Chapter 4. Longitudinal Changes in Creativity

One of the oldest research topics in psychological science is the relation between age and achievement, so it is reasonable to ask about the nature of this relation for great psychologists. I specifically examine the typical career trajectory in output, discuss the relation between quantity and quality of output, and look at how the age curve varies according to the type of contribution. I then integrate these results with those of the previous chapter by presenting a cognitive model of individual differences in career development.

Cattell's (1906) ratings: Thorndike vs. Dewey

Hence,

1. How is a great psychologist's influence on the field distributed over the course of his or her career?
2. At what age do great psychologists begin making major contributions to the discipline?
3. When is their impact most likely to reach a maximum?
4. For how long do great psychologists usually dominate their discipline?
5. At what age do the great psychologists typically cease to be a major force in the development of psychology?

AGE AND ACHIEVEMENT

- "When the age is in, the wit is out," said a character in Shakespeare's *Much Ado About Nothing*.
- According to Oliver Wendell Holmes, Jr., "if you haven't cut your name on the door of fame by the time you've reached 40, you might just as well put up your jackknife" (quoted in Lehman, 1953a, pp. 185-186). According to Albert Einstein, "a person who has not yet made his great contribution to science before the age of thirty will never do so" (quoted in Brodetsky, 1942, p. 699).
- Paul Dirac, a fellow theoretical physicist, put this idea in an even more dramatic form:
  Age is, of course, a fever chill
  that every physicist must fear.
  He's better dead than living still
  when once he's past his thirtieth year.
  (quoted in Jungk, 1958, p. 27)
- Robert S. Woodworth's 1921 *Psychology: A Study of Mental Life*, "seldom does a very old person get outside the limits of his previous habits. Few great inventions, artistic or practical, have emanated from really old persons, and comparatively few even from the middle-aged. On the other hand, boys and girls under eighteen seldom produce anything of great value, not having as yet acquired the necessary mastery of the materials with which they have to deal. The period from twenty years up to forty seems to be the most favorable for inventiveness" (Woodworth, 1921, p. 519).

How justified are these views? An impressive repertory of empirical and theoretical findings deals with three topics:

1. the usual age function describing the relation between age and output,
2. the variation in this typical trajectory as a function of the type of contribution, and
3. the longitudinal association between quantity and quality of output.

Typical Career Trajectory

Pioneer Investigations:

Adolphe Quételet's 835 *A Treatise on Man and the Development of His Faculties* (*Sur l'homme et le développement de ses facultés)*.

George Miller Beard (1874)

Classic Investigation: Harvey C. Lehman's 1953 book *Age and Achievement*.

E.g., chapter 3 age and achievement in philosophy:

A clear, single-peaked function emerged, with the maximum in the 35-39 age period. The median age for producing a philosophical masterwork was 39.6, and the mean 41.5.

Posthumous investigation: Lehman (1966):

- 1,530 important contributions by 1,002 still-living psychologists as listed in the classic introductory text *Experimental Psychology* by Robert S. Woodworth and Harold Schlosberg (1954).
- The peak for making a great contribution to psychology landed once more in the 35-39 age period.
- Furthermore, this career peak holds for both historical and contemporary contributions.

Others since Lehman (1953a, 1966) have more or less replicated this finding (e.g., S. Cole, 1979; Dennis & Girden, 1954). For example, a study of more than 1,000 academic psychologists concluded that "productivity typically began at a low rate in the 20s, increased to a peak around age 40, then decreased in the later years" (Horner, Rushton, & Vernon, 1986, p. 319).

These stats seem to endorse Woodworth's (1921) assertion that the innovative portion of the psychologist's career is basically over by age 40. However, are two reasons why this developmental generalization must be viewed with caution.

1. It always must be remembered that the median and mean of the longitudinal distribution almost invariably falls in the early 40s. That signifies that more than half of a psychologist's career still remains after reaching this supposed life watermark. So, depending on whether one is a pessimist or an optimist, the glass is either half empty or half full by this time.

2. Most important, the age function is only an aggregate result averaged over numerous careers. As all psychologists know, people differ, often greatly – and psychologists are by no means an exception to that rule. In fact, there exists abundant evidence that the career trajectory is moderated by a host of other variables. These influential factors can determine the very shape of the age curve, as well as the location of the peak. It is to these factors that we now must turn.

Quantity and Quality

Lehman's (1953a) *Age and Achievement* provoked considerable controversy and critical reaction centering on the apparently steep age decrement after passing the peak productive period.

