

Visions of Aesthetics,
The Environment
& Development

The
Legacy of
Joachim F. Wohlwill

Edited by
Roger M. Downs
Lynn S. Liben
David S. Palermo

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The Pennsylvania State University

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Acknowledgments

In the Fall of 1988, a 3 day conference entitled "The Legacy of Joachim F. Wohlwill: Visions of Development, The Environment, and Aesthetics" was held at University Park, Pennsylvania. This formal memorial to Jack Wohlwill was possible because of the generous financial support by two divisions of The Pennsylvania State University community to which Jack belonged: the College of Health and Human Development and the Center for the Study of Child and Adolescent Development. We would also like to acknowledge the support of Anne C. Petersen, Dean of the College, and Richard Lerner, who was Director of the Center at the time the conference was held.

Many other people also contributed generously to the success of the conference and thereby helped to make this book possible. We would like to acknowledge the particular contributions of Lisa Grove, Tina Hay, Tina Jacquette, Sandra Rainio, Fay Wohlwill, and David DiBiase and the staff of the Deasy Geo-Graphics Laboratory.

Preface: Reflections on a Scholar

Roger M. Downs, Lynn S. Liben, and David S. Palermo
The Pennsylvania State University

THE IDEAL OF AN ACADEMIC LIFE

In many ways, Jack Wohlwill exemplified the ideal of an academic life. His career was characterized by the enthusiastic pursuit and sharing of scholarship, communication, collegiality, and creativity, the mentoring of students, and above all else, the sheer pleasure of the nurturing of ideas. At the same time, Jack's non-professional world was multifaceted: He approached so many things with passion and commitment. He was a firm believer in personal liberty and in the preservation of the environment; he was dedicated to music, to art, and to the Boston Red Sox; he believed in family and friendship.

While it is impossible to capture all of the aspects of even the academic parts of his life in a book, we have tried to reflect as many as possible in this formal memorial to a scholar. Our unifying theme is the idea of a legacy.

Legacies are gifts handed down from the past and, apart from his personal example, Jack's greatest gifts to us were ideas. We have identified three major areas in which Jack made significant scholarly contributions: art and aesthetics, human-environment interaction, and concepts of development. In each case, Jack Wohlwill made seminal contributions, helping to shape, maintain, and even change the direction of research and thought.

These three areas are a convenient but arbitrary way of representing the dominant emphases of the stages of Jack's career. Of course, Jack being Jack, he continued to work in all three areas simultaneously. We have organized the book as a retrospective on the building of a legacy. We have chosen to begin with the area (art and aesthetics) with which he was most actively involved at

the time of his death and to end with the area that marked the origin (and perhaps the most pervasive concern) of his academic career (development).

In each case, we asked senior scholars to reflect on the directions of their own work as it relates to Jack's work. The relationships are of many kinds: shared experiences of place and time, formal working responsibilities, agreements (and disagreements) over ideas, parallel but intersecting career paths, and joint participation in academic structures.

Jack spoke and wrote about issues that touch some of the fundamental beliefs about the direction and meaning of the social and behavioral sciences. He did so in an honest and forthright way: He was respectful of the views of others and yet firm and insistent in the statement of his own beliefs. We encouraged the contributing scholars to respond in kind. Each chapter evolved from a presentation at the Memorial Conference that was then revised to incorporate ideas raised in formal and informal discussions.

THE ORGANIZATION OF THE BOOK

Howard Gruber's chapter, "Aspects of Scientific Discovery: Aesthetics and Cognition" is a perfect way to introduce this book. Gruber is concerned with the reconstruction of pictures of creative people at work via the case study method; the method is tailor-made for providing an overview of Jack Wohlwill's career. Figure 1.1, The network of enterprise of Joachim F. Wohlwill, provides a context for the structure of this book. So many of Gruber's ideas are echoed in the subsequent chapters: the counterpoints between unity and diversity, and continuity and change in thought, the role of aesthetic feelings in the process of doing science, the range of media for capturing and expressing aesthetic experiences, the use of music as metaphor.

"The Course of Creative Growth" is indeed a tribute to Joachim Wohlwill because it focuses on an idea that was central throughout Jack's thinking: the shape of development. Howard Gardner and Ellen Winner ask, specifically, whether the course of artistic creativity is U-shaped. Their response was formed and in part driven by an extensive debate with Jack, and it offers a detailed picture of the point-counterpoint style that Jack so favored.

While Harry Beilin's chapter explicitly mentions Jack Wohlwill only in the Postscript, the title alone, "Developmental Aesthetics and the Psychology of Photography," is indicative of a commonality of interest. The intermingling of perception and cognition, the balance between innate and acquired processes, the tension between reality and representation, the importance of photography as a medium of expression, the detailed tracing of developmental progressions are all

themes that resonate throughout Jack Wohlwill's work.

Eleanor Gibson gave the keynote address at the Memorial Conference. Her chapter, "The Ecological Approach: A Foundation for Environmental Psychology," has a tone and flavor that Jack would surely have appreciated. In seeking to relate environmental psychology to ecological psychology, Gibson is concerned with theory, with the careful use of concepts, with the recession of the environment in the face of representation, with ecological validity, and with the relation between perception and development.

Irwin Altman's career intersected on many levels and on many occasions with Jack's career. Appropriately enough, therefore, "A Personal Perspective on the Environment and Behavior Field," is a personal historical memoir by means of which we can see the complex of figure-ground relationships in which much of Jack's later career was embedded. Both Altman and Wohlwill were part of a cohort of psychologists who shared common themes and values. Altman offers a detailed picture of the development of one of the strands of the "network of enterprises" that Gruber describes.

The next chapter, by two of us (LSL and RMD), was generated by the same processes that gave rise to Gardner and Winner's chapter. Collegial relationships with Jack inevitably led to thought-provoking exchanges of ideas. "The Role of Graphic Representations in Understanding the World" departs from one of Jack's seminal papers, "The Environment is not in the Head!" We argue for the importance of studying the development of the ability to use external representations of the physical environment. In this way, it complements the analysis of photographic representations presented in Harry Beilin's chapter.

