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ABSTRACT

Crystallizing experiences are defined as those which involve remarkable and memorable contact between a person with unusual talent, or potential, and the materials of the field in which the talent will be manifested. Several biographies of talented people in several disciplines including music, mathematics, and visual arts are discussed. Examples of their crystallizing experiences are cited. The existence and structure of these crystallizing experiences are a derivative of the multiple intelligences theory of human intelligence. The nature of the experience depends on the age of the subject. The crystallizing experience seems to be more prevalent in mathematics and music than in the visual arts. It is a fragile phenomenon which occurs when circumstances combine inborn talent, self-teaching, and proper exposure to a set of materials in a particular way. It is recommended that all children be treated as if they have the potential for crystallizing experiences. They should be exposed at an early age to materials which may motivate them to explore a domain. (DWH)

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The Crystallizing Experience: Discovering an Intellectual Gift

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The Crystallizing Experience:

Discovering an Intellectual Gift

INTRODUCTION

According to standard mathematical history, Evariste Galois (1811-1832) was initially tutored at home by his mother and entered the public school at the age of eleven. Since his unpredictable disposition and stubborn attitude precluded any formal success as a student, he had to make the personal discovery of the world of mathematics on his own. Quite by chance he came across a geometry textbook written by Legendre:

> The book aroused his enthusiasm; it was not a textbook written by some hack, but the work of art composed by a creative mathematician. A single reading sufficed to reveal the whole structure of elementary geometry with a crystal clarity to the fascinated boy. He had mastered it. (Bell, 1965, p. 364)

Galois next turned to algebra and, finding no suitable textbook, began studying the works of Abel, Legrange, and Gauss in the original. After high school, Galois twice failed the entrance examination for the Polytechnique Institute in Paris (presumably for reasons other than mathematical ability); he was killed in a duel at the age of 21. Up to the day of his death he pursued mathematics on his own. His collected papers, many of them published posthumously, served as the basis for a new field of mathematics now called "Galois Theory."

Composer Claude Debussy (1862- 1918) began his formal study

of music at the Conservatory in Paris at the age of 9 and by 14 he had won the prize for piano. During these first years he did not show any interest in composition and in fact he hated his harmony class. This changed, however, when he began studying music theory with the young instructor Lavignac:

> Lavignac introduced Debussy to the music of Wagner. We read in the memoirs of (a fellow student) that one winter evening, after class time, the score was set out on the piano of the Overture to Tannhauser, the work which had recently created a notorious scandal at the Paris Opera. Here is (Debussy) confronted for the first time with the work of the composer who was soon to exert the most powerful influence on his creative life. The experience was overwhelming.
>
> The young professor and his eager pupil became so absorbed in the novel Wagnerian harmonies that they forgot all sense of time. When they eventually decided to leave they found themselves locked in and were obliged to grope their way out, arm in arm, down the rickety stairs and the dark corridors of the crumbling scholastic building. (Lockspeiser, 1962, p. 32)

As an apprentice porcelain decorator, August Renoir (1841-1919) demonstrated a facility with a paint brush that earned him an adult's wages at the age of 12. Despite this useful technical proficiency, he showed little interest in or sensitivity to the aesthetic qualities of the visual arts. During his apprentice years he made regular trips to the Louvre to sketch the masterworks, but only with the intention of using these sketches in designing porcelain.

One day during his apprenticeship he had this experience:

> He made a momentous discover, the sixteenth-century Fountaine des Innocents. "I stopped spell-bound," he said afterward. He gave up the idea of lunch in a restaurant, and instead bought some sausage at a nearby shop and returned to the fountain. He walked round and round it slowly, studying the group

> of statues from every angle. From that moment he felt a particular affinity with the sculptor Jean Goujon; his work possessed everything he loved: grace, solidity, and elegance, with the feeling of living flesh. "Goujon knew how to make drapery cling to figures. Until then I hadn't realized how drapery brings out the form." (Hanson, 1968, p.15)

These three events -- each crucial to the life of a particular creative individual -- share a number of common features. In each case, the individual discovered an important and hitherto unappreciated aspect of a particular field of endeavor. In reading Legendre, Galois chanced upon a world of mathematical discovery, filled with challenges. Through Wagner's opera, Debussy came to realize the creative potential of composition in contrast to musical performance. Renoir's experience at the Fountaine des Innocents crystallized a notion of the power of sculpture to transcend the limited world of decoration.

