time constant of 36 years, comparing almost to a Nobelist, and dies with 93% saturation at 65 years. Beccafumi (b. 1486), an excellent but not so famous painter, also has a good time constant of 32 years, and dies at 79 with 100% saturation. Ribera (b. 1593), again a famous Spanish painter, has a medium time constant of 25 years and dies at 59, with 98% of his task accomplished. Zurbaran (b. 1595) is again in the young league, with a center point at 42, and dies at 69, with 99% of his action pulses exhausted.

Coming to writers, we show Agatha Christie (b. 1890) as a kind of outsider, with Shakespeare (b. 1564) as very much an insider, dying at 51 with already more than 90% of his program accomplished, just as Christie at 86. These coincidences, even if repeated, are obviously no proof, but merely suggest that there is a problem to be explored.

Figure 4.5.1a

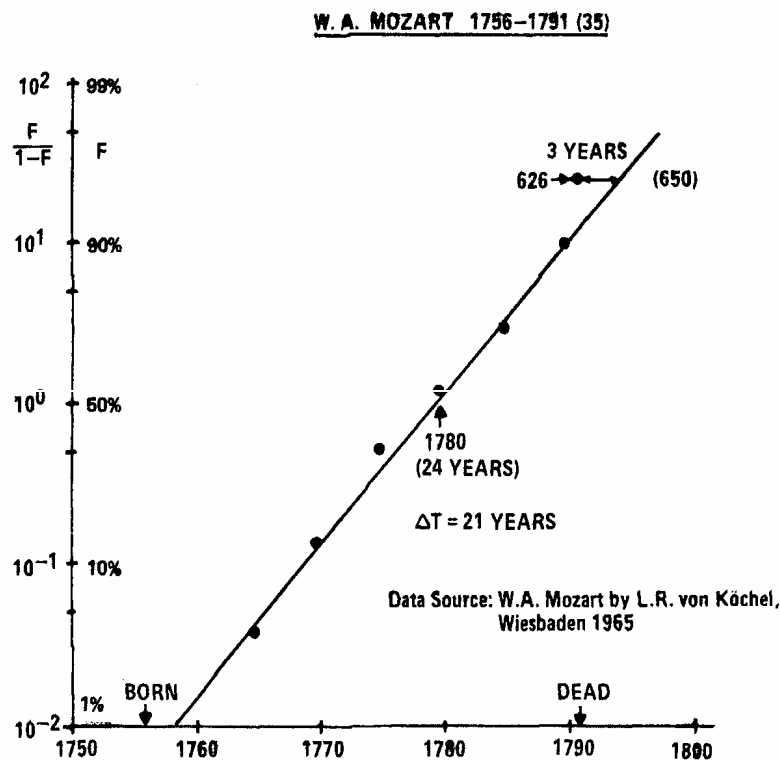


Figure 4.5.1b

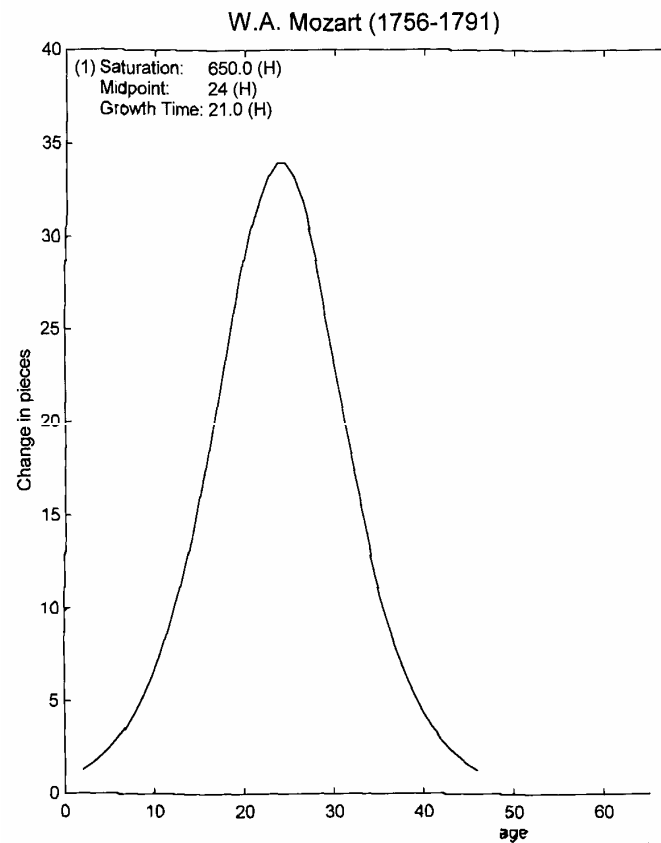


Figure 4.5.2a

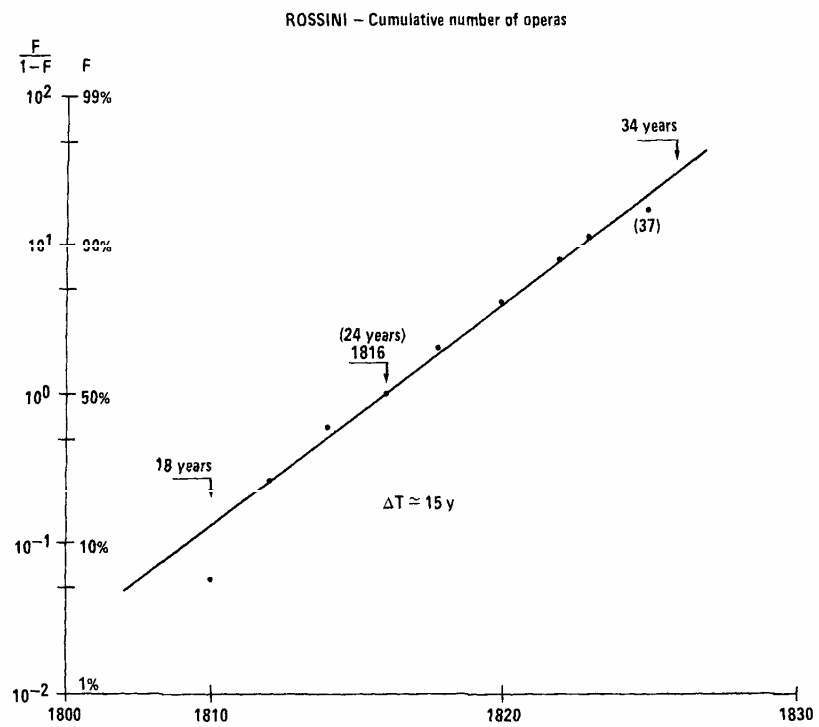


Figure 4.5.2b

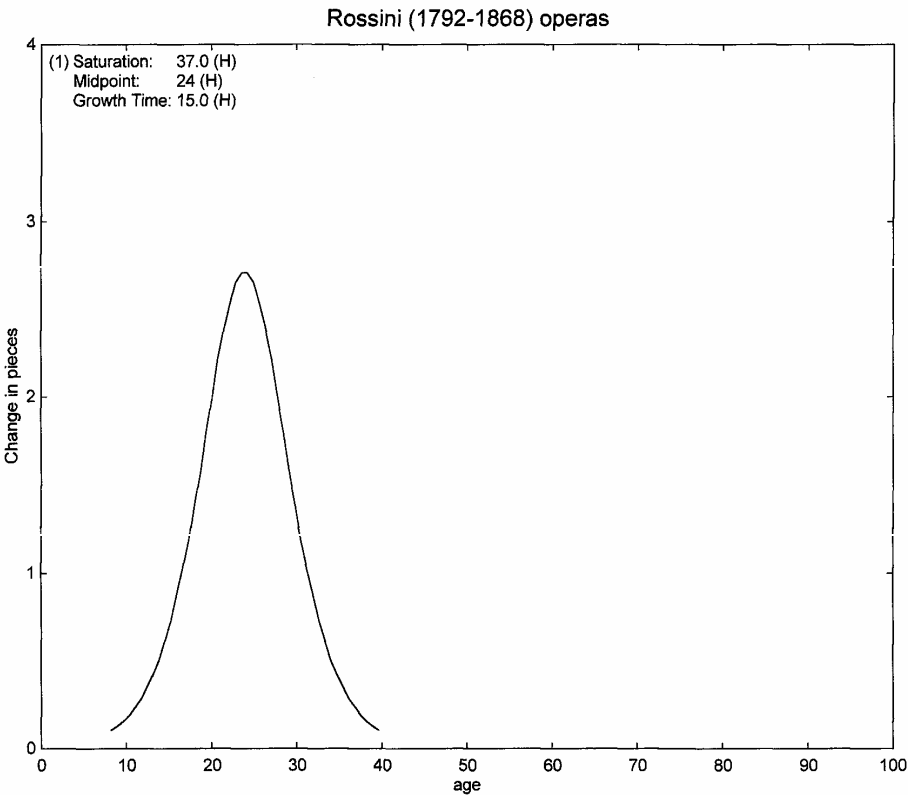


Figure 4.5.3a

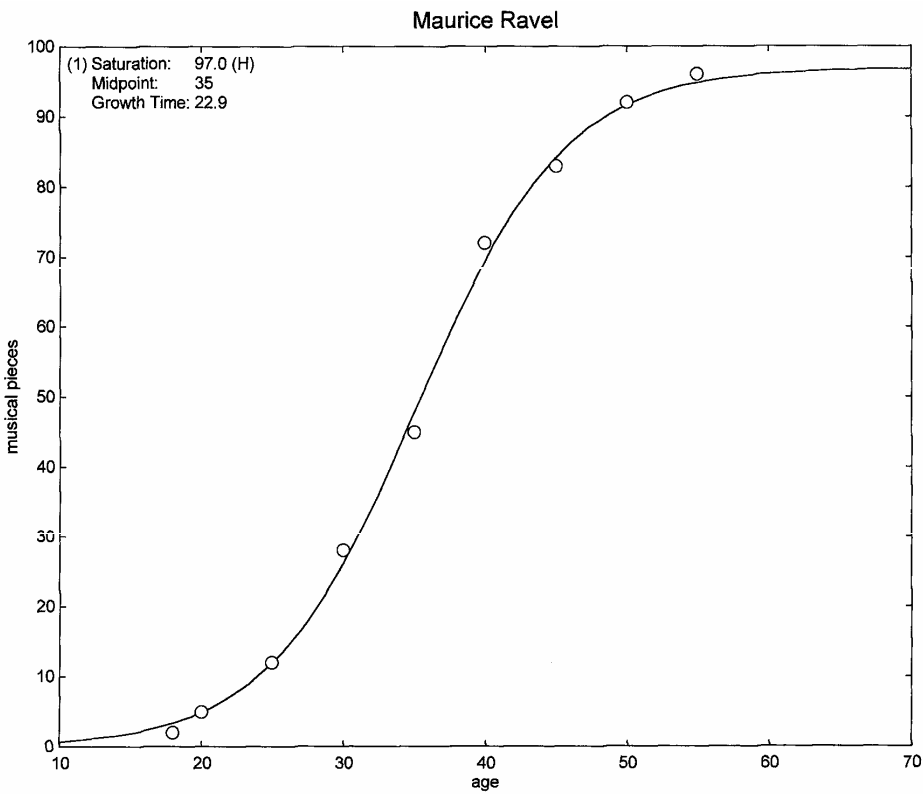