Seymour Wapner, a member of the cohort of environmental psychologists identified by Irwin Altman, is a close contemporary of Jack. Wapner and Demick's chapter, "Some Relations between Developmental and Environmental Psychology: An Organismic-Developmental Systems Perspective," presents contrasts between their approach and that of Jack Wohlwill, and shows how researchers can weave strands of their networks of enterprise into very different patterns while sharing many of the common themes and values that Altman discusses. Written from the perspective of metatheoretical issues, their chapter thus provides an interesting alternative to the organizational structure offered by Gruber which focuses on the substantive domains of Jack's work. This is a telling illustration of the argument for the power of world views in the interpretation of data and theory, a point reinforced in Overton's chapter.

John Nesselroade's title, "The Warp and Woof of the Developmental Fabric," offers more than a superficial echo of the weaving metaphor that we have borrowed from Gruber. The characterization of developmental change was perhaps the dominant theme that wound its way through Wohlwill's network of

enterprises. As Gardner and Winner mention, Jack's last empirical work involved tracing the course of developmental change through the lens of computer programming. Nesselroade offers a careful and incisive blend of theory and methodology that shares the spirit of Wohlwill's (1973) book, *The Study of Behavioral Development*.

In their chapter, "The Interface Between Emotion and Cognition," Margaret Sullivan, Michael Lewis, and Steven Alessandri make use of two metaphors that had great meaning for Jack Wohlwill. In capturing the complex, non-linear relationships between cognition and emotion, they turn to Escher's graphic art and to Bach's fugues. One could readily adapt the form of the fugue as an expression of Jack's academic career and Jack made extensive use of Escher's art. On another level, Jack enjoyed music and art for themselves, and he certainly would have accepted the interplay between cognition and emotion.

As Willis Overton points out in "Historical and Contemporary Perspectives on Developmental Theory and Research Strategies," one of Jack's last papers returned to a theme that had preoccupied him throughout his career: the relation between theory and method in developmental research. Ending this book with Overton's discussion of the way in which world views underpin beliefs about the nature of development is appropriate, for Jack Wohlwill was both secure in and articulate about his world view. It informed and guided him through the network of enterprise that comprised his career. It is perhaps one of the reasons why he was so comfortable in so many areas of knowledge and why we find his legacy to be so enduring and inescapable.

WHAT IS THE LEGACY OF JOACHIM F. WOHLWILL?

As editors, we have struggled to answer this question. Our response begins in a strange way by suggesting reasons why some of the obvious answers do not fully capture the legacy that Jack left us.

Jack's inquiring mind delved into so many diverse areas that he was able to make significant empirical contributions to work on perceptual learning, number, distance judgments, creativity, stimulus complexity, noise, aesthetic response, preferences in the natural environment..., and the list continues. Yet Jack Wohlwill's empirical work, although extensive, carefully crafted, and powerful, does not in and of itself capture the full measure of his many extraordinary achievements.

One might think that Jack's books would singularly characterize his lasting impact—that his 1973 book, *The Study of Behavioral Development*, or the 1987

volume edited with Dietmar Gorlitz, *Curiosity, Imagination, and Play*, will remain essential reading for those interested in development and play. But despite their clear importance, even particular books are not expansive enough to encompass the rich legacy of Joachim F. Wohlwill.

Perhaps in the final analysis it is not the individual pieces of work—whether empirical articles or conceptual books—that we should look to for Jack’s legacy. We might seek to measure Jack’s legacy by the ways in which his general ideas have shaped and will continue to shape fundamental discussions. Jack forced us to reconsider the role of perception, the nature of development, the meaning of the environment, the relation between aesthetics and art, the application of scientific research to real-world problems, and the inescapable interactions among all of these ideas. In each and every case, he challenged us methodologically, conceptually, and theoretically.

The word challenge is appropriate precisely because we will not be able to ignore Jack’s ideas. His formulations will continue to demand our attention in exactly the same way they did when Jack originally presented them in face-to-face discussions. In like manner, cross-cutting the expression of these ideas was Jack’s commitment to the value of inter-disciplinary study, the role of theory, the importance of acknowledging traditions of scholarship, and the need for ecological validity, commitments that we have inherited.

The challenge of ideas aside, the enduring legacy of Joachim F. Wohlwill will be found just as much in his personal example as a scholar, an example for students and colleagues alike, an example that each of us can try to emulate.

Consider, for example, Jack’s insistence on fairness, as evidenced in his articles on Martha Muchow. Jack insisted that we must acknowledge Muchow’s role in establishing the need for a link between developmental and environmental psychology, a link that he himself had done so much to foster. In part, Jack was able to make such a statement because he could speak and read several languages. Scholarship for Jack was bound neither by language nor discipline; it was personal, and yet he was generous in sharing credit for ideas and writing.

Consider also Jack’s courage. Jack not only took stands in his written work, something that comes relatively easily to most of us, but he also made a statement with his personal career. He left a traditional academic home in psychology at Clark University for an unabashedly experimental program in man-environment relations at Penn State. He was willing to put his written beliefs into practice by making a career commitment.

But rather than continue in this vein, we offer an assessment of Jack’s legacy that is taken, appropriately enough, from a memorial written by a former student and colleague, Harry Heft:

While [Jack] clearly held definite positions on theoretical and methodological issues, he was neither polemical nor demonstrative about them. His students were always free to explore in any direction they were drawn, knowing that they had his support to do so and that his critical skills and insights were available as resources for them. His lack of dogmatism and his unassuming manner fostered around him an exciting and open sense of exploration in the best sense of intellectual inquiry. At the same time, his evaluations of colleagues' and students' work while sensitive were unflinchingly rigorous and intellectually honest, for he highly valued careful conceptual and empirical work. In this regard he set a standard for those of us who benefitted from his critical thinking. He served as an exemplary model of a scholar and a teacher for his students and colleagues.

Jack Wohlwill is deeply missed by his colleagues and friends. Those of us who had the good fortune to know him were graced by his rare intellect, his warmth, and his delightful wit. He profoundly shaped environmental psychology, and has left a significant and distinctive mark on it. More important, he has richly contributed to the intellectual and personal lives of so many of us.

Strength in beliefs and freedom in expression, support and critical standards, sensitivity and honesty—these are some of the facets of an ideal academic life. We offer this volume as one measure of the inescapable impact of these and other reflections of Jack's scholarship on our thinking.