The three anecdotes also share the fact that each event occurred in relative isolation, either apart from or prior to formal instruction. Galois read Legendre outside of mathematics class. Debussy's discovery of Wagner occurred only shortly after his first systematic study of composition. Renoir began art instruction when he was 18, several years after his experience at Fountain. In each case, these young individuals brought certain expectations, skills, or predispositions to the three events, something apparently not acquired through previous experiences with the domains, as if they had been "prepared" for those domains in some special way.

Following the work of our colleague David Feldman (Feldman,

1980), we will designate these unusual encounters between a developing person and a particular field of endeavor as "crystallizing experiences." As we define them, such experiences involve remarkable and memorable contact between a person with unusual talent or potential and the materials of the field in which that talent will be manifested. As illustrated in our three examples, these crystallizing experiences may appear in advance of formal training. In any case, their dramatic nature focuses the attention of the individual on a specific kind of material, experience, or problem. Moreover, the individual is motivated to revisit these occasions for the indefinite future and to reshape his self-concept on the basis of these experiences.

Our interest in the existence and structure of these so-called crystallizing experiences has grown out of the theory of human intelligence called multiple intelligences theory (hereafter MI Theory). According to this view (see Gardner, 1983, for a detailed discussion), all normal individuals are capable of at least seven independent forms of intellectual accomplishment: linguistic, musical, logical-mathematical, spatial, bodily-kinesthetic, interpersonal, and intrapersonal. Initially, these intelligences exist as biological potentials; they are manifest in the opening years of life as the capacities to process certain kinds of information (e.g., patterned sounds) in certain kinds of ways (e.g., pitch analysis, phonological analysis). When the individual becomes capable of symbolic behavior, the intelligences are manifested in the deployment of various symbol systems (like natural language, drawing, map-making, religious

customs, and the like). Still later in development, the intelligences form the core capacities involved in all cultural roles, ranging from parenting to tool-making to the practice of science.

Under normal or reasonably enriched conditions, a human being can be expected to become involved with or achieve some measure of competence in each of these intellectual realms. Ultimate achievements, however, will vary greatly across individuals and across specific intelligences or groups of intelligences. One source of variance is probably genetic proclivity, but the earliness of exposure to a field and the amount of practice and training clearly make equally decisive contributions. One may achieve high skill in music through strong biological heritage (autistic children), through intensive training (the Suzuki method) and, most happily, through the epigenetic interaction of these features, as in the case of Mozart (cf. Gardner, 1982).

This overall framework, which we have only briefly sketched here, provides the motivation for our exploration of crystallizing experiences, as well as a structure for our model of giftedness. To illustrate, consider an individual with a rather uneven profile of intelligences, so that he possesses strong potential in domain x but only modest potential in domains y and z. Because of the accidents of parental interests or community concerns, that individual, as a child, receives little exposure to the activities of area x and is consigned to spend much time in the activities of domains y and z. It is possible that the individual will eventually acquire significant skills in y or z, or, less happily,

that he will fail despite his efforts and will lose motivation altogether. It is also possible that through a chance occurrence he will come into contact with materials (e.g., certain symbol systems, trained persons, engaging puzzles, etc.) that activate latent skills of his previously underutilized intelligence, x. Here is the setting for a crystallizing experience which, in the extreme circumstance, will change the individual's major activities of life as well as the way in which he thinks about himself.

A crystallizing experience, then, is the overt reaction of an individual to some quality or feature of a domain: the reaction yields an immediate but also a long-term change in that individual's concept of the domain, his performance in it, and his view of himself. We restrict the term crystallizing experience to those experiences which exhibit the set of symptoms just described. Of course, it is not possible to identify a crystallizing experience at the moment of its occurrence. Only retrospectively, after the individual's behavior in the post-crystallizing period has been observed, is it possible to single out an experience as having crystallized ensuing activities.