Figure 4.5.3b

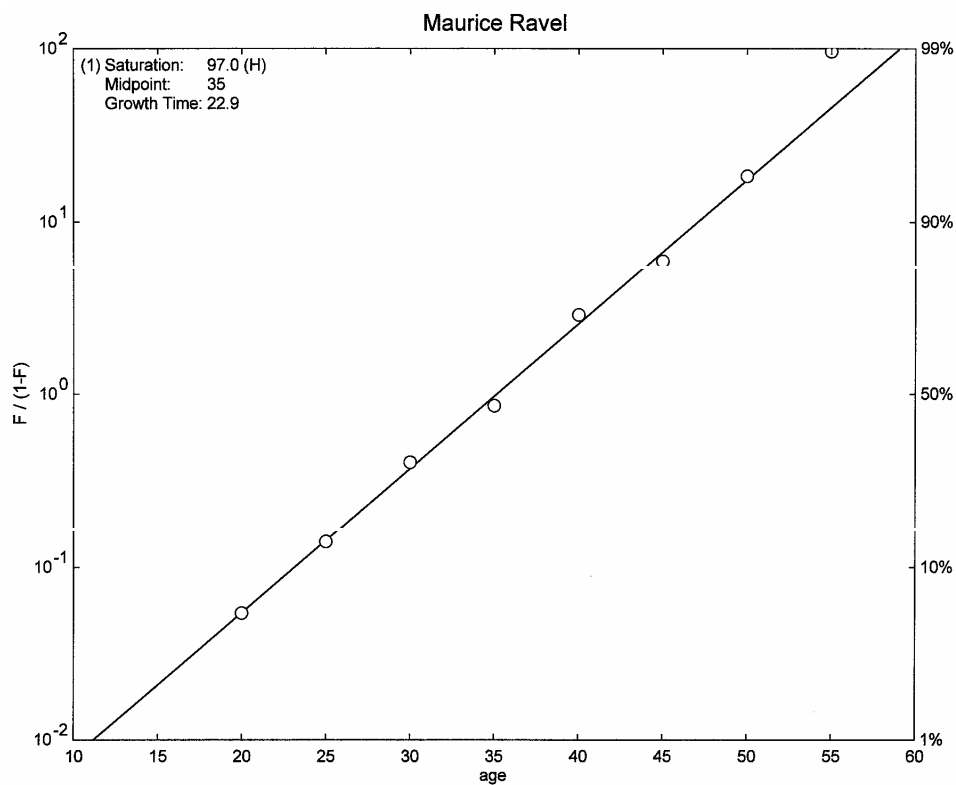


Figure 4.5.3c

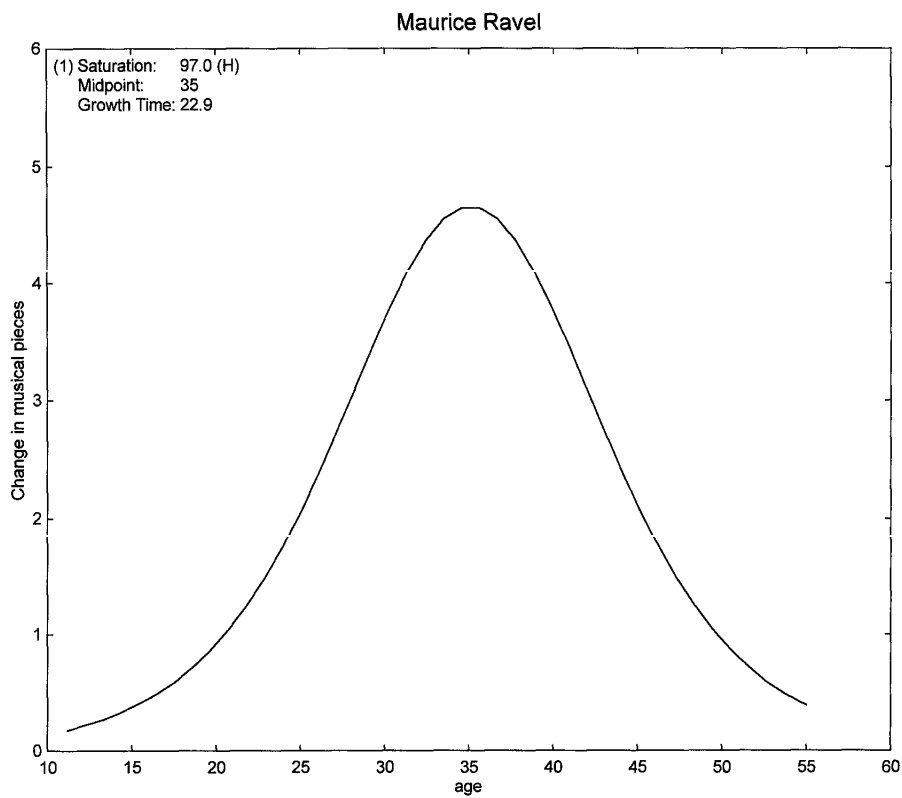


Figure 4.5.4a

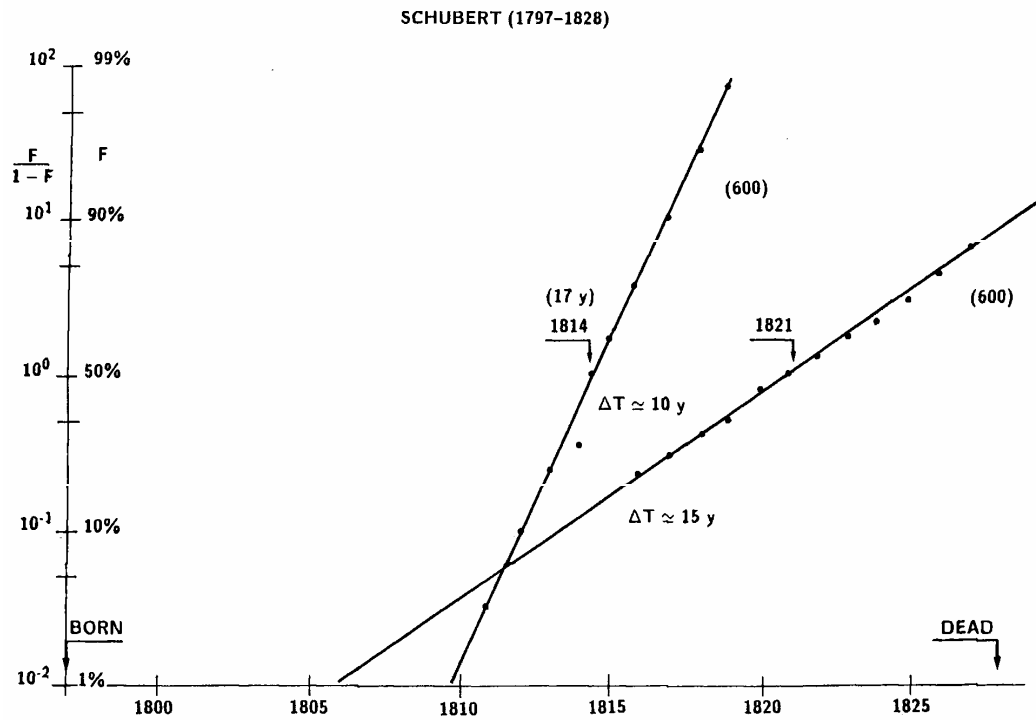


Figure 4.5.4b

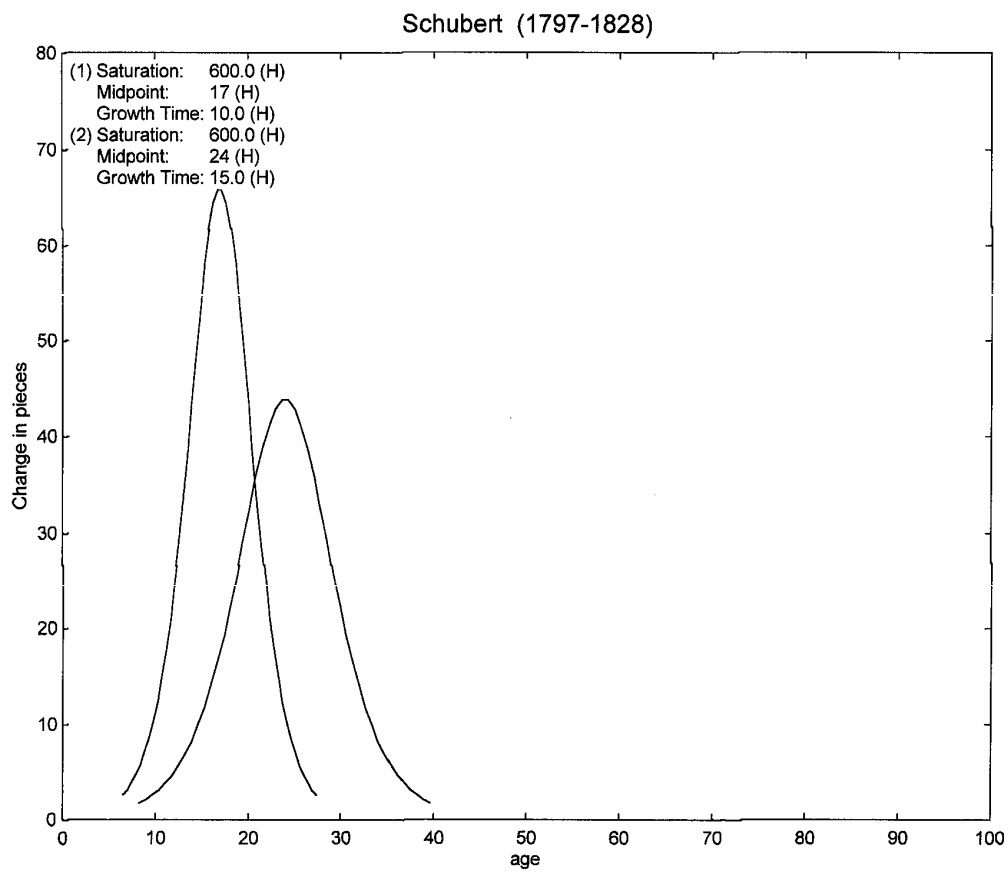


Figure 4.5.5a

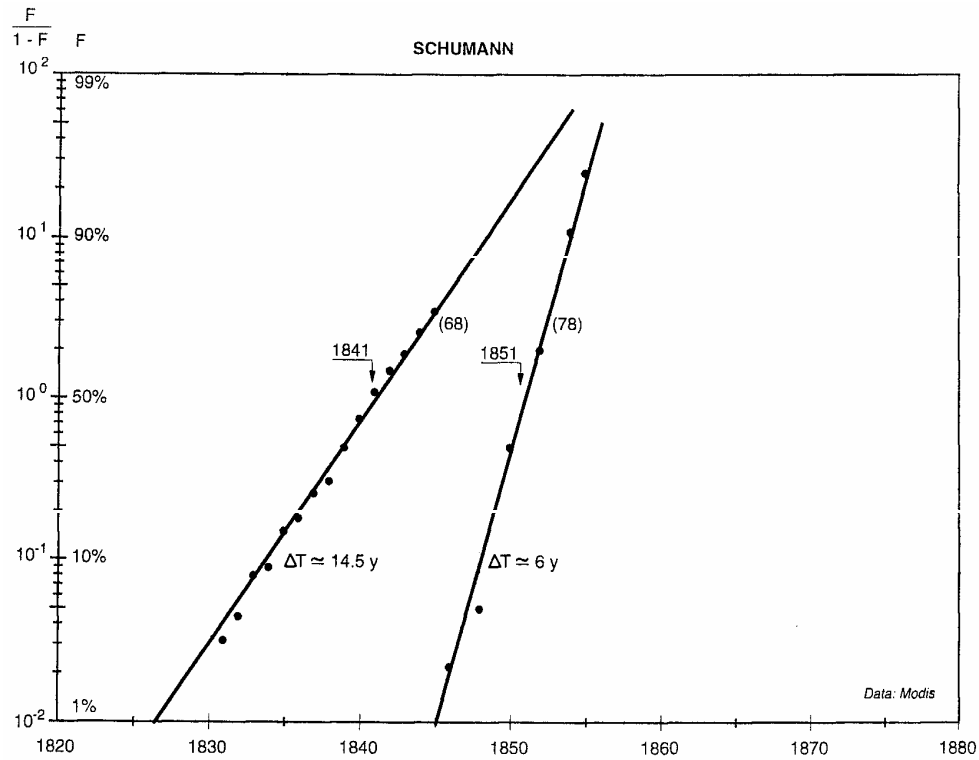


Figure 4.5.5b

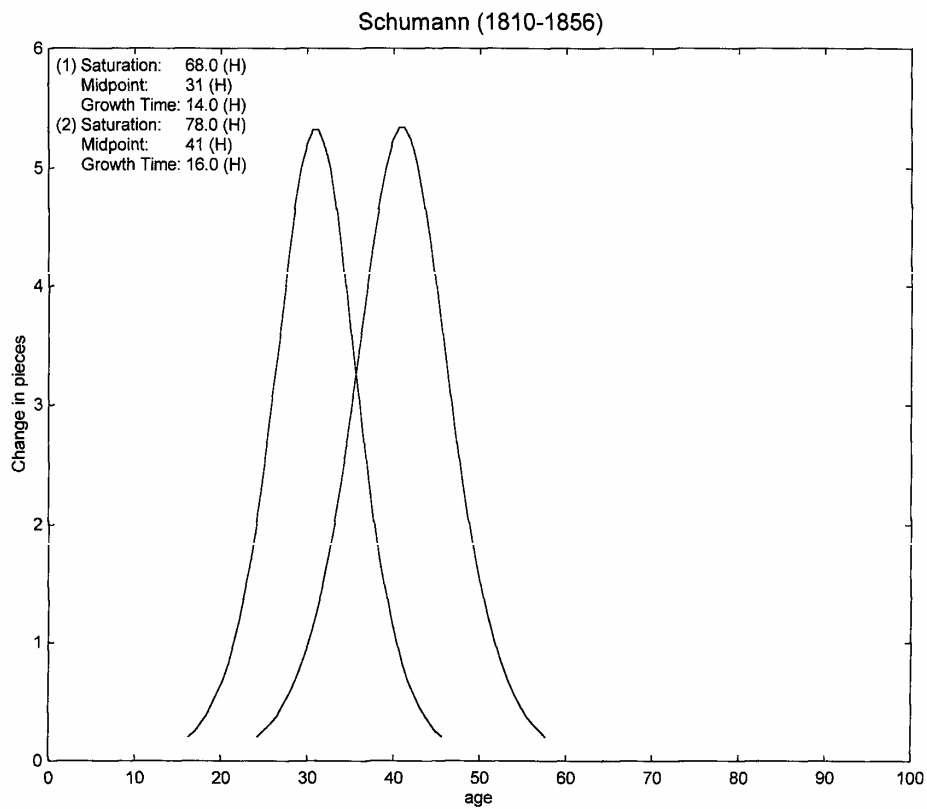


Figure 4.5.6a

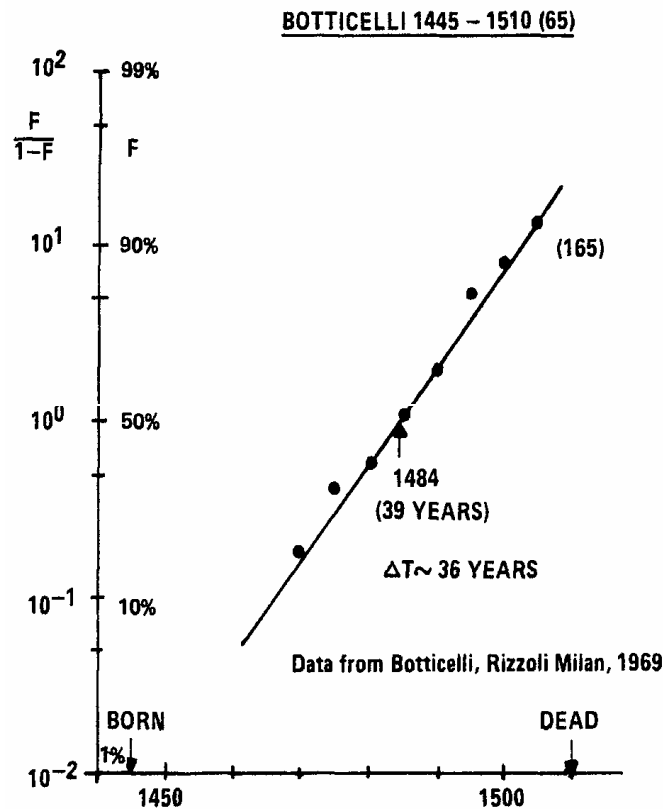


Figure 4.5.6b

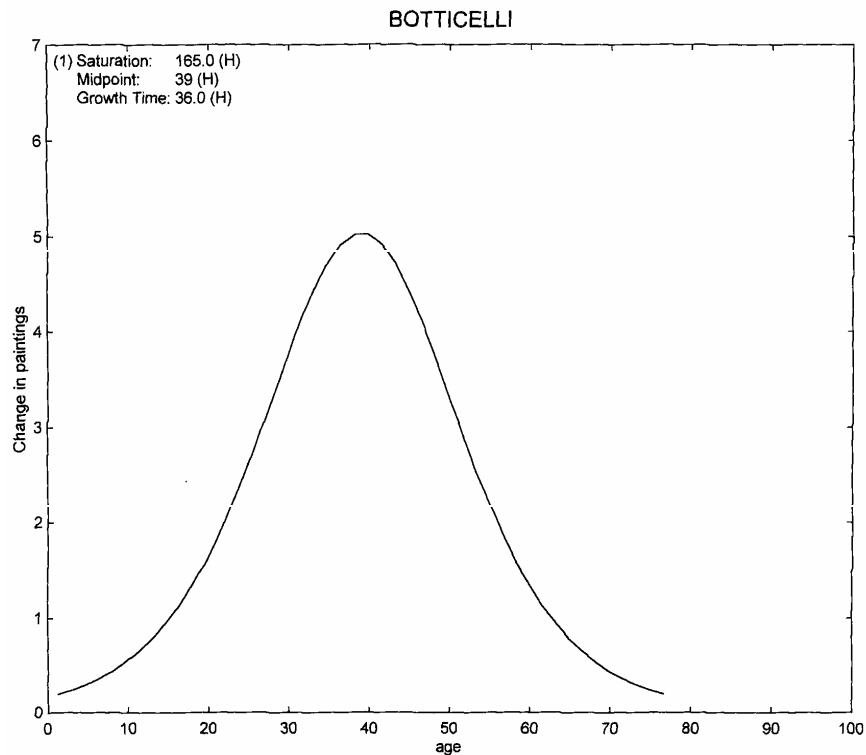


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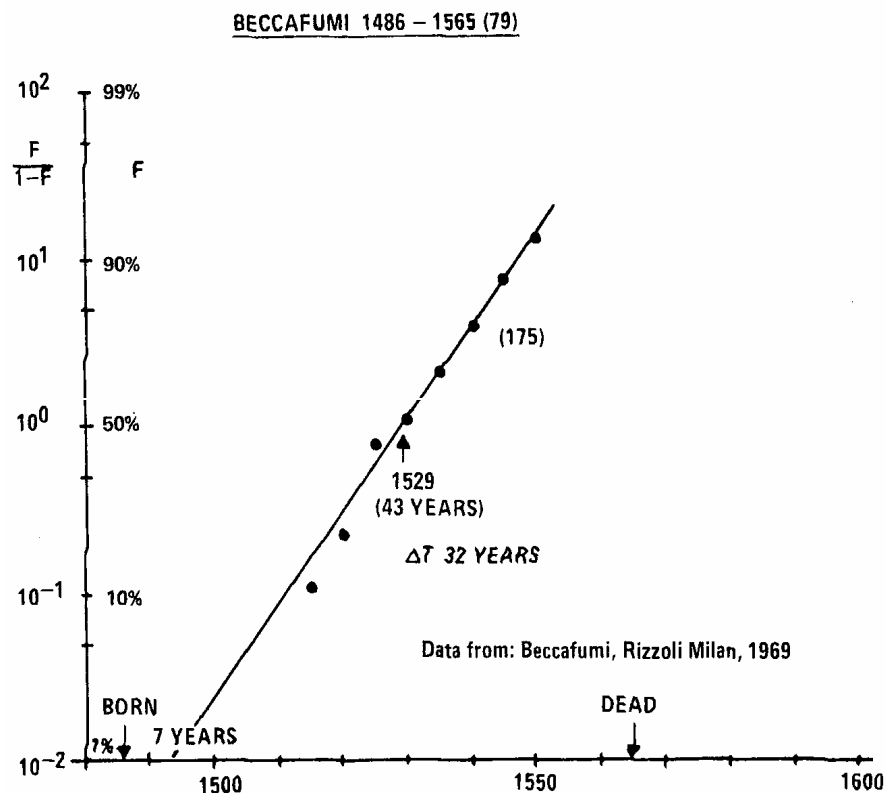