I

**ART AND
AESTHETICS**

1

Aspects of Scientific Discovery: Aesthetics and Cognition

Howard E. Gruber

Teachers College, Columbia University

A cognitive science approach to scientific discovery can be expected to represent the production of a series of problem-solving efforts, a sequence of theoretical models or belief systems, and a series of real-world encounters in which new facts are assimilated into changing mental structures.

But if we want to situate the process of scientific discovery within the context of a purposeful creative life, we need another approach. Indeed, the cognitive sciences most concerned—cognitive psychology, history, and philosophy of science—have no conceptual apparatus and no method for dealing with a creative life. A similar point may also be made about the study of other kinds of creativity.

This situation has led my collaborators and me to devote our energies to the use of the case-study method, to try to reconstruct pictures of creative people at work (Wallace & Gruber, 1989). Each creator is necessarily unique, and it is his or her uniqueness above all that we would like to understand. This is the inescapable task in the study of creative lives. Still, a few common characteristics emerge, providing at least general guidelines for studying the unique creative person.

THE ORGANIZATION OF PURPOSE

One important characteristic of creative work is simply that, being difficult, it generally takes a long time. This prolonged activity requires a powerful organization of purpose to be maintained. Typically, the work of the creator is organized into what we have called a *network of enterprise*. Although the

subjects I have focused on—Charles Darwin and Jean Piaget, among others—have had wide and diversified networks, there is as yet no special theoretical reason to insist that the creator's network of enterprise must be both wide and diverse.

In the case of a productive author, such as Joachim Wohlwill, we can use dates of publication to identify the approximate time of onset, periods of activity, and periods of dormancy of various enterprises. Using journal articles rather than books as indices does not eliminate the error caused by normal publication lags, but it does reduce it. Wohlwill's network of enterprise can be thus simplified and schematized, as shown in Figure 1.1, into four main areas of activity: general psychology (referring mainly to research on perception and learning), developmental psychology, environmental psychology, and aesthetics. The publication dates of his first papers in each area show the steady, rapid emergence of Wohlwill's lifetime preoccupations. All four strands of his work make their first appearance in his publications between 1957 and 1968. The most striking points illustrated in the diagram are: (a) the long periods of time in which two or three of these enterprises were pursued in parallel, that is, simultaneously; (b) the various examples of "cross-talk" between the different enterprises; and (c) the explicit quest for unity in his work, reflected in such titles as "The confluence of environmental and developmental psychology: Signpost to an ecology of development?" (Wohlwill, 1980).

In examining other networks of enterprise I have found that enterprises go dormant as a natural consequence of the multiple preoccupations of vigorous, but after all finite, beings, but they rarely die out completely. In Wohlwill's case, his early interest in the experimental psychology of attention and perception, rather than disappearing, seems to have been assimilated into his other interests; that is, certain experimental methods and attitudes became tools used in pursuing later enterprises. A related facet of his work that does not appear in the diagram is his abiding interest in the methodology of developmental research.

The emergence and development of his various enterprises is reflected also in the professional recognition he received. The diagram shows the periods during which he was on the editorial boards of various journals in three different fields. In each case, as would be expected, this recognition and exploitation of his talents followed, by a few years, his immersion in that field of endeavor.

The question now arises, what motivates the creative person? To some extent we can say that the network of enterprise has motivating power: Tasks undertaken become their own justification, the felt need to complete them the spur. The motivation of work has been described as intrinsic motivation and task

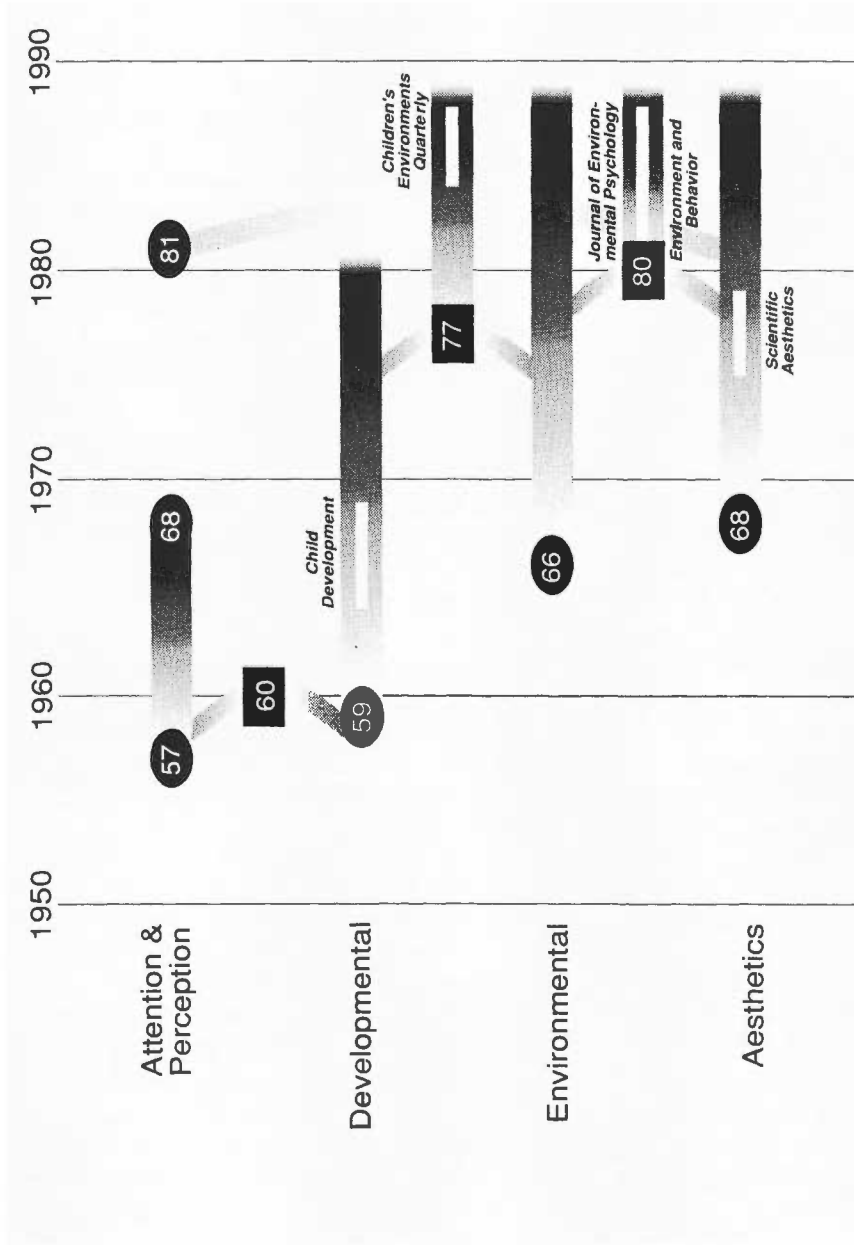


FIGURE 1.1. The network of enterprise of Joachim F. Wohlwill. Note: Year of first publication is several years later than onset of activity in field. White bars indicate time span of service on editorial board of named journal.

orientation, as opposed to ego orientation (Amabile, 1983; Lewin, 1935), the instinct of workmanship (Veblen, 1914), and functional autonomy (Allport, 1937).