In our view, crystallizing experiences can take various forms. For example, some crystallizing experiences, which we term 'initial,' occur early in life and signal a general affinity between an individual and some large-scale domain in his culture: an example would be Galois' discovery of the excitement involved in mathematical proof. Other crystallizing experiences, which we

term 'refining,' occur well after an individual has undergone an initial attraction to a domain. In these refining cases, an individual discovers a particular instrument, style, or approach within a field to which he or she is especially attuned. Both the Renoir and the Debussy epidsodes might be thought of as 'refining' crystallizing experiences.

The theory of multiple intelligences does not prescribe the existence or the importance of crystallizing experiences. But it does suggest that such experiences may well occur across a variety of domains and it provides an explanation for why they may exert powerful, long-term effects upon the individual. It is consistent with the theory that many (if not most) individuals will experience the affective phase of such experiences; however, unless an individual is 'at promise' within a particular intelligence or domain, it is unlikely that the experiences will have a lasting effect and result in ultimate redefinition of self. In short, then, crystallizing experiences are neither necessary nor sufficient for ultimate achievement within the field; yet at the same time, they are a useful construct for explaining how certain talented individuals may first discover their area of giftedness and then proceed to achieve excellence within the field. Our present investigation of the construct of crystallizing experiences thus helps to assess the utility of multiple intelligences and brings that theory into contact with such broader issues as the nature of giftedness and the achievement of talent.

Several empirical questions can be asked of the construct of

crystallizing experiences. One set of questions concerns the commonness of such experiences: for example, are they typical or quite atypical; and if they are typical, are they restricted to those with intellectual gifts or are they found throughout the population? Another set of questions concerns the possible explanations for such crystallizing experiences: why do they occur, how do they occur, and what are their consequences?

Finally, a set of questions arises from the perspective of multiple intelligences. We are interested in determining how crystallizing experiences may differ across the various intelligences; for instance, do they appear in childhood in all domains or are they found at different points in different domains? We hypothesize that there may be "initial crystallizing experiences" that occur when a young child (or novice to the domain) makes his first genuine contact with that domain: these contrast with later-occurring "refining crystallizing experiences" that help the individual discover his or her own particular metier within an intellectual domain. In the present paper, we undertake an empirical investigation of the phenomenon of crystallizing experiences and then offer our own thoughts about why this singular kind of event may unfold in the manner that it does.

Of course there are other possible approaches to the issue of crystallizing experiences. One is to challenge the legitimacy of these reports. For example, to researchers who believe that the differences in achievements are due primarily to the amount of training received (c.f., Bloom, 1982), the crystallizing experiences, as in the vignettes of Galois or Renoir, might be

treated as anomalies, exaggerations, or retrospective justifications or rationalizations. On this view, the example taken from Debussy begs the question o talent versus training, since here the crystallizing experience appears after a considerable amount of training.

To illustrate this point, we can contrast the Multiple Intelligences (MI) perspective with a strict training theory. According to the training explanation, highly talented children like Mozart are anomalies. One cannot diagnose talent in a child until he has received a reasonable amount of training: and even then, what appear in the child's behaviors are manifestations not of inborn "talent" or "gift" but rather of the effectiveness of a particular set of training experiences. On the MI view, on the other hand, gifted children are anticipated -- children with a high degree of "raw" or unmediated intelligence in a specific field should under certain circumstances demonstrate evidence of that intelligence even before they are engaged in any kind of training regimen. In contrast to the training account, MI predicts a small but measurable number of such gifted children in each of the fields identified.

It is possible to subscribe to a combination of these points of view as well. For example, one might insist on the need for many years of training even in those cases where there is an initial, and perhaps inborn, proclivity to excel in an intellectual domain (c.f., Hayes, 1981). In fact, in detailing the basic "intelligences," MI theory is careful to distinguish between the "raw" or unmediated intelligence which predominates in

children; the marshalling of that intelligence to various symbol systems, as evidenced in older children; and the adoption of a much more specific and focused domain of expertise by the adolescent or young adult. Development from the "raw" intelligence to the focused domain of expertise is as much a function of training as a function of the raw intelligence. In this way, MI theory describes a lengthy gestation period for the development of even the most brilliant adult from the initial crystallizing experience to the level of mature performance in the domain.