- Among psychologists, the most vocal critic was Dennis (1954d, 1956a, 1958).
- Among the most serious was Lehman's frequent failure to control adequately for differential life span. Because fewer individuals live to 80 than live to 60, the number of great contributions by 80-year olds will necessarily be smaller than the number produced by 60-year olds.
- Nonetheless, subsequent investigators have introduced sophisticated methodological controls for this and other sources of artifact, and still obtain an age decrement, even if more gradual than those that Lehman reported (S. Cole, 1979; Dennis, 1966; Simonton, 1977a, 1985b).
- On occasion, this elevation of the post-peak decline sometimes shifts the career optimum, so that the high point appears in the 40-44 interval rather than the 35-39.
- Another of Dennis' (1956a, 1958) criticisms is more problematic: the relation between quantity and quality of output across the course of a career. Lehman's tabulations included only major contributions. This methodological decision underestimated the impact of those who were past their prime. This downward bias would take place for two reasons.
  1. First, because the number of researchers has been growing exponentially in recent times (Price, 1963), the older an investigator gets, the more junior colleagues he or she must compete with. That means that the later works might be less often mentioned in history and introductory texts even if they are of equal quality to the earlier works. This potential artifact can be addressed by introducing the appropriate controls, such as counting the number of potential competitors for attention in a given age period (e.g., Simonton, 1977a). Although this factor seems to have some effect, its impact is relatively modest, and certainly too small to account for the age decrement in any significant way (Simonton, 1988a). One reason why the repercussions are so minimal is that the frequency that contributions are cited has more or less kept pace with the number of available contributors.
  2. Second, it could be that the career trajectory for total output is described by a different longitudinal trend than what holds for high-impact output. Both believed that quantity peaked later and exhibited a more gradual decline than did quality (e.g., Dennis, 1966; Lehman, 1953a). Unfortunately, this agreement was founded on data analyses that had their own methodological flaws. The developmental trends for total output were usually calculated for different samples of individuals than those for quality output only, making direct comparison impossible (Simonton, 1988a).

  What about the equal-odds rule?

The age distribution of success rates.

Quantity positively correlated with quality; ratio of hits to total attempts more or less constant (Oromaner, 1977; Over, 1989; Quételet, 1835/1968; Simonton, 1977a; Simonton, 1984d; Weisberg, 1994).

1. Table 4.1 (S. Cole, 1972).
2. "Although the majority of articles in *Psychological Review* were published by authors under the age of 40," the investigator concluded (Over, 1988, p. 215), "such a bias is to be expected in terms of the age distribution of American psychologists. When allowance was made for the number of authors in different age ranges, older authors were no less likely than younger authors to have generated a high-impact (an article cited 10 or more times in the fifth year after publication)."
3. The final investigation looked at the careers of 10 distinguished psychologists (Simonton, 1985): (a) the output of high-impact publications correlates highly with the output of low-impact publications and (b) the ratio of high-impact publications to total output fluctuates randomly throughout the career, neither increasing nor decreasing systematically.

If psychologists evidently do not learn from experience to raise their hit rates, then they may never acquire the capacity to become good judges of their own work.

The age distribution of career landmarks.

Given that that a psychologist's career must consist of an unpredictable mix of hits and misses, an interesting and important issue necessarily arises. Certain hits will have special significance in delineating the highlights of the career. In particular, some hits can be considered as *career landmarks*. These landmarks are the *first major contribution*, the *best contribution*, and the *last major contribution*.

- Raskin (1936): 120 scientists and 123 writers. The scientists typically launched their career at age 25, produced their greatest work at age 35, stopped having impact after 59, and died around 69.
- Simonton (1991a): career landmarks in 2,026 scientists (mathematics, astronomy, physics, chemistry, biology, medicine, technology, earth sciences, and a miscellaneous group). Across all disciplines, the first major contribution came at 31, the best at 40, and the last at 54 (with a life expectancy of 70). Nonetheless, it was the miscellaneous group that contained the largest proportion of historic figures who made contributions to psychology. Among these 102 individuals the three career landmarks fell around 33, 42, and 55 (with a life expectancy of 69).
- Zusne (1976a): 213 luminaries whose bibliographies appeared in R. I. Watson's (1975) *Eminent Contributors to Psychology* (Zusne, 1976a). For this group, the first major publication appeared around age 30, the most significant around age 40, and the last around 65.
- Simonton (1992b): sample was also drawn from Watson (1975), but confined to 69 Americans and used the *Social Sciences Citation Index* to determine the first still-cited work, the most-cited work, and the last still-cited work. The first career landmark appeared around age 30, the second around age 47, and the last around age 63.

So the first major contribution usually occurs around age 30, the most important in the early or middle 40s, and the last major contribution in the middle 50s to early 60s. The placement of the career landmarks is asymmetrical, just like the underlying curve for total output.

The agewise position of the second career landmark links with the equal-odds rule. If quality is a positive (if probabilistic) function of quantity, then those periods in a psychologist's career in which the most works are produced should have the highest probability of containing the psychologist's major works. And among those major works should be found the best work. Therefore, the period during a psychologist's career in which the maximum output obtains should most likely contain the psychologist's single most critical contribution. In other words, the magnum opus should appear near the career peak rather than at the career's cumulation. There exists direct evidence for this intimate connection in other creative domains (Simonton, 1991b, 1997b), but no direct tests have yet been conducted for psychology.

- Nonetheless, many studies have shown that psychologists attain their maximum output rate sometime in the late 30s and early 40s (e.g., Horner, Rushton, & Vernon, 1986), about the same period when the second career landmark is most prone to appear.
- In addition, there exists anecdotal evidence that these periods may be coterminous. At least such a temporal conjunction occurred in the life of psychology's very founder, Wilhelm Wundt. "The period from 1870-1879, during which Wundt published his *magnum opus* … was the most productive period of Wundt's life in terms of individual publications" (Bringman & Balk, 1983, pp. 72-73). The masterwork in question was the *Principles of Physiological Psychology* (*Grundzüge der physiologischen Psychologie)* that appeared in 1873-1874.