THE ORGANIZATION OF AFFECT AND AESTHETIC EXPERIENCE

But this organization of purpose must be linked with an organization of affect, or emotion. Just what are the satisfactions and frustrations to which the creator responds? How does it feel when the going is good? Or bad? Psychologists interested in emotion chronically focus attention on negative affects: anxiety, depression, fear, guilt, anger, hate. Without denying the power of these darker forces, we must also ask, What are the positive feelings that reward the creative person at work, the presence and prospect of which draw him or her ever back into the unfinished work, and on and on through the long struggle?

The principal aim of this paper is to address one aspect of that question. Specifically, I want to focus attention on aesthetic feelings that arise in a life devoted to science. And here I feel most timid. Whereas there is a wealth of philosophical writing on aesthetics, the aesthetics of science does not follow so easily.

Of course, to the working scientist it is not news that scientific work provokes moments of great feelings of beauty and awe, or other aesthetic experiences: When scientists write or talk about their lives, they often tell about such moments (Keller, 1983; Levi-Montalcini, 1988; Yukawa, 1982). Our task is to get beyond the mere bow of recognition of aesthetics in science toward something more probing and, in the long run, more systematic. For this we will look at a few cases in some detail, especially Charles Darwin and Jean Piaget. But first I want to touch on a few general questions.

ASPECTS OF THE AESTHETIC EXPERIENCE IN SCIENCE

First, we should take cognizance of the point of view reflected when we speak of aesthetic *feelings*, such as feelings of beauty and awe. Aestheticians are divided on this matter, but for understanding scientific discovery it seems to me that the right place to locate aesthetic experience is as one region within the affective domain, a region where cognition and emotion interact.

Second, it seems to me that the appropriate unit of analysis is not a single emotion or feeling, which might occupy a few seconds, but rather an emotional

experience, a structured period of time set off from other such experiences. Metaphorically, we are not speaking of single notes or chords, but rather of phrases, movements, and sonatas.

Third, in this enlarged idea of an emotional experience, it may be that any feeling might participate. Roughness prepares the way for smoothness, calm for thunder, frustration or sadness for joy, banality for astonishment. This opens the question then, whether, if any feeling can participate, what makes an experience an aesthetic one?

Fourth, how does the shape of aesthetic experience change during the life history of the creative person?

Fifth, what are the connections between the organization of affect and the other great organizations—knowledge and purpose—at work in a creative life?

Sixth, to what extent does the creative person have control over the occurrence and course of emotional experiences? Are emotions merely *reactions to* events in the creative life, or are they also purposeful acts and *part of* the process?

Seventh, what is the actual function of aesthetic experience in the process of scientific discovery? Psychologists interested in emotion have traditionally differed as to whether its function is primarily expressive, energetic, or directive. My impression is that scientists writing about their own lives often emphasize the directive function, as in statements insisting on the ultimate truth value of beautiful theories, even when those theories seem to be contradicted by the facts currently available. Sometimes, then, the desire to make one's science more aesthetically satisfying actually guides the direction of the work.

Finally, can science be taught well without adequate attention being given to aesthetic experience? Is the approach that says, "First learn enough, then you'll appreciate it," among other things, self-defeating?

VARIETIES OF AESTHETIC EXPERIENCE

When we ask more specifically, "What is aesthetic experience?," a useful way to begin is by trying to separate characteristics of the experiencing subject from properties of the object (or process, or idea) being contemplated. When we say, "Beauty is in the eye of the beholder," we implicitly take cognizance of this distinction, for the statement suggests its negative, that beauty is *not* in the object. Feelings of beauty and awe are good examples of subjective experience, while attributes of symmetry and complexity are examples of properties of objects.

In addition to properties of objects and experiences of subjects, a third aspect of aesthetic experience in scientific discovery must be the form or medium in which it is represented, both to the experiencing subject and to the world. Images, metaphors, diagrams, narratives, raw feelings and so on, all come to mind as media in which aesthetic experiences take shape. I mention this here for the sake of completeness but will not discuss it further.

I believe it is safe to say that the aesthetic of simplicity, symmetry, and harmony has been the dominant mood among those discussing the aesthetics of science (see, for example, *Fearful Symmetry: The Search for Beauty in Modern Physics* (A. Zee, 1986), and likewise, C. N. Yang's (1980) "Beauty and Theoretical Physics"). But an aesthetic of asymmetry, complexity, and diversity has found contemporary voices (see, for example, Freeman Dyson's chapter, "Manchester and Athens," in *The Aesthetic Dimension of Science* (Curtin, 1980), or my own paper, "Darwin's 'Tree of Nature' and Other Images of Wide Scope" in *On Aesthetics in Science* (Wechsler, 1978)).

In the past fifty years a third aesthetic has come into prominence: the aesthetic of the absurd, the incoherent, the quasi-formless. Beckett's *Waiting for Godot*, and Pollock's paintings come to mind as artistic examples; in science, more recently, we have seen the "chaos" movement (Gleick, 1987). Richard Feynman, a Nobel laureate in physics, recently gave voice to a measure of acceptance of this mood:

The theory of quantum electrodynamics describes Nature as absurd from the point of view of common sense. And it agrees fully with experiment. So I hope you can accept Nature as She is—absurd.

I'm going to have fun telling you about this absurdity, because I find it delightful. (Feynman, 1985, p. 10)

Rather than casting the discussion in the framework of a di- or trichotomy of two or three aesthetics, there is another approach that takes fuller account of the diversity of aesthetic experiences. Each person undergoes many forms of aesthetic experience. By attending to the various aspects of this domain, we may be able, eventually, to draw a multidimensional profile of each person and each experience. This approach would also help us to describe developmental changes in the aesthetic experience over the life history.