With our own approach to crystallizing experiences and these alternative views as a background, we undertook an empirical investigation designed to assess the commonness of crystallizing experiences and to cull information on the ways in which they may occur. We used two sources of data in our study. First, we reviewed the biographical and autobiographical literature in the three aforementioned domains: mathematics, music, and the visual arts. A total of twenty-five people in these three fields were chosen and the available biographical materials were reviewed for each subject. We recorded the experiences that we considered as crystallizing as well as any other evidence documenting a subject's unusual talent as a child. Finally, any information about the nature of talents outside the domain, including success or failure in school in other areas, were noted as well.

The second part of the study involved interviews of teachers of especially talented students in the same three areas. We asked these teachers how they recognized talent in their students, how

the students performed during lessons, and whether or not they were cognizant of crystallizing experiences in their students or in their own personal histories.The results from the interviews are presented in the second part of the paper.

It is important to indicate how we regard these data. In our view, we have secured support for the notion of crystallizing experiences as a relatively common phenomenon among talented contributors in certain fields. On the other hand, we do not consider this review as decisive confirmation of our orientation or our conclusions for several reasons. First, the subjects were not selected in a random fashion; how can any preliminary study of giftedness in musicians fail to consider Mozart, for instance? Second, because of their retrospective nature, biographies lack the objectivity of an "on-line" longitudinal account of development. Finally, our analysis of the biographical materials is interpretive because of inevitable incompleteness in these reports.

In sum, our work here is presented as a preliminary investigation of the construct of crystallizing experiences derived from the theory of multiple intelligences. Our purpose is not to confirm or disconfirm the theory with these results; in that sense, the construct of crystallizing experience is not a critical variable within the theory. Instead, we look upon this work as an exploration of the theory of Multiple Intelligences through one particular manifestation. We feel that these findings may provide important insights into the nature of giftedness.

THE BIOGRAPHIES

Musicians

Our study indicates that 10 of the 11 distinguished musical composers and performers included in this review were either very talented as children or demonstrated crystallizing experiences. Table One indicates that three subjects who were recognized as talented while still young did not have crystallizing experiences: Mozart, Beethoven, and Mendelssohn announced their talent very early but the crystallizing of that talent occurred without fanfare or self-recognition.

--- Table One about here ---

Mozart and Beethoven came from musical families and their total immersion in the world of music can be attributed to the efforts of others; but this is not always the case. For example, Mendelssohn's parents provided the opportunity for private music lessons, but they had him tutored in other subjects as well. Later he studied law at the University and pursued music only as a sideline. Indeed, for the affluent and privileged Mendelssohn-Bartoldy family, musicianship and the life of the stage were considered degrading.

Rubinstein also came from a non-musical family. He announced

his talent in what might be considered a crystallyzing experience at the age of three, when the family purchased a piano:

> The drawing room became my paradise... Half in fun, half in earnest, I learned to know the keys by their names and with my back to the piano I would call the notes of any chord, even the most dissonant one. From then on it became mere "child's play" to master the intricacies of the keyboard, and I was soon to play any... tune that caught my ear. (Rubinstein, p. 4)

The family recognized the extraordinary talent of their son and obtained an audition with Joseph Joachim, a renowned nineteenth century musician, who guided his career and obtained patron support for him. It appears, then, that childhood talent, as exemplified by Mendelssohn and Rubinstein, can be recognized even by parents who are untrained in music.

The crystallizing experiences that appear in the biographies of the musicians are of two distinct types. First, there are the earliest experiences with music: experiences that reveal a "raw talent." For instance, Menuhin's reaction at age 3 to the violin sound of Louis Persinger or Stravinsky's reponse to Glinka's orchestra both fall into this category. The anecdote reported by Rubinstein above might also be considered as an illustration, although it does not have the same sense of immediate insight. Finally, Wagner's reaction as a teenager to the singing of "Fidelio" can be included in this category as well, even though he was appreciably older. These experiences suggest the minds of these musicians were "prepared" in some way for the experience of hearing the violin, the orchestra, or the voice.