Contribution Type

A complete understanding of a psychologist's career trajectories may require adjustment for the type of contribution. Accordingly, we now will scrutinize how the career course may depend on both the genre and domain of psychological publication.

Genre.

- According to an analysis of 30 eminent Australian academics who were 70-90 years old, "productivity increased to a peak age of 40-49 years for journal articles, 50-59 for new books and cross-disciplinary publications, and 60-69 for revised and edited books, technical publications and non-technical books" (Christensen & Jacomb, 1992, p. 681).
- Another investigation concentrated on an unselected group of 324 American experimental psychologists, but found a similar pattern (Bayer & Dutton, 1977). "Unlike article publications, lifetime publication of books tends to increase linearly with career age for most fields, with *r*'s ranging from approximately .30 to .50" (p. 275).
- Interestingly, there is evidence that social scientists tend to turn from refereed journal articles to book chapters as a main publication vehicle as they attain increased eminence in their fields (Rodman & Mancini, 1981).

Of these career shifts in publication genre, the most critical may be the transformation from articles to books. As observed earlier, the most influential (highly cited) work of any psychologist is more likely to be a book rather than an article.

Domain.

A large empirical literature, expected career trajectories are not invariant across different domains (e.g., Bayer & Dutton, 1977; McDowell, 1982).

Peak for quality (best contribution) –

- Lehman (1953a): According to the output of high-impact work, the career peaks for representative scientific fields are as follows: chemistry, 26-30; mathematics, physics, botany, and classical descriptions of disease, 30-34; surgical techniques, genetics, and psychology, 30-39; astronomy, geology, physiology, pathology, and medical discoveries, 35-39. For philosophical domains, the peaks were located at 35-39 for logic, ethics, aesthetics, and general philosophy, but at 40-44 for metaphysics.
- Adams (1946): A roughly contemporary but independent investigation provided point estimates for the age at which the best work was most likely to appear for 4,204 scientists: mathematics, 37; bacteriology and chemistry, 38; physiology and physics, 40; engineering, 43; pathology, 44, astronomy, surgery, and psychology, 45; geology, botany, and zoology, 46; and anthropology, 47 (Adams, 1946).
- Stephan and Levin (1993): A more recent inquiry looked at the ages that scientists do the work for which they received the Nobel prize, obtaining means of 36 for physics, 38 for chemistry, and 39 for physiology or medicine (also see Manniche & Falk, 1957).

Peak for quantity –

- Dennis (1966): complete bibliographies; Mathematicians peaked in the 30s and 40s, chemists and biologists in the 40s, geologists in the 50s, and philosophers in the 60s.
- S. Cole (1979): study used the citation index; mathematicians peaked at 35-39, physics and geology at 40-44, psychology at 40-49, and chemistry and sociology at 45-49. The same citation analysis determined the age at which a scientist published his or her first 5-citation article. The means were as follows: physics 27, chemistry 30, biochemistry 35, experimental psychology 34, clinical psychology 34, and sociology 34.

First contribution –

- S. Cole (1979): The mean age for publishing the first 10-citation article was calculated for the first three disciplines as well: physics 28, chemistry 34, and biochemistry 36 (S. Cole, 1979). Hence, domains may differ by as much as 8 years with respect to the appearance of the first career landmark.

Final portion of curve –

- Dennis' (1966) inquiry demonstrated that substantial interdisciplinary differences also emerge at the other end of the age curve. One way of expressing the magnitude of this contrast is to compare the output in the 70s with the output at the career peak for a particular domain (see his Table 2). For philosophy, such septuagenarians are still producing at 88% of their maximum rate. Yet in biology, chemistry, and geology, the corresponding rates decline to 55%, 53%, and 53%, respectively.
- Dennis' study did not include psychology, but an earlier investigation found evidence that sexagenarians publish at only half the rate as seen in the 30s and 40s, the discipline's presumed career maximum (Dennis & Girden, 1954).

Complicating factors –

- The peak age for producing a scientific discovery or invention has increased over the years, by as much as a dozen years since the Renaissance (Zhao & Jiang, 1986).
- Intradiscipline heterogeneity: Atomic and molecular physicists have peaks at 39-40, solid-state/condensed-matter physicists at 40-45, and geophysicists at 53-59 (Levin & Stephan, 1991).
- But perhaps the most severe problem concerns sampling error. In Dennis' (1966) study, for example, no scientific domain had as many as 50 scientists, and the chemists had only 24.