To give you a sense of this process, consider the following lists of attributes of aesthetic experience, one for the experiencing subject and one for the contemplated object, discussed earlier. These lists are provisional and incomplete, based on a number of conversations, and on autobiographical and other

accounts written by scientists. In some cases I have specified both members of a pair of polar opposites and listed them together; I have also listed near-synonyms together. In all cases these are not terms drawn from a thesaurus but are descriptions actually given by people experiencing scientific discovery, and talking or writing about it in a mood of interest in the aesthetic experience:

For the contemplated object

Order, pattern, rhythm, repetition, regularity
 Modularity (and non-modularity)
 Universality
 Law, inevitability
 Uniqueness
 Simplicity, unity, harmony
 Fitness, correspondence, invariance
 Balance, equilibrium, symmetry (and broken symmetry)
 Complexity, diversity, intricacy
 Density, richness of nature
 Growth, progress
 Reversibility, irreversibility

For the experiencing subject

Awe
 Beauty, admiration of nature or science
 Surprise, astonishment
 Joy, ecstasy, elation
 Struggle
 Pleasure of contemplation, fascination
 Strangeness, familiarity
 Expansiveness, flow, growth

With regard to each potential attribute of the aesthetic experience, there probably is no absolute value or intensity that is decisive. It is, rather, change in awareness that evokes the aesthetic experience. In our thinking about these matters, however, room must somehow be made for repeated changes: A symphony does not lose its value or its freshness on the second hearing. M. Csikszentmihalyi and I. Csikszentmihalyi's (1988) concept of flow—happy, exultant response to challenge—is a sensitive attempt to take account of this need for continuous extension of the self through cycles of strenuous effort, mastery,

and accomplishment.

The importance of each attribute to the creator cannot be measured by a frequency count of the number of times he or she mentions it. For example, one cannot imagine D'Arcy Thompson's great work, *On Growth and Form* (1917/1942), without imagining the writer as someone in love with pattern; and one cannot appreciate the book without sharing this love. Yet it is written in a rather dry style, and only in the epilogue at the end of the second volume does the author drop the veil: "For the harmony of the world is made manifest in Form and Number, and the heart and soul and all the poetry of Natural Philosophy are embodied in the concept of mathematical beauty." (Vol. 2, pp. 1096-1097).

I turn now to the examination in some detail of one scientist's aesthetic experience.

CHARLES DARWIN'S AESTHETIC FATE

My mind seems to have become a kind of machine for grinding general laws out of large collections of facts, but why this should have caused the atrophy of that part of the brain alone, on which the higher tastes depend, I cannot conceive....The loss of these tastes is a loss of happiness, and may possibly be injurious to the intellect, and more probably to the moral character, by enfeebling the emotional part of our nature. (C. Darwin, 1958, p. 139)

Charles Darwin's well known confession of the atrophy of his aesthetic sensibilities should be taken seriously, but in context. To do this we must look at the trajectory of Darwin's aesthetic development. He wrote his autobiography between the ages of 67 and 73. In it, he describes his earlier interest in various arts: music, poetry, fiction, drama, painting. From this document, from his notebooks, and from his published writings, it has been possible to reconstruct a fairly full account of Darwin's aesthetic tastes and development in the arts. (For a recent and probing effort, see Beer, 1983.) It appears that Darwin had a long and very full period of interest in the arts, fluctuating in intensity from moderate to very strong. Even in his later years he retained a love of fiction, especially novels with happy endings, as might befit an apostle of evolutionary progress.

More to the point, perhaps, is an examination of Darwin's scientific work. Line for line, he was not an especially eloquent writer. For literary style he certainly could not match his colleague, Thomas Huxley. The power of his writing, his ability to evoke the reader's aesthetic feelings, lies more in the structure and fullness of his argument, and in his devoted, tireless marshalling of the evidence to support it (Gruber, 1985). Still, we often see, especially in the

closing paragraphs of his chapters, a sudden turn toward a more eloquent and passionate style. As I have already pointed out in the case of D'Arcy Thompson, it is reasonable to suppose that Darwin's feelings, thus overtly expressed from time to time and in strategic places, actually suffused his whole work.

There is, furthermore, no reason to suppose that there was some mysterious split between the aesthetic feelings Darwin evoked in others and those he felt himself. It is much more plausible that he felt the feelings he evoked. This idea, that he was a vicarious reader of his own writings, applies even to the feelings of outrage he provoked in his antagonists. Darwin could empathize with them, and he used various literary devices to de-fang or placate his critics, as well as to answer them directly.

A key passage in Darwin's writings is the closing paragraph of *On the Origin of Species* (C. Darwin, 1859), the celebrated "tangled bank" metaphor. Here Darwin clearly expressed the synthesis of the two aesthetics, simplicity and complexity. On the one hand he evokes the richness of nature; on the other hand, he extols the few laws that, taken together, can explain this richness:

It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us. These laws, taken in the largest sense, being Growth with Reproduction; Inheritance which is almost implied by reproduction; Variability from the indirect and direct action of the external conditions of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and as a consequence of Natural Selection, entailing Divergence of Character and the Extinction of less-improved forms. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved. (pp. 489-490)

We encounter a similar, albeit less developed, duality in Darwin's vision in a passage in the *Beagle Diary* (C. Darwin, 1934), the more personal notes he kept alongside of the scientific notes, during his voyage on the H.M.S. Beagle.

I believe from what I have seen Humboldt's glorious descriptions are and will for ever be unparalleled: but even he with his dark blue skies and the rare union of poetry with science which he so strongly displays when writing on tropical scenery, with all this falls far short of the truth. The delight one experiences in such times bewilders the mind: if the eye attempts to follow the flight of a gaudy butter-fly, it is arrested by some strange tree or fruit; if watching an insect one forgets it in the stranger flower it is crawling over; if turning to admire the splendour of the scenery, the individual character of the foreground fixes the attention. The mind is a chaos of delight out of which a world of further and more quiet pleasure will arise. I am at present fit only to read Humboldt; he like another sun illumines everything I behold. (p. 39; written February 28, 1832, when Darwin was 23 years old, on first visiting Bahia, Brazil).