Such responses to musical sound are not restricted to a few

isolated examples. In the interview portion of our study, a violin teacher reported a similar response in her selection of the violin as the preferred instrument when she was around six years old:

> I always knew it was the violin: I was always satisfied with the violin, and I never wanted to play a bigger instrument. Now part of that is a physical identification since I am a rather small person and it would have been hard for me to cope with a viola or cello. But some of it is identification with sound.
>
> I think that striking the keys of the piano is a very mechanical process. The piano is colder and the violin warmer. I had in my mind this very warm and very beautiful sound. When I began to play the violin and it was in my hands, I could feel a lot more direct control for the sound. I think that appealed to me.
>
> (How old were you at the time?) About 6 or 7.

A second type of crystallizing experience occurs later in development and presupposes an individual who is already attuned to the area of music. In this particular case, the "refining crystallizing experience" guides the individual to that area of the musical domain in which his strongest talents or deepest inclinations may lie. In the cases we studied, individuals who were already musically inclined discovered that composition -- or a certain kind of composition -- was the appropriate form of involvement in music. The experience of Debussy in transcribing the opera of Wagner (reported in the Introduction) and the reaction of Stravinsky to harmony and counterpoint are good examples of this form of crystallizing experience. In each case, the crystallizing experience involves the recognition of the complexities of composition. The reaction is not that of the "initiating experience" of early youth, in which the "raw

intelligence" encounters the domain itself for the first time. Rather, one sees at work a more mature problem-solving faculty that perceives subtle distinctions or potentials in the materials of the domain. This "refining experience" also served as a revelation to the artist, but in a way that is more sophisticated than the earlier "initiating" experience.

As a young adult, Pierre Boulez recognized in the music of Messiaen a "new language:"

> Here was the music of our time, a language with unlimited possibilities. No other language was possible. It was the most radical revolution since Monteverdi, for all the familiar patterns were now abolished. With it music moved out of the world of Newton and into the world of Einstein. (Peyser, 1976, p.25-26)

Boulez had been trained in standard analyses of harmony and counterpoint, but his understanding of these dimensions changed when he heard Messiaen's compositions. In this case, we see the reaction of the relatively mature artist to the most serious and profound deliberations of the art form. According to our analysis, these insights reflect not the "raw intelligence" or even the manipulation of the symbol system, but rather the skills important to a domain or subdomain of the adult culture.

It appears, then, that all crystallizing experiences are not the same: instead, they reflect the level of development in the artist (or scientist). The developmental gap between the young Menuhin and the mature Boulez provides a picture of a spectrum of experiences that range from first contacts in childhood -- the more dramatic crystallizing experiences of the untrained but

extremely talented individual -- to the more mature decisions and reflections of young adult artists and scientists.

On several counts, Haydn emerges as an anomaly. He did not attend the Conservatory, he received no individual training, and he was never an accomplished performer. Haydn sang in the Vienna Boys' Choir as a child, but during that time he received no systematic instruction. His talent for musical composition developed over a period of many years through self-guided methods and, indeed, at the time he was 50, his younger brother Michael was considered by contemporaries as a far better composer. However, unlike Michael, Franz Joseph continued to develop, greatly influenced Mozart, and ended up as one of the titans of composition.

In sum, the musicians are characterized by talented childhoods, some crystallizing experiences that occur at different points during development, and relatively little self-instruction, especially in the realm of performance. There are important similarities as well as significant differences to be found in the analysis of the domain of mathematics.

Mathematicians

An early beginning proves even more important in the area of mathematics than it is in music. In almost every case, our subjects made important, seminal contributions to the field of mathematics before they were 30 years old. This appears to lend credence to the contention that "mathematics is a young man's game." Also, 6 out of the 8 mathematicians were legitimate childhood prodigies; and this list does not include G.H. Hardy, who was an outstanding high school student, and David Hilbert, who consistently received "Excellent" in mathematics. Table 2 also documents the five instances of crystallizing experiences in this group.