Figure 4.5.7b

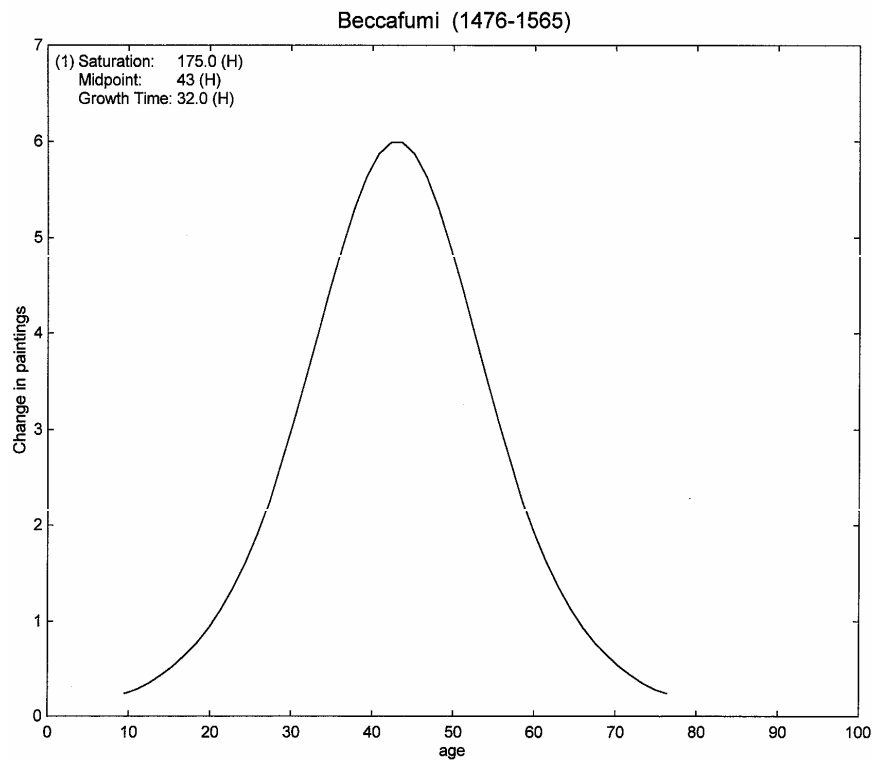


Figure 4.5.8a

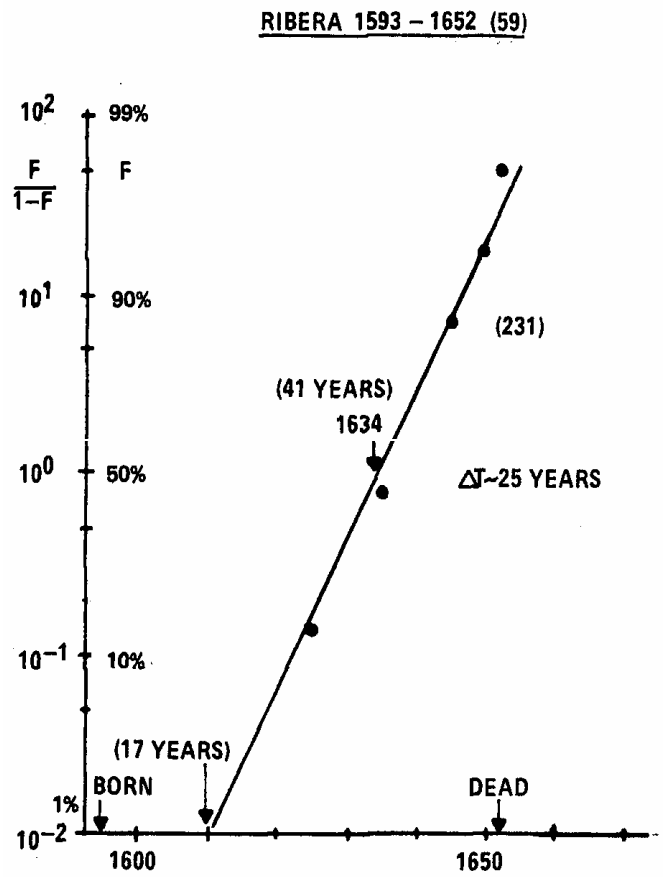


Figure 4.5.8b

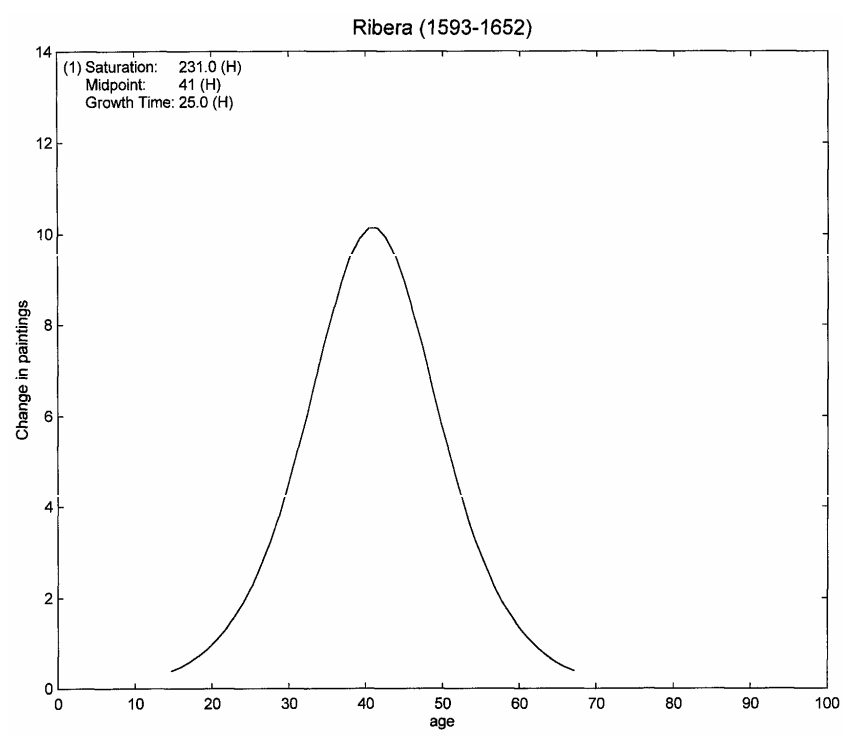


Figure 4.5.9a

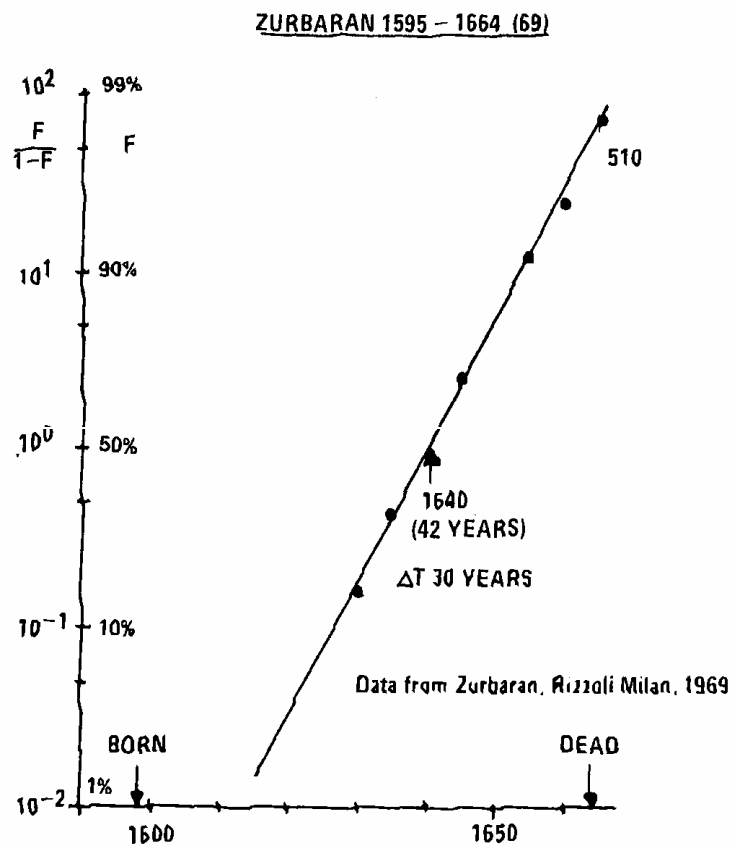


Figure 4.5.9b

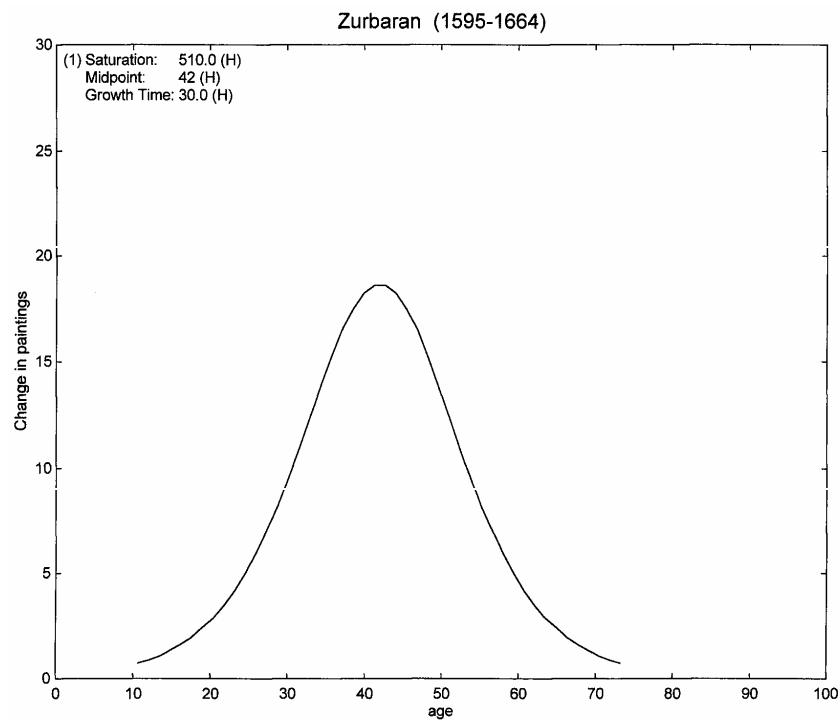


Figure 4.5.10a

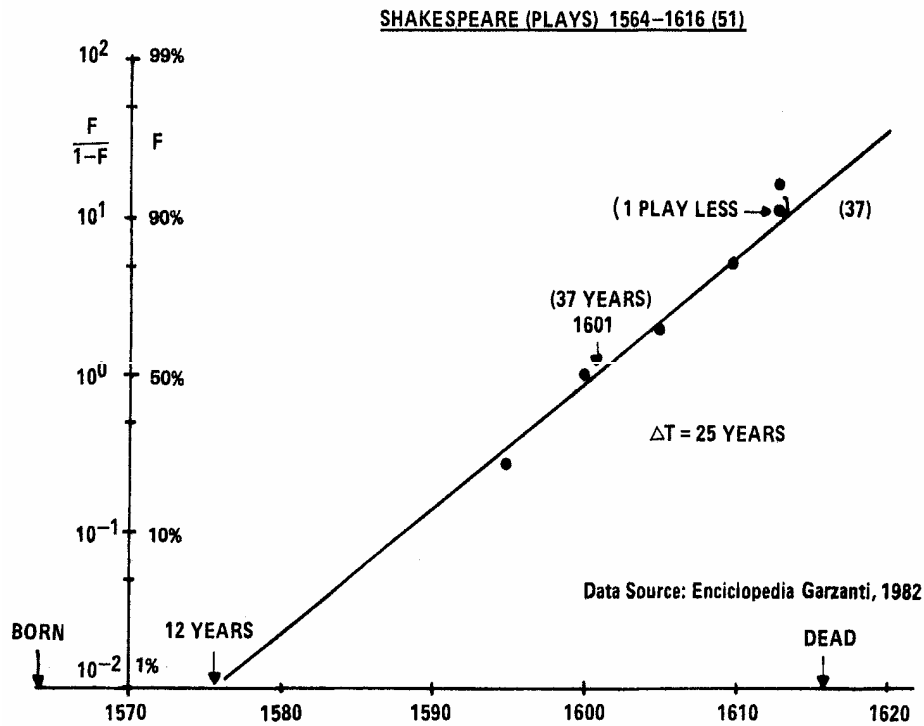


Figure 4.5.10b

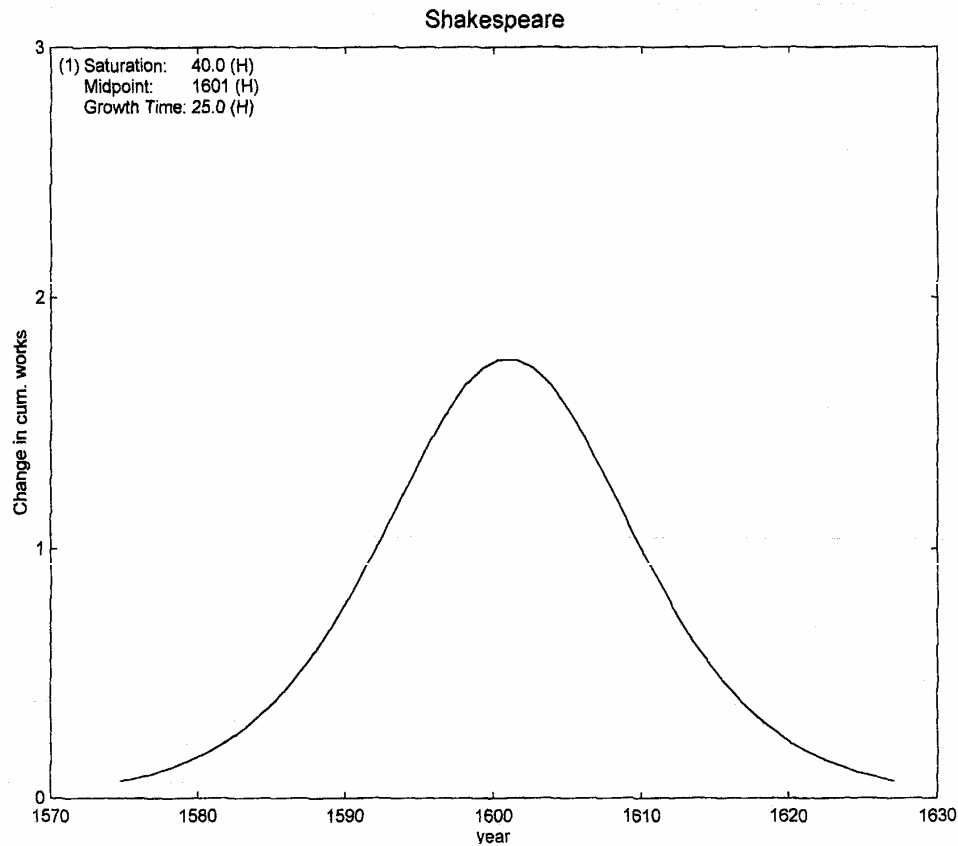


Figure 4.5.11a

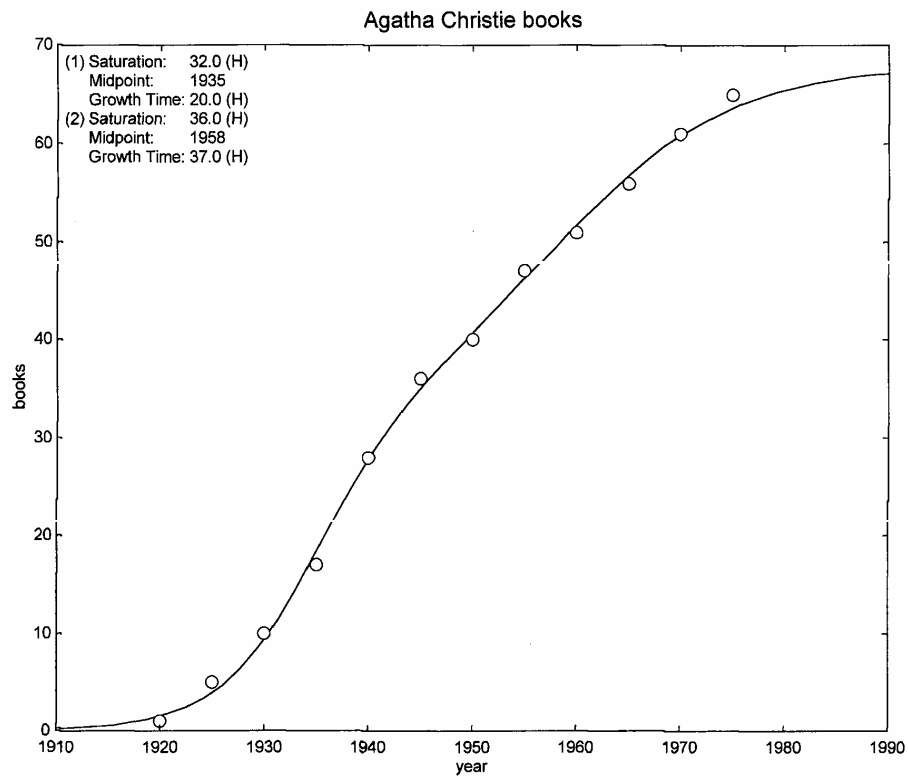


Figure 4.5.11b

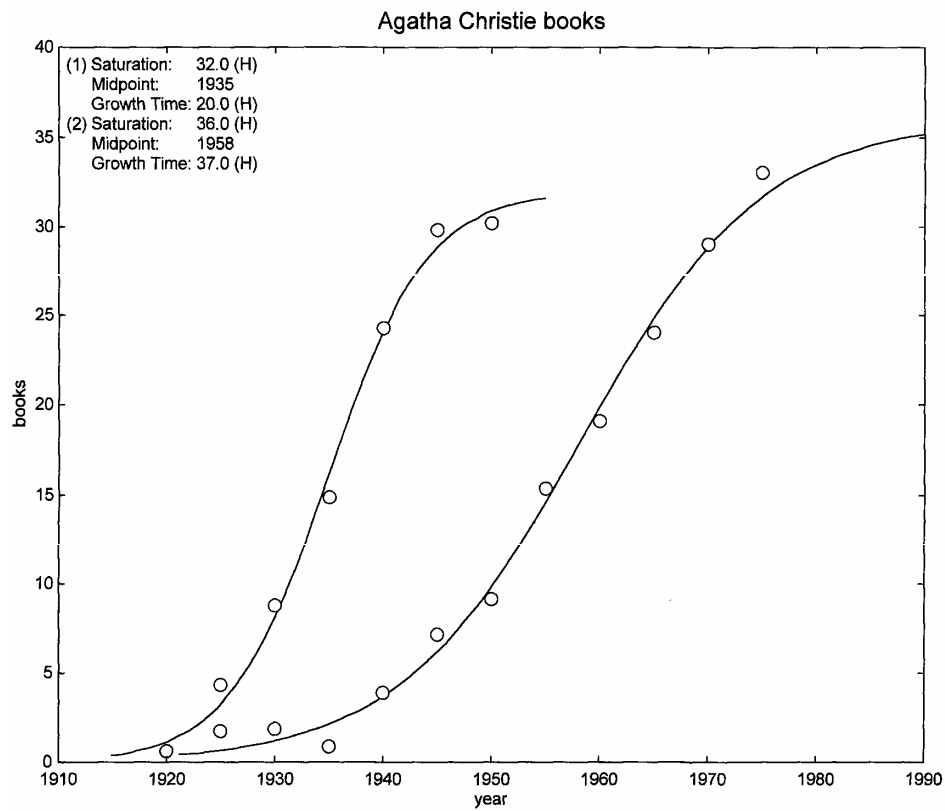


Figure 4.5.11c

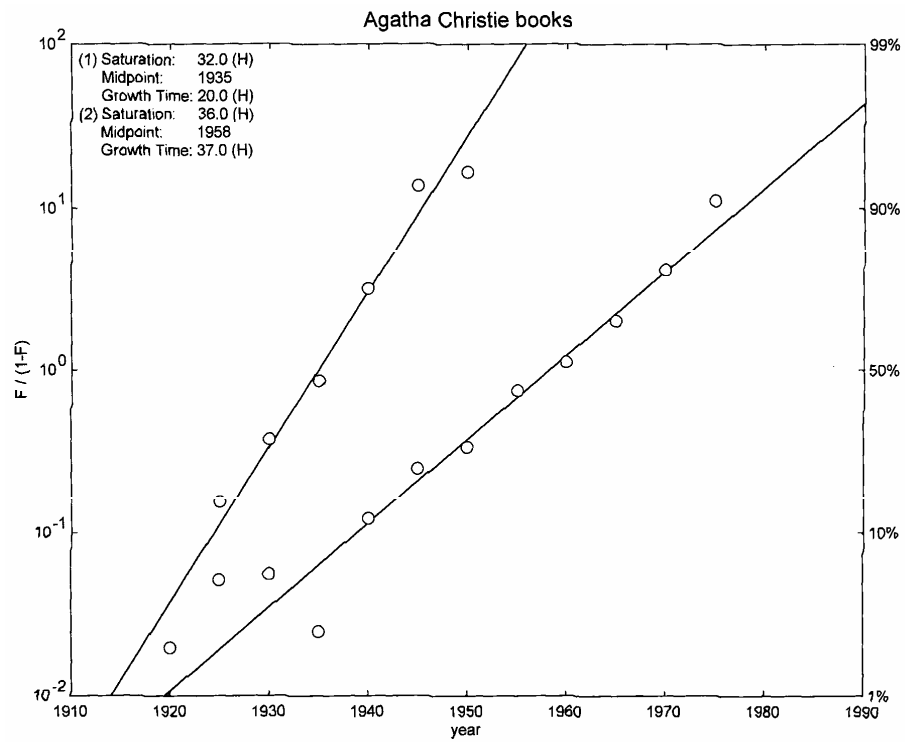
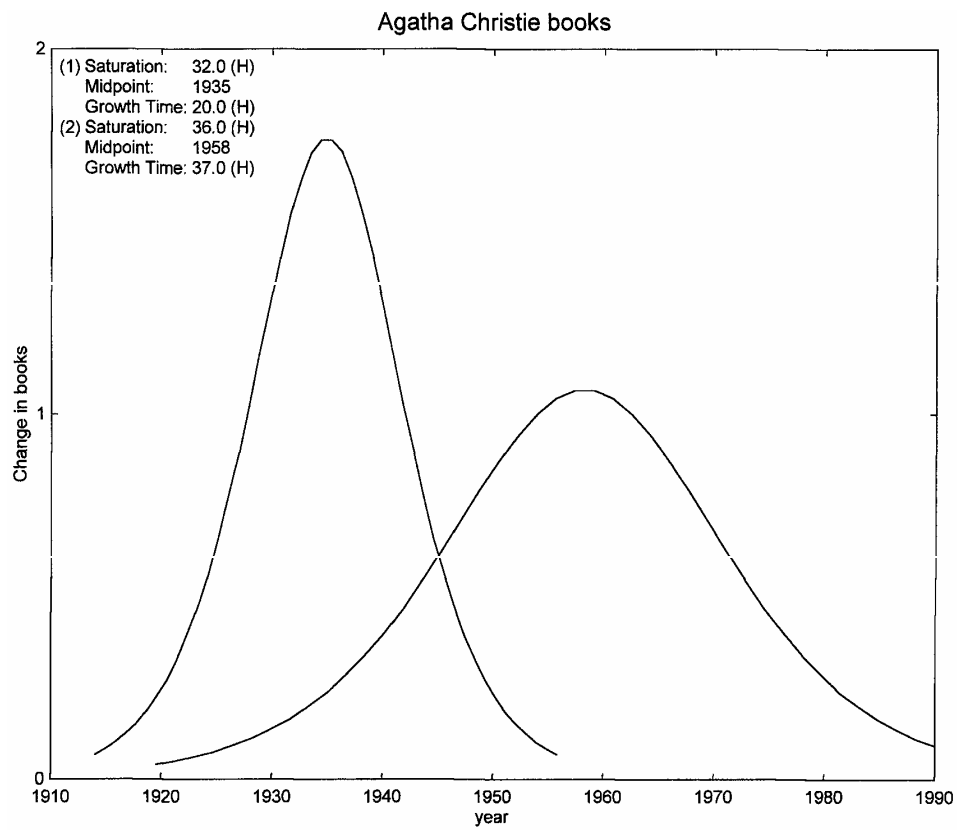


Figure 4.5.11d



5. Age extension and late productivity: The problem of externally stimulated “action pulses”

Our analysis, conducted on hundreds of individuals, makes it unavoidable to think that the rate of productivity as a function of age depends more on internal clocks providing a sequence of “action pulses” than on the general health and energetic condition of an individual. We think this observation has very important consequences on the way one can approach the productivity problem at higher ages, say above 45 years. The importance comes from the first fact that our productivity-obsessed society is always alert in finding new ways of extracting production from individuals. Not in a sense of slavery—the individuals are usually properly compensated—but as a sort of philosophical imperative. Let us consider for a moment the joy of the administrators of a university if they could rekindle the productivity of a Nobel Prize winner, or keep it at top level for professors of Nobel Prize stature.