But see Table 4.2 (Simonton, 1991a) with controls

Table 2

Ages at First, Best, and Last Work and at Death by Scientific Discipline

	First work			Best work			Last work				Death			
Discipline	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range	*N*	*M*	*SD*	Range	*N*
Mathematics	27.3	8.5	14–60	38.8	10.7	19–68	53.4	15.0	21–81	117	63.4	15.3	21–95	133
Astronomy	30.5	8.7	17–73	40.6	11.2	18–77	56.0	14.0	20–84	162	70.5	14.0	22–98	150
Physics	29.7	7.8	15–66	38.2	9.1	19–70	52.3	13.3	25–90	327	69.5	14.0	27–102	277
Chemistry	30.5	8.1	14–72	38.0	9.0	18–74	51.1	13.2	22–102	425	70.8	12.2	30–103	394
Biology	29.4	7.2	17–64	40.5	11.0	18–77	57.8	13.7	29–87	187	72.0	13.2	31–95	176
Medicine	32.3	8.2	17–62	42.1	10.4	22–81	54.5	14.0	27–92	280	69.5	13.3	31–98	271
Technology	31.6	9.5	11–60	39.7	10.8	20–80	53.1	14.9	21–93	229	69.9	12.9	27–100	233
Earth sciences	30.9	8.2	17–59	42.5	12.1	17–78	58.2	13.8	27–85	85	71.3	13.2	30–94	89
Other	33.4	11.0	20–67	41.6	11.1	23–69	55.2	14.4	23–86	72	68.7	13.8	28–101	102

INDIVIDUAL VARIATION IN CAREER DEVELOPMENT: A COGNITIVE MODEL

Tremendous variation –

- Thomas Young was just 19 when he read a paper before the Royal Society in which he experimentally established visual accommodation in terms of the changing curvature of the lens – a contribution of sufficient importance to have him elected as a member at age 21.
- Darwin's greatest single contribution, *The Origin of Species*, did not appear until he was 50, and his *The Descent of Man* was more than a dozen years in the future.
- Gustav Fechner was 75 when he published his noteworthy *Introduction to Aesthetics* (*Vorschule der Aesthetiks)* and he continued making contributions for the last decade thereafter.

Such landmark ages do not seem to fit very well with the means shown in Table 4.2. It is for this reason that the table also provides two measures of dispersion about each average, namely the standard deviation and the range. These latter statistics are huge.

Many empirical investigations have underlined the extreme variation that exists in career trajectories (Simonton, 1988a, 1997b). For the most part, if the goal is to predict how much a person will produce in a given time interval, it is far more critical to know *who* the individual is than *how old* he or she may be (Levin & Stephan, 1989, 1992; Over, 1982a, 1982b).

- Thus, in one study of more than a thousand academic psychologists, age accounted for less than 7% of the variance in a researcher's output in consecutive career periods from ages 25 to 64 (Horner, Rushton, & Vernon, 1986).
- This proportion may be compared with the findings reported earlier in this chapter regarding the stability of individual differences in output across consecutive decades of the career (e.g., S. Cole, 1979; Dennis, 1954b; Rodger & Marano, 1989). Judging from that research, between a third and two-thirds of the variance in productivity in any given period may be predicted from the individual differences observed in the previous period. Hence, cross-sectional variation is probably between 5 and 10 times more powerful as a force shaping career trajectories.

In concrete terms, Prolific psychologists in their late 50s or 60s are more productive per annum than near Silent psychologists at their own career peaks (Simonton, 1988a, 1997b).

How can such individual differences be accommodated? Do their very existence threaten the utility of any treatment of career trajectories? To answer these questions, let me turn to a cognitive model that not only integrates cross-sectional and longitudinal variation, but also accounts for interdisciplinary differences. I start with the longitudinal model, and then extend it to the individual-differences model.

The Longitudinal Model

The cognitive model begins by assuming that each individual begins his or her career with a certain amount of *initial creative potential*.

- In abstract terms, this hypothetical quantity gauges the total number of ideational variations a creator is capable of generating given an infinite life span.
- In more concrete terms, this quantity is proportional to the total number of publications a person is capable of producing, given an unrestricted amount of time.

The creative potential is converted into actual products through a two-step mental process.

1. The first step ideation, involves the generation of ideational variations that provide a raw stock of "works in progress." These are the basic but rudimentary ideas that fill up notebooks and sketchbooks.
2. The second step, elaboration, entails the more laborious conversion of these ideas to finished works, such as publications.

The process may be summarized simply as follows:

CREATIVE POTENTIAL — Ideation→ IDEAS — Elaboration→ PUBLICATIONS

The coupled processes of ideation and elaboration do not take place instantaneously, but rather both consume a certain amount of time.

- The *ideation rate* specifies how quickly potential ideas are converted into actual ideas, whereas
- the *elaboration rate* indicates how fast the items in the latter repertoire become finished contributions.

These two information-processing parameters will be positive decimal fractions, usually less than 0.1, and may or may not be equal.

Significantly, the exact size of the ideation and elaboration rates depends on the specific nature of the concepts and techniques that define a particular domain of creative achievement. In some domains, ideational variations can be generated rather quickly, whereas in other domains the production of new ideas takes a considerable amount of time. Similar contrasts take place in how long it takes to elaborate the initial inspirations into publishable products.

The ideational and elaboration rates are not necessarily correlated, and, in fact, have been shown to be empirically uncorrelated across any heterogeneous collection of disciplines (Simonton, 1997b).

In any case, the foregoing two-step model yields the following equation:

$$p(t) = c(e^{-at} - e^{-bt}), \qquad (4.1)$$

where $c = abm/(b - a)$.