For Darwin, this was a momentous occasion, akin to one of Wordsworth's "spots of time." About the same scene, he wrote the next day:

To a person fond of natural history, such a day as this brings with it pleasure more acute than he may ever again experience." (p. 40, February 29, 1832)

On revisiting this scene later in the voyage, Darwin's diary entry displayed the same dualism, the same movement of ideas between wildness and taming:

...the land is one great wild, untidy luxuriant hot house, which nature made for her menageries, but man has taken possession of it, and has studded it with gay houses and formal gardens. (p. 417, written August 1-6, 1836)

A quarter of a century later, in the concluding passage of the *On the Origin of Species*, Darwin displayed the same dualism, but the focus was not the contrast between the subject-oriented "chaos of delight" and "quiet pleasure," or between the object-oriented "wild, untidy luxuriant" nature and "formal gardens." The epistemological movement 25 years later was between the visible "entangled bank" and the inferred "laws acting around us." When Darwin wrote, "There is grandeur in this view of life...." he was writing neither of the wildness nor of the laws, but of the productive relations between them (C. Darwin, 1859, pp. 489-490).

Various writers have mentioned Darwin's love of Milton's poetry, the fact that it was the one book he carried everywhere during the voyage of the *Beagle*, and the Miltonic voice in which he often wrote. Gillian Beer has pointed out some pertinent passages in Milton's *Comus*:

Wherefore did Nature pour her bounties forth.
 With such a full and unwithdrawing hand.
 Covering the earth with odors, fruits, and flocks.
 Thronging the seas with spawn innumerable,
 But all to please, and sate the curious taste?
 (*Comus*, lines 710-714, cited in Beer, 1983, p.35)

Milton goes on to argue that man must consume immensely, to counteract this superfecundity of nature, otherwise:

...strangled with her waste fertility,
 Th' earth cumbered, and the winged air darked with plumes;
 The herds would over-multitude their lords.
 (*Comus*, lines 728-31, cited in Beer, 1983, p. 35)

To this I would only add that it seems plausible to me that Darwin read the highly erotic, rhymed verse of his grandfather, Erasmus Darwin (1803), while still an adolescent in Shrewsbury. In both poets the richness of the world was a powerful theme, and though Milton was the greater poet, Erasmus Darwin was closer to home. He was also easier to read and a good bridge to Milton. Elsewhere (Gruber, 1974/1981; Keegan & Gruber, 1983), I have discussed the relevant proto-Malthusian passages (and now we see, Miltonic) in Erasmus Darwin's poetry, such as this one, which has quite a Miltonic ring:

All these, increasing by successive birth,
 Would each o'er people ocean, air and earth...
 The births and death contend with equal strife,
 And every pore of Nature teems with Life.
 (Erasmus Darwin, 1803, Canto IV)

I have said enough to recall the poetic origins and echoes to be found in Charles Darwin's thinking. But in addition to the particular passages I have cited, or others that could as easily have been cited, there is a more general point: the simple fact that Darwin had the opportunity to write the *Beagle Diary* and later the *Journal of Researches* (C. Darwin, 1839) as a free-ranging account of the voyage of the *Beagle*. The latter work is not simply a travel book enlivened with descriptive natural history. It is a great travel book, and it is so because it is permeated with Darwin's burgeoning theoretical preoccupations during and immediately after the voyage. (For a fuller account of Darwin's very early theoretical work, see "The Many Voyages of the *Beagle*" in Gruber, 1974/1981.)

I believe that creative workers often find some form in which to elaborate an early *initial sketch* of an important major work, sometimes much later, as C. Darwin did with the *Beagle Diary* and the *Journal of Researches*. Westfall (1980) described this process for Isaac Newton, Tahir (1989) did the same for George Bernard Shaw, and I discuss later a similar stage in the work of Jean Piaget. For creative scientists, the use of a relatively free literary form may be a good way to get some ideas down on paper provisionally, unhampered by the demands of scientific discipline.

I return now to the celebrated case of atrophy of aesthetic sensibility recounted in Darwin's autobiography (C. Darwin, 1958). I begin by discussing possible reasons for it, and then I question its extent and generality.

We probably cannot attribute the change in aesthetic taste perceived by Darwin to a general loss of gusto sometimes associated with aging: Darwin claimed that the change began when he was in his forties or younger, 20 to 30 years before he wrote his greatest works. Nor can it have been that an overwhelming preoccupation with work excluded all distractions. We know he had time to listen to readings of novels, and he had time for his children and friends, and for various community activities.

What was it then? It seems to me that cultural life, especially in the countryside of Down, may not have been all that stimulating. Moreover, the time in question was the heyday of the Victorian age. Perhaps Darwin did not come across any new material that would have captured and re-awakened his attention at any time in his life. As for rereading Shakespeare and Wordsworth, he had already done that. Sometime, probably in the 1840s, he had read Wordsworth's *The Excursion* twice. He never left Britain after the voyage of the *Beagle* around the world in his 20s, so the scenery he saw in later years was all more or less familiar to him.

Finally, he did not entirely lose his touch as an imaginative writer. The ingenuity of his late botanical experiments and of his studies of the behavior of earthworms excites our admiration. And, true to form, the closing passage of his last work, finished in 1882, the year of his death, displays the same sense of paradox, the same antinomic cast that we have encountered in his earlier writings. This time the paradox is not between wild and tame, or between entanglement and law, but between the lowly and the mighty, the minute cause and the great effect:

When we behold a wide, turf-covered expanse, we should remember that its smoothness, on which so much of its beauty depends, is mainly due to all the inequalities having been slowly levelled by worms. It is a marvellous reflection that the whole of the superficial mould over any such expanse has passed, and

will again pass, every few years through the bodies of worms. The plough is one of the most ancient and most valuable of man's inventions; but long before he existed the land was in fact regularly ploughed, and still continues to be thus ploughed by earth-worms. (C. Darwin, 1882, pp. 287-288)

It is worth noting the consistency with which Darwin used this antinomic literary device. *The Descent of Man* (C. Darwin, 1871) closes with a passage having a similar structure, this time declaring the contrast between humanity's lowly origins and the "godlike" creatures we have become.

I do not qualify Darwin's autobiographical remarks on aesthetic atrophy in order to deny their importance. But seen in the context of the life history, those remarks do not seriously challenge the idea that aesthetic sensibility is a ubiquitous and indispensable part of the process of scientific discovery.