The second fact is that in one way or another the life span of individuals may well be prolonged to the 120 years that Gompertz or logistic extrapolations seem to indicate as a natural final limit, if one finds a way to eliminate all the medical stumbling blocks. Centenarians actually tend to be people who during their lifetime were rarely sick, pointing in the direction of a simple formula to become centenarian. On the other hand, aging is not due to wear and tear of the pieces compounding our body, as doctors and journalists often claim. Body maintenance in fact operates at a feverish rate: few molecules in our body last more than a month before being substituted. The loss of punch that comes with age seems to be basically due to a programmed reduction in maintenance. The program is inevitably coded in DNA, and clever DNA manipulators may soon find a way to inhibit that reduction and block the aging process. People will continue to die in one way or another, but with intrinsic mortality basically eliminated, they may last for hundreds of years. The problem from our point of view is that their “action pulse” cycle may well not be rejuvenated, as it sits deep in some part of the limbic brain, and we may face crowds of psychological retirees producing nothing for society and earning nothing in return.

So we may raise a very interesting problem for the present, and a quintessential one for the fairly near future. In the short term, the study of extra-cycle creativity may well demonstrate the social and psychological circumstances that lead to extra pulses. In the case of Verdi, who had a small pulse very late in his life, it seems clear that his publisher, with the help of the librettist, Boito, who aroused interest with splendid librettos, exerted high pressure on him to produce. Verdi was the publisher’s most profitable author, and he did not want this excellent source to dry out. One should not forget pride, for the forthcoming applause and money by the way. Verdi also ran a farm, and anyone in the same situation knows well that money is never enough. Here a formula to perhaps