This equation specifies the publication rate p as a function of time t, where m is the initial creative potential, a is the ideation rate, b the elaboration rate, and e is the exponential constant (= 2.718…).

In the special case where the two information-processing parameters are identical ($a = b$), the equation becomes:

$$p(t) = a^2 tme^{-at}, \qquad (4.2)$$

a slightly simpler form, but with essentially the same predicted career trajectory.

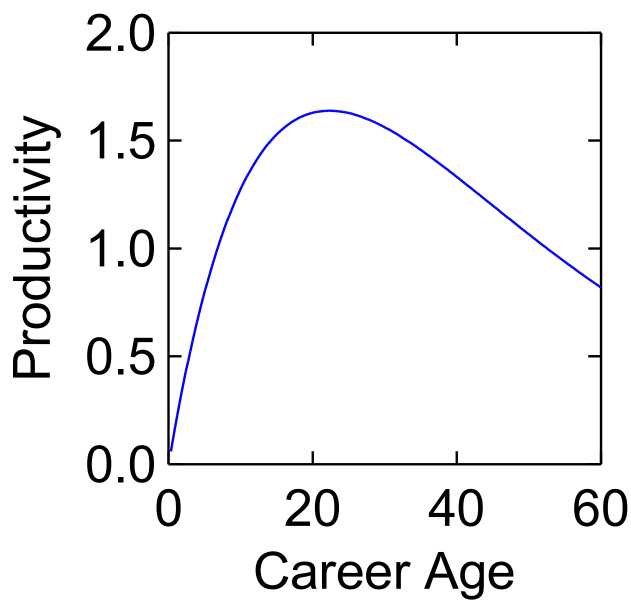
Note that t is not chronological age, but rather career age. That is, $t = 0$ at the moment that the individual begins generating ideational variations in a particular domain.

This function permits us to formulate a number of empirically testable statements about the typical age curve, interdisciplinary contrasts in the shape of that curve, and corresponding contrasts in the longitudinal location of the three career landmarks (see Simonton, 1984b, 1997b, for details).

The specific form of the age curve.
Figure 4.1 shows what this curve looks like for m = 100, a = .04, and b = .05, which can be considered fairly typical parameters. As is immediately apparent, the model predicts an age function with the following three fundamental attributes.

1. the curve is single-peaked rather than having two or more maxima.
2. the ascending portion of the curve is concave downward (i.e., decelerating rather than accelerating).
3. the descending portion of the curve eventually exhibits an inflexion point where the curve becomes concave upward, and thereafter approaches the zero-output point asymptotically.

All three of these features of the predicted age curve have been successfully verified against actual empirical data (using appropriate methodological controls; see Simonton, 1984b).
The hypothesized curve was even confirmed for the psychologists of sufficient importance to have their bibliographies listed in R. I. Watson's (1975) *Eminent Contributors to Psychology* (Simonton, 1984b). For instance, the asymptotic form of the descending segment was confirmed using all 196 psychologists in Watson who lived to at least 70 years of age.
When the predicted function is tested against data that is aggregated across many individual careers – so as to remove the random shocks that affect any one career – the correlation between expected and observed output is usually in the upper .90s (Simonton, 1984b). For example, the correlation between the observed output of American Nobel laureate scientists and the predicted output is .96 (using the data in Zuckerman, 1977).



The information-processing basis for interdisciplinary contrasts.

- The high degree of correspondence between fact and theory requires that the ideation and elaboration rates be chosen to fit the typical trajectories of a given domain of achievement. Because these two information-processing parameters determine the overall shape of the age curve, such as the location of the peak and the slope of the decline, this adjustment can be accomplished via nonlinear estimation procedures.
- This strategy was actually performed using the Dennis (1966) data, obtaining estimates of the ideation and elaboration rates for 16 different domains of creative achievement (Simonton, 1989a). Thus, the 42 philosophers exhibited extremely slow rates (a = .023 and b = .027) relative to the 32 biologists (a = .033 and b = .052).
- Because the predicted curve is strongly determined by even the smallest changes in the two parameters, this contrast has major repercussions. In particular, the predicted age difference between the career peaks for philosophy and biology is over 16 years.
- The correlations between predicted and observed levels of output are .95 for the philosophers and .98 for the biologists, so the agreement is very good once the adjustment is made. Presumably, it takes much longer to conceive and develop ideas in philosophy than it does in biology.
- Psychology in this respect falls closer to biology than philosophy, as might be expected. The parameters a = .04 and b = .05 are probably the most typical for the field.

The equal-odds rule, output, and career landmarks.

Once these parameters are allowed to vary according the information-processing specifics of each discipline, a great diversity of career trajectories can be supported. Peaks may be early or late, the post-peak decrement gradual or steep. This tremendous interdisciplinary diversity in career trajectories permits the model to accommodate conspicuous contrasts in the longitudinal location of the three career landmarks (Simonton, 1991a, 1997b). To make this connection, it is only necessary to apply the equal-odds rule.