-- Table Two about here--

A brief review of the mathematicians who demonstrated talent during childhood underscores the fact that in mathematics the accomplishments of these subjects far surpass those of even the most gifted high school students. Gauss derived important principles of prime numbers at the age of 15, and Poincare's genius for mathematics was a matter of public record even before he took the admissions test for the Polytechnique Institute. Wiener's school career speaks for itself: B.A. at 14 and Ph.D. at 18. Von Neumann was considered a genius by everyone who knew him. Eugene Wigner, a Nobel laureate in physics, was a good childhood friend who said:

Particularly from having known Jansci von Neumann (as a

child), I realized what the difference was between a first-rate mathematician and someone (like me). (Heims, 1980, p. 43)

We may conclude that marked talent during the childhood years is fairly commonplace among mathematicians, just as it is among musicians.

Mathematics proves quite different from music, however, with respect to the role that self-training can play. Although highly unusual in music -- Haydn alone fell into this category -- self-training is almost commonplace in mathematics. Galois and Ramanujan were almost entirely self-trained, and, to a lesser extent, most of the other mathematicians taught themselves a significant part of their field. Furthermore, one of our interviewees, a university mathematician, asserted that "all the masters taught themselves mathematics." Of course, it is possible that self-training is more difficult in contemporary mathematics, where there is so much material to be mastered before original contributions are possible. It is also possible that self-training is found only in those areas marked by the fewest conventional constraints (the frontiers of mathematics, writing, jazz, and so on), simply because the conventional constraints can only be learned through rigorous formal training (e.g., performance of classical music, mastery of law, medicine, or laboratory science). At any rate, the distinction is fairly robust in the subjects reviewed here under mathematics and music.

Both Galois and Ramanujan serve as excellent illustrations of the role of a crystallizing experience in the developing career of a mathematician. In both cases, initial contact with the field

came in the course of reading a mathematics textbook on one's own. Galois read Legendre, whereas Ramanujan read a text of a substantially different sort.

Born to a poor family in India, Ramanujan's facility with numbers and interest in mathematics appeared in elementary school. His obsessive devotion to mathematics, however, made him a poor student overall. He failed to complete even one year at the University, though he had received a scholarship for his mathematical skills. Leaving the University, he took up a job as a clerk and continued his mathematical research on his own, publishing several papers and receiving some encouragement from local mathematicians. At the age of 25, he wrote a letter to the English mathematician, G.H. Hardy, in which he announced several of his discoveries. Hardy was so impressed with the originality and insight of the work that he secured a scholarship for Ramanujan at Cambridge, and they collaborated there until Ramanujan's death at the age of 32. Ramanujan was the first Indian elected to the Royal Academy, receiving that accolade at the age of 28.

Ramanujan's crystallizing experience occurred while reading a mathematics textbook:

> It was in 1903 on a momentous day for Ramanujan, that a friend of his secured for him the loan of a copy of Carr's Synopsis of Pure Mathematics. Through the new world thus opened to him, Ramanujan went ranging with delight. It was this book that awakened his genius. He set himself to establish the formulae given therein. As he was without the aid of other books, each solution was a piece of research so far as he was concerned.
>
> He first devised some methods for constructing magic squares. Then he branched off to Geometry, where

> he took up the squaring of the circle and succeeded so far as to get a result for the length of the equilateral circumference of the earth which differed from the true length only by a few feet. He (then) turned his attention to Algebra where he obtained several new series. (Seshu Aiyar, 1927, p. xii)

These feats are even more remarkable when considered in the light of the text that Ramanujan was working with. G.H. Hardy noted:

> I suppose that the book is substantially a summary of Carr's coaching notes. If you were a pupil of Carr, you worked through the appropriate sections of the Synopsis. It contains the enunciations of 6165 theorems, systematically and quite scientifically arranged, with proofs that are often little more than cross-refences and are decidedly the least interesting part of the book. All this is exaggerated in Ramanujan's famous notebooks (which contain practically no proofs at all), and any student of the notebooks can see that Ramanujan's ideal of presentation had been copied from Carr's. (Hardy, 1940, p.7)

Ramanujan's experiences with Carr's text prove relevant to our discussion in two ways. First, despite its unusual pedagogical style and a minimum of explanation, this book revealed to Ramanujan the world of mathematics; his intellect filled in the gaps. Second, the book had a profound impact on the manner in which Ramanujan pursued the field as an adult. In other words, Ramanujan was crystallized to mathematics via Carr's Synopsis and can be said to have been stunted by it as well.