re-start a pulse starts to take shape. Verdi was also in possession of his full creative power, matured and refined, which was made brilliant perhaps by the feeling of an approaching end. This creative power in full swing is obviously an independent variable, but my personal conversations with Nobel Prize winners invariably revealed very nimble and creative minds even if their days of paper production were already over.

6. Reproductivity

When speaking of productivity, one thinks automatically of hand and mind labor that produces something marketable. However, a biologically and socially central production activity is human reproduction. Here we also have a level of actual fertility that grows with age, and then a progressive phase-out toward final sterility. Incidentally, the mathematics describing the actual fertility cycles is the same as for productivity in general, as hinted by the case of J.S. Bach. The logistic model seems to embody a very deep-reaching mechanism.

We can, for example, take the fertility of American women for a given year, say 1990. A logistic equation fits fertility versus age, cumulative, quite well by. It may be a little distorted at the beginning, as among very young women there are various hindrances to produce children. But they catch up. The curve for males matches, as American men are basically monogamous, with a small displacement of the central point due to a tendency for the male to be older when marrying. The fact that the logistics have the same course typical of female fertility shows them as the controlling factor. In the US there is also a longitudinal polygamy, whereby younger wives make up for second and third marriages. Consequently, males have a small second flash, reflecting perhaps the production of children when remarrying, usually with substantially younger women in a higher phase of fertility.