- If quality is a probabilistic function of quantity, then the single best work will be placed near the productive peak. Early peaking disciplines will therefore differ from late peaking disciplines in the typical location of the most influential work.
- Furthermore, all other factors held constant, those fields that exhibit steep ascents in the pre-peak period will more likely see the first career landmark appear earlier than holds for those fields where the ascent is much more gradual.
- A like expectation can be composed for the last career landmark. Those fields where the post-peak decline is very gradual will most likely witness last major contributions by the most senior members of the discipline, whereas in those fields where the decrement is quite substantial, the last career landmark will tend to appear earlier during the contributor's life span.

Even more critically, the relative placement of the three career landmarks does not have to be consistent across different disciplines. Because the longitudinal location of the first, best, and last major work depends on the underlying productivity curve, and given that the latter curve can vary appreciably according to the domain-specific information-processing rates, a large number of distinct career patterns can result. Something of this diversity is evident in Table 4.2. Although mathematicians have the earliest first contribution, their best contribution tends to come after those found among physicists and chemists, and their last contribution arrives after those of the physicists, chemists, and inventors.

The Individual-Differences Model

Although the foregoing longitudinal model was originally designed to handle longitudinal changes in output, it contains the rudiments of a more comprehensive model that can explicate individual differences as well. In particular, two distinct individual-difference variables are implicitly part of the model.

1. First, creative personalities must differ according to their initial amount of creative potential. Some will have a rich fund of ideas that can generate one ideational variation after another. Others are basically "one-idea" or "one-shot" intellects. According to the theoretical model, m should exhibit a highly skewed distribution in line with the Lotka and Price laws.

2. Second, creative personalities must differ according to the age at career onset, that is, the age at which $t = 0$. The most common operational definition for this variable is the age at which an individual earns his or her highest degree (e.g., Lyons, 1968). Admittedly, chronological and career age often correlate very highly, often in the .80s (e.g., Bayer & Dutton, 1977). Nevertheless, by making the career trajectory a function of career age, the model can account for individual differences in the paths that cannot be explained otherwise (Simonton, 1997b).

The distinctive predictions that can be derived from the individual-difference model fall into two sets, namely, those that concern (a) the longitudinal stability of individual differences in output and (b) the longitudinal placement of the three career landmarks.

The longitudinal stability of individual differences in output.

As already noted, the two information-processing parameters for ideation and elaboration account for the shape of the predicted curve.

- Initial creative potential (*m*), on the other hand, does not affect the general form of the longitudinal function. The peak remains in the same place no matter whether creative potential is high or low. Yet the impact of creative potential on the career trajectory is quite dramatic: The higher the initial creative potential, the faster productivity accelerates in the early years of the career, the higher the output rate at the career peak, and the longer productivity is maintained in the declining years of the career. In short, creative potential determines the overall height of the curve rather than its broad shape. This fits with the earlier observation that publication rates exhibit appreciable stability across consecutive periods of an individual's career. Those who publish more in their 30s will also publish more in their 40s, and those who publish more in their 40s will publish more in their 50s. If the individual-differences model holds, variation in productivity in every period of a career is a function of a single latent variable, namely initial creative potential. Accordingly, the correlations will be of roughly equal magnitude throughout the correlation matrix.
- This explanation contrasts with what is argued in the sociology of science, namely, that this longitudinal stability illustrates the phenomenon known as *cumulative advantage* (Allison, 1980; Allison, Long, & Krauze, 1982; Allison & Stewart, 1974; also see Price, 1976). The Matthew Effect after the passage in the Gospel According to St. Matthew that says that "For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath" (quoted in Merton, 1968, p. 58). An implication of the doctrine of cumulative advantage is that those who begin their careers with roughly equivalent capacities will eventually find themselves separated out into winners and losers by the luck of the draw. If not everyone can publish in the most prestigious journals, win the most remunerative grants, or receive appointments at the most select universities, then someone has to come out on the bottom. This possibility has even been styled the Ecclesiastes Hypothesis (Turner & Chubin, 1976). "The race is not to the swift, nor the battle to the strong, neither bread to the wise, not yet riches to men of understanding, not yet favor to men of skill; but time and chance happeneth to them all" (quoted in Turner & Chubin, 1979, p. 437). If the cumulative-advantage model is correct, then individual differences in output should correlate far higher for two consecutive age periods than for two nonconsecutive age periods. In fact, the larger the temporal separation between two age periods, the smaller should be the correlation between them. The result is a highly distinctive correlation matrix known as the "simplex" (Loehlin, 1992b). The largest correlations will be those next to the diagonal, and the off-diagonal correlations become progressively smaller the farther removed they are from the diagonal.

This critical test has actually been carried out for different data sets using confirmatory factor analysis, and the outcome uniformly supports the model advocated here (Simonton, 1997b).

- For example, a single-factor latent-variable model does an excellent job explaining the data that Wayne Dennis (1956b) had collected on 56 scientists (yielding a comparative fit index of 0.994, where 1.00 indicates a perfect fit).
- Moreover, the factor loadings of each age period on the general creative-potential factor tend to be uniformly high. For instance, when the model was fit to the careers of 435 mathematicians (from S. Cole, 1979), the output in any given age period correlated between .74 and .88 with the general factor.

All in all, the results flatly contradict the cumulative-advantage explanation.