JEAN PIAGET'S SENSE OF MISSION

Jean Piaget, the great Swiss psychologist and epistemologist provides a sharp contrast to Charles Darwin. At the age of 19 he published a long prose poem, *La Mission de l'Idée* (Piaget, 1915), in which he expressed his burgeoning ideas about religion, science, and philosophy (Gruber, 1982). By that time he was already an established malacologist, with over 20 published articles, some of them lengthy monographs, to his credit. A few years later he published a philosophical novel, *Recherche* (Piaget, 1918) which included a very interesting initial sketch of what was to become his life work. In spite of these literary beginnings, Piaget's later writings are notorious for their turgidity and opacity. This only shows how important it is to study the whole person, for Piaget was a clear, witty, and brilliant lecturer.

From Piaget's early writings one might have predicted his development toward a humanist, philosophical style, similar to Henri Bergson, whom he greatly admired. But he moved in the direction of increasing formalism in his attempt to logicize child thought. We can see his gusto and sense of play in the techniques he and his collaborators used to bring out children's thinking, but they disappear very quickly in his insistent formalism. We know, or guess, that the poet is still there, but he is hidden under a mass of symbols that are hard to appreciate, much less understand.

At the same time, Piaget maintained a lifelong interest in literature and music. He loved Proust and Bach, and he never lost his interest and pleasure in the world of nature—both the Alpine scenery that surrounded him in his walks, and his childlike, yet sophisticated pleasure in finding interesting specimens of

snails, or of the plant genus, *Sedum*, which he studied and wrote about for many years (Piaget, 1976; Vidal, 1989).

In a seminal work, *Icon and Idea: The Function of Art in the Development of Human Consciousness*, Herbert Read (1955) took up the theme of the necessity of aesthetic experience for the well-functioning of mind: "Poetry is a taking possession of reality, a first establishment of the frontiers of reality in our understanding" (p. 18), and cited Heidegger, quoting:

Poetry is the establishment of being by means of the word....poetry is the inaugural meaning given to being...not just any speech, but that particular kind which for the first time brings into...consciousness...the essence of all things—all that we can then discuss and deal with in everyday language. (Read, 1955, p. 18)

The creator, especially when starting out—as part of the process of commitment to a line of work, to a first and fateful set of projects, and to a personal style—needs some rich and flexible medium in which to explore the broad range of possibilities. Private notebooks can play this role, as Holmes (1989) has shown for Lavoisier, Bernard, and Krebs. Darwin, too, used his notebooks to this end, but, as I have shown (Gruber, 1974/1981), he also used his great travel book about the Beagle voyage as a medium for exploring issues in theoretical biology that were conspicuous in the 1830s, when he was young. Perhaps we ought to speak of *poetic liberty* rather than poetic license.

Part of this poetic liberty of the creator starting out is the search for an appropriate medium, and the medium appropriate for first moves is often abandoned along the way. The young Piaget had some sense of this, for he wrote:

The poet feels in himself a higher beauty, that his verses cannot paint and that they half kill. In his soul he attends a sorcerer's symphony of virtualities, a procession of dreams, colored and alive. But reality is singular, expresses only one of these possibilities, even depriving him of that which makes his true life. (Piaget, 1915, verse VI, p. 10, my translation)

In a beautiful chapter on adolescent thinking, Inhelder and Piaget (1955) discussed the adolescent's discovery of the set of all possible things and of the romantic, newly egocentric upsurge of exploratory, utopian, and even oceanic thinking that is liberated in adolescence, as a prelude to the productive work to follow.

Perhaps that chapter has something quite autobiographical in it. Its tone and its content, perhaps alone among Piaget's later works, remind one of his youthful

prose poem, *La Mission de l'Idée*. In Piaget's later work on the "equilibration model" of development (1985), he elaborated the theme that development takes the path of successive equilibrations and disequilibrations, leading to ever higher and more powerful forms of thought. He spoke of this as *equilibration majorante*, which has been translated as "optimizing equilibration." Perhaps it would be better to say "re-optimizing," because the optimum does not stand still. In any event, the fundamental thought-form is one in which the way to escape each cognitive developmental impasse is to move upward on the ladder of abstraction.

It is fascinating to discover this metaphor of *moving upward* in various passages in the prose poem, *La Mission de l'Idée*. In one verse of the 68-page work he creates an image of two boys lost in the forest:

The one worshipped, then persuaded himself that reality was good and the trails of the forest were a wise work whose unknown laws would not let him get lost. In his sincere faith he departed, refusing to look at anything but the end that his faith saw. He abdicated because he was afraid, and made himself stupid because he mistrusted himself.

The other doubted, thought. Then only did he pray. He felt the good in reality, but because he was courageous and because truth was dearer to him than his own happiness, he climbed a tree and studied the depths of the forest. And thus through his search he spied a pathway. He took heart and rushed toward it joyously.

Such is faith and such is sincere doubt. What the first boy calls humility is often only fear and cowardice. What the second calls skepticism is often only respect for an ideal of truth. (Piaget, 1915, verse XXXIII, p. 50, my translation)

The same theme of upward movement reappears in the final verse of *Mission*:

...When the idea is reborn, every man now suffering in the shadows will find his place in the vast harmony which by its crescendo will make life grow, so high that it will see God. But the rebirth of the idea requires the help of everyone. Metaphysics is not an aristocratic art. The scientist, who finds hypotheses, must build over them a grand edifice that can contain them; the Christian, who in the depths of his heart has felt a life, must assimilate it by an interpretation which justifies it; the moral man, who wants a rule of conduct to govern his life, must construct an idea to justify it. The special mark of each man must be his idea and from these ideals, numerous as the cells, the true idea will come forth like the soul from the body

Oh! that the tears shed during the war bear this beautiful fruit: the new birth of Christianity

For that is the mission of the Idea.

(Piaget, 1915, verse XLVI, p. 67, translation from Gruber & Vonèche, 1977, p. 37)

In my illustrations taken from the lives of Darwin and Piaget for this essay, I have chosen to emphasize one major theme for each: Darwin's recurrent interest in the antinomy between order and complexity, captured in his image of the "tangled bank" and Piaget's enthralment with the strategy of always transcending the level thus far achieved, captured in the telling term, *equilibration majorante*.