When the two sexes operate in the more liberal polygamic environment of Islamic countries, the central point for women is slightly displaced upward because the actual reproduction period lasts longer as the number of children produced tends to be larger than in the American case. The central point for men is substantially displaced upward above 40 years, as they tend to roam more freely, and are better positioned to control reproduction. They also have a second pulse, presumably when becoming economically established and able to afford very young wives. This behavior is not really linked to race or religion, but to external constraints. Bach produced 18 children, with two wives. He seemed perfectly free in his expression of reproductive power. The fact that he got one equation in spite of two wives points to the fact that he was in control of reproduction.

Reproduction levels are an extremely important factor for the vitality, stability, and future positioning of a society in the game of competition. Europe, from the Atlantic to the Urals, is now set at the mean level of about one child per woman, when a little more than two children are needed to keep a society even. This is leading to a rapid substitution of Europeans with biologically and culturally non-miscible populations from North Africa, with the consequent disappearance of European identity in a few decades. The political shock will be felt worldwide. Our quite abstract analysis of the basic mathematics of basic instincts controlling productivity versus age in the case of reproduction may pave the road toward a solution.

Another link to exploring the psychological or perhaps better psychoanalytical underground comes from an unexpected source, namely soap opera, or more precisely US television serials. A statistical office counts, measures, and records their appearance and structure. A curious situation appears when the apparent ages of the characters in

the plot are evaluated. Their statistical distribution strongly differs from that of the actual population, basically concentrating on a central age bracket. I studied this distribution, and my previous interest in fertility led to an easy comparison: the age distribution, e.g., of the female characters, coincides with their actual fertility curve. One may perhaps hastily conclude that male spectators covet the females for their actual fertility. It must be clear that this does not appear in any theatrical handbook; it is the responsibility of the *metteur en scène* to judge what his customers want, a necessary prerequisite to his success.

A different picture emerges when we analyze male characters. Their age distribution again has the shape of a fertility curve, but it does not coincide with the actual one, which is the same of the women, as mentioned above. The center point is displaced upward to higher ages, as for the “free” J.S. Bach, who had his center point at 45 years. I then examined the case of Islamic men, e.g., in Libya and Egypt, who enjoy much more freedom in their reproductive activity through the institution of polygamy. The hunch was correct: their actual fertility age distribution matches fairly well the age distribution of the male characters in US soap operas.

A curious sideline is that female presence in television comedies has a second small peak, at exactly double the age of the first peak. It obviously represents grandmothers, who are felt to be part of the reproductive process, presumably as natural protectors of the infants.

As far as general research on productivity versus age is concerned, the fact that we find the same pattern in reproduction puts the stress on a limbic nature of the productivity cycle in all cases. The proof, however, is in biological mechanisms that are still to be explored.

7. General questions

As we have seen from numerous examples taken from the most variegated type of human activities, the productivity of a certain individual has a simple pattern over the arch of his life, nicely fitting a simple mathematical equation, and smoothly meshing with other characteristics of the life cycle, such as aging and death. The progress in medicine and especially in general hygiene has increased the life span in the last 100 years, drastically reducing infant mortality, but also suppressing many ailments that truncated life in the past. We may assume that this progress continuing, rich humanity may reach the limits of longevity we can project by fitting present mortality curves with one of our multipurpose logistics. We took the American case at three different points in time, and found a converging extrapolated limit at about 120 years. The connection with the present research is that if the productivity versus age curves stay the same as they are now, we may finally have half the population wandering around staring into emptiness. There is also the menace of genetic engineering bringing natural mortality coefficients to zero or very near to this particular privilege that, e.g., sturgeons seem to enjoy. Producing nothing is against our Western instinct, but not against any law of nature. Nor is there an a priori obligation to produce: monkeys that live on the fruits of the forest trees just pick them according to their needs. The progressive automation of the processes of production and distribution may at the limit not need any human labor. The only exception may be the expression of wishes. But robots may one day even be able to read our minds.

Scrolling through our analysis of hundreds of personal cases of productivity versus age, our central result for intellectual professions is a productivity equation fitting the life span. An observation that may become of extraordinary importance, at least philosophically, is that these equations seem never to be truncated by the sudden death of the individual, e.g., due to an accident. We explicitly searched for important people who died in uncontrollable accidents, e.g., the physicist Bhabha, who died in an air crash, and found that, if only for the very limited sample we could collect, they were at the end of the equation when death came. Our question is then when manipulating longevity, does the productivity equation re-adjust or should we with external manipulation reactivate the flow of action pulses? The problem is certainly long-term, but the short-term issue is how to reactivate the flow of “action pulses” in aging individuals that keep popping up for the reasons just said.

We had the feeling that Verdi was one of the guys reactivated by the external pressure of his admirers and peers. However, a precise quantitative analysis of his work shows a regular second little wave of activity for the last part of his life. Double waves often appear in the turbulent careers, e.g., of movie artists. We are not sure, however, that they represent a real physical feature or just the mathematical fine adjustment for an otherwise wobbly, if decent, logistic fit. We might be dealing with what astronomers called perturbations giving them the dignity of orbits. The concept of one man one logistic seems formally most attractive, also in view of the precise multiple meshing of the social system that logistic analysis unveils.

As the case of Verdi clearly shows, creativity and productivity can be mismatched. External pulse or not, Verdi’s creativity in his eighties was top-class, reaching new levels of technical quality, vision, and imagination. The case is by far not unique, and the top Italian gerontologist F. Antonini, in his book on the creativity of very old painters, sustains the thesis that the freedom and experience that old age brings automatically spurs creativity to its best. These old painters in fact produced the innovations that would carry fruit later in the following generation or even in the second one, as academia always act as an inhibitor. In a way hints of jazz can be found in Bach: his imagination made them, his aesthetic filters approved them, only the times were not mature enough for them.

On the subject of music, Antonini quotes a number of old men producing musical works of spectacular beauty: Verdi created *Othello* when he was 74 and *Falstaff* at 80, Claudio Monteverdi wrote his masterpiece, *L’incoronazione di Poppea*, when he was 75, Igor Stravinski wrote the choral to the death of Martin Luther King when he was 85. Many musicians that did not reach old age, such as Bach, Beethoven, and Brahms, produced profound and revolutionary pieces before their death, such as the “art of the fugue” when Bach was almost blind, or Beethoven’s quartets when he was deaf, producing dematerialized and transcendent music, so to speak.

8. General bibliography

- Amabile, T.M., 1988, A Model of Creativity and Innovation in Organizations, in B.M. Staw, and L. L. Cummings (eds.), *Research in Organizational Behavior*, JAI Press, Greenwich, US.
- Andrews, F.M., (ed.), 1979a, *Scientific Productivity. The Effectiveness of Research Groups in Six Countries*, Cambridge University Press/UNESCO, Cambridge/Paris.
- Andrews, F.M., 1979b, The International Study: its data sources and measurement procedures, in F.M. Andrews (ed.), *Scientific Productivity. The Effectiveness of Research Groups in Six Countries*, pp. 17–52, Cambridge University Press/UNESCO, Cambridge/Paris.
- Andrews, F.M., 1979c, Motivation, diversity, and the performance of research units, in F.M. Andrews (ed.), *Scientific Productivity. The Effectiveness of Research Groups in Six Countries*, pp. 253–289, Cambridge University Press/UNESCO, Cambridge/Paris.
- Antonini, F., and Magnolfi, S., 1991, *L'età dei capolavori (The age of masterpieces)*, Venezia, Marsilio, ed.
- Bass, S.A., 1994, *Productive aging and the role of older people in Japan: New approaches for the United States*, International Leadership Center on Longevity and Society, New York, US.
- Bass, S.A., Caro, F.G., and Chen, Y.-P., eds., 1993, *Achieving a Productive Aging Society*, Westport, CT, US, and Auburn House, London, UK.
- Becher, T., 1989, *Academic Tribes and Territories: Intellectual Enquiry and the Cultures of Disciplines*, SRHE/Open University Press, Buckingham, UK.
- Berger, P.L., and Luckmann T., 1966, *The Social Construction of Reality. A Treatise in the Sociology of Knowledge*, Doubleday, New York, US.
- Brotherhood, J.R., Budd, G.M., Hendrie, A.L., Jeffery, S.E., and Beasley, F.A., 1997, Project Aquarius 11: Effects of fitness, fatness, body size, and age on the energy expenditure, strain, and productivity of men suppressing wildland fires, *International Journal of Wildland Fire*, 7(2):181–199.
- Buchholz, K., 1995, Criteria for the analysis of scientific quality , *Scientometrics*, 32(2):195–218.
- Burnham, J.C., 1992, How Journal Editors Came to Develop and Critique Peer Review Procedures, in H. F. Mayland and R. E. Sojka, *Research Ethics, Manuscript Review and Journal Quality*, ACS Miscellaneous Publications, Madison, US.
- Butler, R.N., and Gleason, H.P., 1985, *Productive Aging: Enhancing Vitality in Later Life*, Springer Publishing Company, Berlin, Heidelberg, New York.
- Cohen, J.E., 1991, Size, age and productivity of scientific and technical research groups, *Scientometrics*, 20:395–416.
- Cole, S., Cole, J.R., and Simon, G.A., 1981, Chance and consensus in peer review, *Science*, 214:881–886.