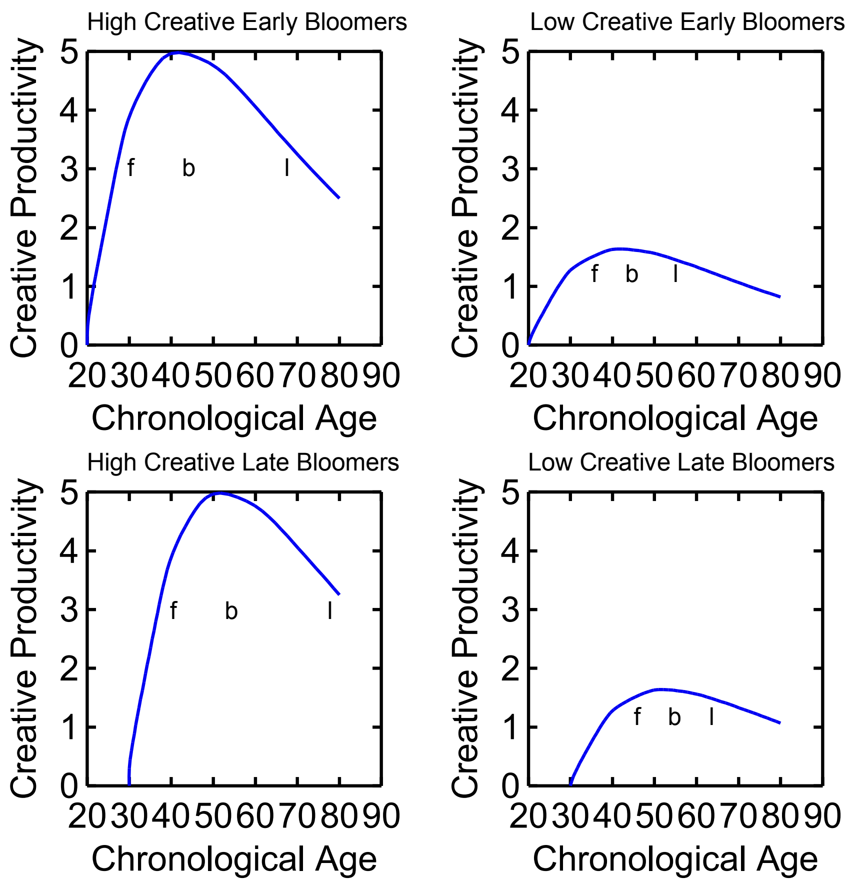
Cf. previous treatment of Galton's *G* (Simonton, 1991c).

Longitudinal location of the three career landmarks.

Thus far our focus has been on individual differences in creative potential and their consequences across the course of the career. Yet it is necessary to consider a second individual-difference variable, namely variation in the age at career onset. Some individuals may be "early bloomers," others "late bloomers." On both theoretical and empirical grounds, the individual-differences model posits that variation on these two factors is largely uncorrelated (Simonton, 1996a). That is, a highly creative individual may bloom either early or late, and the same holds for a less creative individual. Hence, those persons who fall at the extremes on these two factors may be said to define a fourfold typology of career trajectories (see Figure 4.2).

- The *high-creative early bloomers* start young, begin producing at a fast rate, reaching their productive peak at a relatively young age, but still maintain a high level of output until late in life.
- The *low-creative early bloomers* have a very similar career trajectory, with the peak at the same longitudinal location, but with the overall level of output consistently lower throughout the career.
- The *high-creative late bloomers* are older when they launch their careers, and peak correspondingly later, but maintain a high level of output throughout their career, the full realization of their potential often being cut short by death.
- Finally, the *low-creative late bloomers* display a similar pattern, but with an appreciably lower output level throughout the career.

Furthermore, according to the equal-odds rule, the specific placement of the three career landmarks will vary across these four types of career trajectories. On the one hand, if creative potential is held constant, then all three career landmarks will be shifted earlier or later in direct proportion to whether the career onset is earlier or later. On the other hand, if age at career onset is held constant, then the higher the level of creative potential, the earlier will appear the first major work (because of the faster accumulation of output) and the later will appear the last major work (because the higher level of output in the final years), whereas the best work will appear in the same place regardless of the level of creative potential (because the latter individual-difference variable affects only the height, not the shape, of the predicted curve). When these two orthogonal effects are combined, a rich variety of career outcomes emerge. Moreover, when these outcomes are combined with the strong positive association between creative potential and eminence, the following 10 predictions obtain (see Simonton, 1997b, for the formal derivations and additional predictions):


High Creative Early Bloomers
Low Creative Early Bloomers
High Creative Late Bloomers
Low Creative Late Bloomers
Creative Productivity
Chronological Age
0 1 2 3 4 5
20 30 40 50 60 70 80 90
f b l

1. *Total lifetime productivity correlates negatively with the chronological age of the first contribution and positively with the chronological age of the last contribution*.
Confirmed on a sample of 69 eminent American psychologists (Simonton, 1992b). In particular, the total number of cited publications correlated -.25 with the age at first cited work and .30 with the age at the last cited work. Cf. if O is lifetime output, then it is given that $O = R(L - P)$, where R is the mean annual rate of output, L is the chronological age that output ended (longevity), and P is the chronological age that output began (precocity). E.g., Rudolf Arnheim (1986)

2. *Individual eminence correlates negatively with the chronological age of the first contribution and positively with the chronological age of the last contribution*.
This statement follows from the tight theoretical and empirical link between lifetime output and Galton's *G*. E.g., the posthumous reputation of American psychologists correlates -.26 with the age at first cited work and .35 with the age at the last cited work (Simonton, 1992b). Also, those eminent enough in their own time to be elected APA president have their first hit at a younger than normal age and their last hit at an older than average age (Albert, 1968; Lyons, 1968; Simonton, 1992b).