Hardy's own crystallizing experience was as different from Ramanujan's as their cultural backgrounds and schooling. Whereas Ramanujan was self-educated in a small village in India, Hardy was thoroughly trained in the English public school system. Though an excellent mathematics student throughout school, he did not develop a passionate devotion to the subject until he worked with

a particular professor at Cambridge. That experience crystallized his sense of the subject matter as well as his view of himself as a "real mathematician with sound mathematical ambitions" (Hardy, 1969 pp. 23-24).

In contrast to Galois, Ramanujan, and Hardy, the crystallizing experiences of Hilbert and Gauss were manifested in significant mathematical discoveries made during early adulthood. Gauss discovered the construction of the 17-sided polygon, a major contribution to the geometry of Euclid. In announcing the discovery, Gauss stated with evident pride the significance of his achievement within the context of mathematics. At the age of 25, Hilbert published the proof demonstrating that the solution to Gordan's problem was impossible. This proof raised a considerable stir in the mathematical community at the time, and later, when the proof was demonstrated to be correct, Hilbert's concept of himself as a mathematician, as well as his reputation within the field, was firmly established.

The aforementioned relationship of crystallizing experience to developmental level re-appears in mathematics. The earlier "initiating" crystallizing experiences ushered in the rapid development of certain talented subjects, in which they reached adult levels at an early age (Galois and Ramanujan; Rubinstein and Menuhin). With the older children and young adults, on the other hand, the "refining" crystallizing experiences reflect an interaction between an already blossoming talent and certain more subtle, but crucial, distinctions within the domain (Debussy and Boulez; Gauss and Hilbert). In some cases, a prodigious talent

together with a highly supportive initial environment removes the opportunity (or the need) for a crystallizing experience in childhood (Mozart; Wiener). One finds examples of autodidacts in mathematics as well as music (Haydn; Galois and Ramanujan).

Finally, in both domains, the nature and extent of crystallizing experiences appears closely related to the environment in which the talented child is raised. Crystallizing experiences prove more likely in those environments in which the domain is not stressed or where it is underutilized -- Ramanujan and Galois serve as illustrations. But Hardy and Debussy suggest a more complex explanation. In these two cases, the domain was thoroughly supported in childhood -- Hardy in the English public schools and Debussy at the Conservatoire -- and consequently the crystallizing experiences occurred closer to adulthood, as the subjects developed new insights into their respective domains. For instance, Debussy's crystallizing reaction to the scandalous music of Wagner was in part a response to the conservative and perhaps uncreative atmosphere that permeated his theory and composition instruction. Finally, those environments that provided strong, immediate experiences in the domain from an early age (Wiener, Mendelssohn, Mozart) were least likely to produce crystallizing experiences.

Visual Artists

The pattern of childhood talent and crystallizing experiences that cuts across the domains of music and mathematics does not recur in the domain of the visual arts. As seen in Table 3, there are only two talented children, Rembrandt and Turner, and there are only two clear-cut crystallizing experiences, Renoir and Klee. Consequently, while the evidence from music and mathematics provided support for the notion of crystallizing experiences, the evidence from the visual arts causes us to reconsider the pervasiveness of this phenomenon.

--- Table 3 about here ---

Turning first to the question of early talent, there are no child prodigies; the closest contenders were Rembrandt and Turner, who had acquired substantial reputations by the early twenties. Second, both candidate crystallizing experiences occurred in early adulthood to subjects who had already defined themselves as practitioners in the field. In a sense, Renoir at the Fountain des Innocents and Paul Klee experiencing the beauty of nature in an aquarium in Naples, are reminiscent of Debussy or Hardy: young adults making a refined discrimination in their chosen field. Only if we broaden the concept of crystallizing experiences to a more general experience -- like working with fellow artists or viewing the masters in a gallery -- can a greater number of visual

artists be included. For instance, Cezanne, Miro, and Cassatt all found inspiration for their own work in these ways.