- Colonia-Willner, R., 1998, Practical intelligence at work: Relationship between aging and cognitive efficiency among managers in a bank environment, *Psychology and Aging*, 13(1):45–57.
- Colonia-Willner, R., 1999, Investing in practical intelligence: Ageing and cognitive efficiency among executives, *International Journal of Behavioral Development*, 23(3):591–614.
- Creswell, J.W., 1985, *Faculty Research Performance: Lessons from the Sciences and the Social Sciences*, ASHE-ERIC Higher Education Reports, No. 4.
- Crozier, W.R., 1999, Age and individual differences in artistic productivity: Trends within a sample of British novelists, *Creativity Research Journal*, 12(3):197–204.
- David, G., and Patterson, G., 1997, Productive aging: 1995 White House Conference on Aging, challenges for public policy and social work practice, *Journal of Gerontological Social Work*, 27(3):9–25.
- Doherty, G., 1994, Can we have a unified theory of quality? *Higher Education Quarterly*, 48(4):240–255.
- Finlayson, M., 1997, The paths to productive aging, *Canadian Journal of Aging*, 16(1):160–163.
- Fox, M.F., 1983, Publication productivity among scientists: a critical review, *Social Studies of Science*, 13:285–305.
- Fox, M.F., 1992, Research productivity and the environmental context, in T.G. Whiston, and R. L. Geiger (eds.), *Research and Higher Education. The United Kingdom and the United States*, pp. 103–111, SRHE/Open University Press, Buckingham, UK.
- Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott P., and Trow M., 1994, *The New Production of Knowledge. The Dynamics of Science and Research in Contemporary Societies*. Sage Publications, London, UK.
- Gilbert, G.N. and Mulkay M., 1984, *Opening Pandora's box. A Sociological Analysis of Scientists' Discourse*. Cambridge University Press, Cambridge, UK.
- Glass, T.A., Seeman, T.E., Herzog, A.R., Kahn, R., and Berkman, L.F., 1995, Change in productive activity in late adulthood: Macarthur studies of successful aging, *Journals of Gerontology Series B – Psychological Sciences and Social Sciences*, 50(2):65–76.
- Griffiths, A., 1997, Ageing, health and productivity: A challenge for the new millennium, *Work and Stress*, 11(3):197–214.
- de Haan, J., Leeuw, F.L., and Remery C., 1994, Accumulation of advantage and disadvantage in research groups, *Scientometrics*, 29:239–251.
- Hargens, L.L., 1978, Relations between work habits, research technologies, and eminence in science, *Sociology of Work and Occupations*, 5:97–112.
- Harris, G., and Kaine, G., 1994, The determinants of research performance: A study of Australian university economists, *Higher Education*, 27:191–201.

- Helson, R., 1998, Ego identity and trajectories of productivity in women with creative potential, in *Creativity and Successful Aging: Theoretical and Empirical Approaches*, C.E. Adams-Price (ed.), Springer Publishing Company, New York, US.
- Hemlin, S., 1991b, Scientific Quality in the Eyes of the Scientist: A Questionnaire Study, *Göteborg Psychological Reports*, 21(3). (Også 1993 i *Scientometrics* 27:3–18).
- de Hemptienne, Y., and Andrews, F. M., 1979, The International Comparative Study on the Organization and Performance of Research Units: an overview, in F.M. Andrews (ed.), *Scientific Productivity. The Effectiveness of Research Groups in Six Countries*, pp. 3–15, Cambridge University Press/Unesco Cambridge/Paris.
- Herzog, A.R., and Morgan, J.N., 1992, Age and gender differences in the value of productive activities: Four different approaches, *Research on Aging*, 14(2):169–198.
- Hughes, T., 1987, The Evolution of Large Technological Systems, in W.E. Bijker, T.P. Hughes, and T. Pinch, 1987: *The Social Construction of Technological Systems. New Directions in the Sociology and History of Technology*, pp. 51–82, The MIT Press, Cambridge, Massachusetts, US.
- Jones, O., and Sullivan, T., 1994, Establishing the determinants of internal reputation: the case of R&D scientists, *R&D Management*, 24:325–339.
- Katz, R., and Allen, T.J., 1982, Investigating the Not Invented Here (NIH) Syndrome: a look at the performance, tenure, and communication patterns of 50 R&D project groups, *R&D Management*, 12:7–19.
- Kotlikoff, L.J., and Gokhale, J., 1992, Estimating a Firm's Age: Productivity profile using the present value of workers earnings, *Quarterly Journal of Economics*, 107(4):1215–1242.
- Kuhn, T.S., 1977, Second Thoughts on Paradigms, in T.S. Kuhn, *The Essential Tension. Selected Studies in Scientific Tradition and Change*, pp. 293–319, The University of Chicago Press, Chicago/London.
- Kumashiro, M., 1999, Strategy and actions for achieving productive aging in Japan, *Experimental Aging Research*, 25(4):461–470.
- Kumashiro, M., ed., 1995, *Paths to Productive Aging*, Taylor & Francis, London, UK.
- Levi, L., 1978, *Society, Stress and Disease, Vol. 3: The Productive and Reproductive Male-Female Roles and Relationships*, Oxford University Press, Oxford, UK.
- Lindsey, D., 1989, Using citation counts as a measure of quality in science: Measuring what's measurable rather than what's valid, *Scientometrics*, 15(3/4):189–203.
- Mani, B.G., 1996, Measuring productivity in federal agencies: Does total quality management make a difference, *American Review of Public Administration*, 26(1):19–39.
- Marchetti, C., 1998, Notes on the Limits to Knowledge explored with Darwinian Logic, *Complexity*, 3(3):22–35.

- Marquis, D.G., 1988, The Anatomy of Successful Innovations, in M.L Tushman, and W. L. Moore (eds.), Readings in the Management of Innovation, pp. 79–87, HarperBusiness, New York, US.
- Mazuzan, G.T., 1992, Good science gets funded ... The historical evolution of grant making at the national science foundation, *Knowledge*, 14:63–90.
- Merton, R.K., 1973 [1968], The Matthew Effect in Science, reprinted in *The Sociology of Science: Theoretical and Empirical Investigations*, pp. 439–459, The University of Chicago Press Chicago/London.
- Mittermeir, R., and Knorr, K., 1979, Scientific productivity and accumulative advantage: a thesis reassessed in the light of international data, *R&D Management*, 9:235–239.
- Muller, C.F., 1994, Senior scientists and engineers: A study in productive aging, Final Report, International Leadership Center on Longevity and Society, New York, US.
- Nagpaul, P.S., 1995, Quasi-quantitative measures of research performance: an assessment of construct validity and reliability, *Scientometrics*, 33:169–185.
- Narin, F., 1976, *Evaluative Bibliometrics: The Use of Publication and Citation Analysis in the Evaluation of Scientific Activity*, National Science Foundation Washington, US.
- O'Reilly, P., and Caro, F.G., 1994, Productive aging: An overview of the literature, *Journal of Aging & Social Policy*, 6(3):39–71.
- Oster, S.M., and Hamermesh, D.S., 1998, Aging and productivity among economists, *Review of Economics and Statistics*, 80(1):154–156.
- Pelz, D.C., 1976, Problem solvers vs. decision makers, in D.C Pelz, and F.M. Andrews, (eds.), 1976, *Scientists in Organizations. Productive Climates for Research and Development*, Revised Edition, pp. 321–336, Institute for Social Research, The University of Michigan, Michigan, US.
- Prasad, P.L.S., and Reddy, I.V.R., 1995, Impact of age and experience on supervisory efficiency, *Indian Journal of Social Work*, 56(4):457–465.
- Price, D. J. de S., 1963, *Little Science, Big Science*, Columbia University Press, New York, US.
- Price, D. J. de S., 1965, Networks of scientific papers, *Science*, 149:510–515.
- Reitan, B., 1996, Creativity and Innovation in Research Groups – a Literature Review, Swedish Council for Building Research, Scientific Advisory Board, BVN 1996:3, Stockholm, Sweden.
- Romanov, A.K., and Terekhov, A.I., 1997, The mathematical model of productivity- and age-structured scientific community evolution, *Scientometrics*, 39(1):3–17.
- Rubenstein, E.S., 2000, A golden age of productivity, *Forbes*, 165(11):80.
- Sasaki, H., Sekizawa, K., Yanai, M., Arai, H., Yamaya, M., and Ohrui, T., 1996, Will aging of the population make Japan less productive, *Journal of the American Geriatrics Society*, 44(8):1013–1014.

- Seglen, P., 1992, The skewness of science, *Journal of the American Society for the Information Science*, 43:628–638.
- Seglen, P., 1996, Quantification of scientific article contents, *Scientometrics*, 35:355–366.
- Shepard, R.J., 2000, Aging and productivity: Some physiological issues, *International Journal of Industrial Ergonomics*, 25(5):535–545.
- Simon, R.J., 1974, The work habits of eminent scientists, *Sociology of Work and Occupations*, 1:327–335.
- Sonnert, G., 1995, What makes a good scientist? Determinants of peer evaluation among biologists, *Social Studies of Science*, 25:35–55.
- Spangenberg, J.F.A., Starmans, R., Bally, Y.W., Breemhaar, B., Nijhuis, F.J.N. and van Dorp, C.A.F., 1990, Prediction of scientific performance in clinical medicine, *Research Policy*, 19:239–255.
- Stankiewicz, R., 1979, The size and age of Swedish academic research groups and their scientific performance, In F.M. Andrews (ed.): *Scientific Productivity. The Effectiveness of Research Groups in Six Countries*, pp. 191–222, Cambridge University Press/Unesco, Cambridge/Paris.
- The Generational Contract: Growth & Productivity in an Aging Society 1988, Edited Conference Proceedings, Americans for Generational Equity.
- Travis, G.D.L., and Collins, H.M., 1991, New light on old boys: Cognitive and institutional particularism in the peer review system, *Science, Technology & Human Values*, 16:322–341.
- von Hippel, E., 1986, Lead users: a source of novel product concepts, *Management Science*, 32.
- Zettermeyer, F., and Hauser, J.R., 1995, Metrics to Evaluate R&D Groups. Phase I: Qualitative Interviews, MIT: International Center for Research on the Management of Technology, Working Paper #125–95.
- Ziman, J., 1994, *Prometheus Bound: Science in a Dynamic Steady State*, Cambridge University Press, Cambridge, UK.
- Zuckerman, H., 1977, *Scientific Elite. Nobel Laureates in the United States*, The Free Press, New York, US.
- Zuckerman, H., and Cole, J.R., 1994, Research strategies in science: a preliminary inquiry, *Creativity Research Journal*, 7:391–405.
- Zuckerman, H., and Merton, R.K., 1971, Patterns of evaluation in science: institutionalisation, structure and functions of the referee system, *Minerva*, 9:66–100.
- Zuckerman, H., and Merton, R.K. 1972, Age, Aging and Age Structure in Science, in M. W. Riley, M. Johnson, and A. Foner (eds.), *Aging and Society – Volume Three: A Sociology of Age Stratification*, Russel Sage Foundation, New York, US. Reprinted in Merton, R.K., 1973, *The Sociology of Science: Theoretical and Empirical Investigations*, pp. 497–575, The University of Chicago Press, Chicago/London.