But I do not mean to suggest that each creative life can be reduced to one major theme. On the contrary, it is the interweaving of a number of themes and thought-forms that make up the fabric of a creator's thought. (I have developed this idea in more detail in other writings; see Gruber, 1978, 1974/1981; Gruber & Davis, 1987.) To distinguish the stable ideas from those emerging and those declining requires the careful study of the subject's whole *oeuvre*.

DIFFERENT STROKES FOR DIFFERENT FOLKS

Diversity

In looking at the lives of various creative scientists it becomes apparent that the aesthetic dimensions of their lives are quite varied. Consider two examples.

In his autobiography, the biologist Salvador Luria, (a Nobel laureate himself and mentor of another, James Watson, who co-discovered the structure of DNA), mentioned only briefly certain moments of ecstasy in his scientific work (Luria, 1984). Although he did not make much of the aesthetic side of his scientific life in this work, he devoted a whole chapter to his protracted struggles to develop his extra-scientific tastes, his appreciation of various arts. His efforts and pleasures in this vein continued unabated into his 70s.

Robert B. Woodward, the organic chemist, must have been one of the most single-minded scientists of his time, according to his daughter, Crystal Woodward, who wrote a biographical account of his life (C. E. Woodward, 1989). In it, she makes him appear almost monomaniacal in his pursuit of organic synthesis, in his immersion in his laboratory, and in his painstaking and brilliant visualizations of organic chemical structures. In her account, he seems to have had little extra-scientific aesthetic life, except for his personal style—

always dressed in blue—and his beautiful, polished lectures, which he illustrated at the chalkboard, always with his personal collection of colored chalks. His Nobel Prize citation mentioned specifically his contributions to "the art of organic synthesis," and his private notes show a constant attention to drawing skill and to pleasure on the occasion of discovery. A colleague, Frank Westheimer, wrote of him:

Even scientists who mastered his methods could not match his style. For there is an elegance about Woodward's work—his chemistry, his lectures, his publications—that was natural to him, and as unique as the product itself.

His real style was most clearly expressed in the syntheses themselves, in the ways he found to put molecules together, ways that somehow feel right—each step neatly designed to prepare for the next, a kind of art that combined inevitability with surprise, as in great classical music. (Cited in Woodward, 1989, p. 229)

Diversity in Similarity

In the annals of science there is hardly a more striking coincidence than the independent generation of the theory of evolution through natural selection by two individuals, Charles Darwin and Alfred Russel Wallace. Yet even when the creative product of two creators' efforts is quite similar, as with Darwin and Wallace, there is good reason to believe that the aesthetic trajectory of their lives was not. Darwin and Wallace, for all the similarity of the contents of their thought during one crucial period, differed widely in personal and scientific style; they also took quite different directions in their later works.

Another most dramatic example of this diversity in similarity is provided by the lives of Picasso and Braque. For a time they collaborated closely in the creation of cubism, and their individual works were virtually indistinguishable. But even at their closest there were important differences (see, for example, Rubin, 1989). Not only did they have different personal styles, but the overall development of their life histories was very different. I believe that when we make similar comparisons of scientists we will find the same diversity in similarity.

The Functions of Aesthetic Experience

Given our knowledge of the diversity of aesthetic experience, both in style and in developmental pattern, there is no reason to expect that such experiences will have the same profile of functions for all creative scientists, or to presuppose that

each form the aesthetic impulse takes in any one scientist has the same function. The physicist Richard Feynman took drawing lessons regularly for many years. He was also a talented and enthusiastic drummer. His lectures in physics were noted for their elegance, wit, and clarity. Although Feynman wrote two humorous autobiographical books toward the end of his life, his writing was not especially introspective. We probably would not guess that all these various expressions of his aesthetic feelings grew out of a single motive force. Rather, they appear to be the workings of a many-sided mind.

The idea of a profile of functions may be useful here. We can identify various functions that play some part in aesthetic experiences and activities, and we can devise means of indicating the relative importance of each function in a particular creator's life. The functions I have in mind include: expressive, decorative, recreational, motivational, and constitutive. The constitutive functions of aesthetic experience can be broken down still further: the idea of initial sketch, the suggestion and discovery of novelty, and the synthesis or integration of ideas and observations into more powerful, better organized schemata. Even one form of aesthetic expression, such as metaphor, may have all these functions. But to grasp the significance of a particular aesthetic act we must know the creator's life and work, and know them well.

I have been using almost interchangeably the terms "aesthetic experience" and "aesthetic act." I think this is justified, because the purpose of such acts is to engender such experiences, and the experiences cannot occur without the acts.

Eleanor Duckworth (1987) called her book about science education *The Having of Wonderful Ideas*. For a creative scientist there is no lure, no motive power more powerful than the prospect of having wonderful ideas. That feeling of wondrousness is both the rainbow and the rainbow's end. To draw students into the web of scientific work scientists should find ways to let their students know that this rainbow is their destination.

Wohlwill's *The Study of Behavioral Development* (1973) is a dry, technical book. It has the great merit of addressing itself to methods for the study of behavioral change, yet change is a subject that readily evokes the poetic mood. And so it was with Joachim Wohlwill. He created the epigraph for this book by selecting a page of three literary citations. Remarkably, Wohlwill chose to publish one poem, the longest citation, in the original German (Wohlwill, 1973, p. viii). He knew that the book would be read almost entirely by people with hardly a word of German at their disposal, so his choice provokes reflection. To me it suggests that printing that poem where he did was not so much a communicative act as it was a form of self-expression of Wohlwill's innermost feelings, something deeply personal, like planting his private flag.

The poem (translated quite literally here by Doris B. Wallace and me), by the 19th century German writer, Gottfried Keller, says:

Time does not pass, it stands still,
 We travel through it;
 It is a Caravanserai,
 In which we are the pilgrims.

A Something, formless and colorless
 That gains shape only
 As you emerge and plunge back into it.

It is a white parchment,
 Time, and everyone writes
 On it with his own red blood,
 Until the current disperses it.

Taken by itself, this might seem a little gloomy, suggesting that our best efforts are soon brought to naught, all our works ephemeral. But the poem should not be taken by itself, for it appears together with two lines from Robert Burns,

Look abroad thro' Nature's range
 Nature's mighty law is change.

And that is what excited Joachim Wohlwill.

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