3. *Maximum output rate correlates negatively with the chronological age of the first contribution and positively with the chronological age of the last contribution*.
There exists some empirical support for this prediction (S. Cole & J. R. Cole, 1973; Simonton, 1991b), including studies by both Dennis (1954b) and Lehman (1958). Yet the prediction has not yet been tested for a sample of psychologists.

4. *Total lifetime productivity correlates zero with the chronological age at the maximum output rate and zero with the chronological age at the best contribution*.
This is a more surprising prediction than the first, but it follows immediately from the fact that, according to the model, only chronological age at carrier onset, not level of creative potential, determines the location of the career peak. This prediction has been amply confirmed (Christensen & Jacomb, 1962; Simonton, 1991b; Zuckerman, 1977), the first such confirmation being published by Lehman (1958) for a sample of chemists. The two predicted null relations have been demonstrated to hold in psychology as well (Horner, Rushton, & Vernon, 1986; Simonton, 1992b). Hence, the great psychologists tend to attain their career optima at about the same chronological age as their less well known colleagues.

5. *Individual eminence correlates zero with the chronological age at the maximum output rate and zero with the chronological age at the best contribution*.
For example, among notable American psychologists, those who manage to earn election to the APA presidency produced their best work at the same chronological age as their less distinguished colleagues (Simonton, 1992b).

6. *Maximum output rate correlates zero with the chronological age at the maximum output rate and zero with the chronological age at the best contribution*.
Empirical support for this proposition may be found in several investigations (Christensen & Jacomb, 1992; Horner, Rushton, & Vernon, 1986; Lehman, 1958; Simonton, 1991b; Zuckerman, 1977), albeit only one study (Simonton, 1991b) addressed the issue directly, and did so using a sample of 120 classical composers.

7. *The chronological age at the maximum output rate correlates positively both with the chronological age at the first contribution and with the chronological age at the last contribution*.

8. *The chronological age of the best contribution correlates positively both with the chronological age at the first contribution and with the chronological age at the last contribution*.
On first glance, one might think that these two predictions are almost tautological, given that the career peak that contains both the maximum output rate and the best contribution must fall in the interval bounded by the first and last contributions. Given the career lengths that are typically seen, these two propositions are by no means necessary. The only way that Predictions 7 and 8 can receive empirical confirmation is when the career peak is determined endogenously by career age rather than exogenously by chronological age. Both predictions have been empirically confirmed (Simonton, 1991a, 1991b, 1992b). In addition, Prediction 8 is theoretically compatible with the "harmonic-mean model" that was proposed and tested on a sample of 213 eminent contributors from psychology's history (Zusne, 1976a). In this model, a psychologist's single most significant work will appear at an age that is the harmonic mean of the age at the first and the last publication. The correlation between predicted and observed age at best work is .52, a fairly impressive figure.

9. *The first-order partial correlation between the ages of first and last contribution is negative after partialling out the chronological age at the best contribution or the chronological age at the maximum output rate*.
This proposition is in many respects the most distinctive of all. This distinctive prediction has been confirmed on a sample of nearly 2,000 scientists and inventors (Simonton, 1991a) and another sample of 120 classical composers (Simonton, 1991b). In the former case, for instance, the partial correlation between the age at first contribution and age at last contribution controlling for the age at best contribution is -.22.

10. *The time interval between the chronological age at career onset and the chronological age at first contribution is negatively correlated with total lifetime productivity and the maximum output rate*.
Although there are plenty of studies that indirectly support this prediction (e.g., Christensen & Jacomb, 1992), only one investigation tested it directly, using a sample of classical composers rather than scientists (Simonton, 1991b). However, I did perform a secondary data analysis on data that had been collected on 69 eminent American psychologists (Simonton, 1992b), and found confirmatory results. The total number of cited publications correlated -.31 with the difference between the age at first publication and the age at first cited publication. One nice feature about this proposition is that it actually provides the basis for genuine prediction rather than postdiction. Returning to the data on 69 American psychologists, posthumous reputation correlated -.26 with the time lapse between first and first-cited publications.

Taken together, Predictions 1-10 provide a baseline for evaluating whether a particular psychologist exhibits the career trajectory typical of psychology's recognized greats. Those who are most likely to make a mark on the discipline's history will begin to have an impact early, will still continue having an impact until late in their careers, will attain an impressively high level of output throughout the career, with an especially impressive maximum output rate. At the same time, the age at the career peak: whether gauged by the best work or the maximum output rate: is not diagnostic of a psychologist's greatness. However, the longitudinal location of the career peak is symptomatic of another crucial aspect of what it takes to make it in psychology's history: the domain of achievement.
Cf. John B. Watson (extraneous circumstances)