One possible reason for this distinction between the Visual Arts and the other two domains arises from the following: it is much more likely for an artist to take up the career during young adulthood than for a musician or mathematician. VanGogh and Matisse are come to mind as examples. In our interviews with teachers (discussed in detail shortly), we asked a distinguished and extremely knowledgeable college mathematics professor if he knew of any students who entered the mathematics program after a career in another field. He answered, "It probably happened twice in the history of mathematics. I really don't know of any examples of that.". We asked the same question of the director at a college of art. His response was quite different:

> In this school this year we only took 23 students out of high school in the whole student body of about 600 students. We tend to have older students. It is a tough school to get into out of high school, simply because if we let them in they flounder...(Do you find people who quit a job in order to come to school for art training?) Yes, all the time. One of my staff members was an attorney. He is now an artist. He was in his 30's or early 40's and he made a complete turnaround. It took him a long time of real struggle to get anywhere. But now he is an artist of real merit.

From one perspective, it might appear that our view of crystallizing experiences is invalidated by these findings from the visual arts. Yet, paradoxically, these findings reinforce a principal tenet of MI theory. Rather than development occurring in a parallel fashion in every domain, our survey suggests that an experience critical in certain domains -- e.g., the early

emergence of the talented mathematician or the musician -- proves relatively unimportant in another cultural domain, the visual arts. Just why this is so is difficult to say. It may be that these three domains are viewed in a particular way by Western culture and may, in fact, be viewed differently by other cultures. For example, in Bali it might turn out that the visual arts are heavily stressed in early life, and that consequently there are more crystallizing experiences and more examples of prodigious behavior in that domain. It is also possible to imagine a society in which logical-mathematical precocity is of no relevance, or even actively discouraged, in which case one would not expect to find rapid development in that domain.

Another quite different explanation suggests that the mental processes involved in the visual arts develop at a different rate and hence are less susceptible to the one-time crystallizing experiences than are the quickly developing and more digitalized processes entailed in other domains. Mathematics and music, for example are both more self-contained, more likely to develop in relative isolation from the real world, and relatively digital and notational. In contrast, according to this analysis, the visual arts relate from the first to the external world, and are not in any sense self-contained; also, digital or notational processes do not play any role in the visual arts which inherently entail continuous and analog symbol systems (Goodman, 1968).

THE INTERVIEWS

The information and insights obtained from the biographical literature provided one important and useful perspective on the phenomena of Crystallizing Experiences. As a source of data, however, the biographies have several significant shortcomings. First, biographies are often derived from the reminiscences of the subject and the subject's friends after a successful career. The biographies also restrict our exploration, in tha: they provide no opportunity for cross-examination. It was for these reasons then that we supplemented the investigation of biographies with interviews of master teachers in these three domains. We hoped that intensive conversations with master teachers would provide an important supplement (and perhaps a needed corrective) to information culled from the genre of written biography.

During the interviews, we posed a large set of questions. We sampled broadly for two reasons: (1) our interest in the issues surrounding the discovery and development of talent in general; (2) our desire not to focus directly on crystallizing experiences. (As will become evident, we succeed quite well in masking our goal of eliciting crystallizing experiences from these teachers!). Among the questions we posed were whether or not teachers perceived some of their students as more talented than others; if they could recognize that talent quickly and easily; what skills co-occurred with the talent in question; and, of course, whether or not the teachers had observed or been informed of any

crystallizing experiences.

The subjects of the interviews were teachers who had worked with gifted students. The music and art teachers were affiliated with private schools or colleges for music and art. The two teachers of mathematics were professors at a university. The interviews lasted about one hour; they were tape recorded and the tapes were later transcribed. The quotations reported here are taken from those tapes with only minor editing to improve continuity. Since the teachers responded to the interviews with a frank honesty, even when the questions concerned their own development, we will refer to them only through their specialties: violin, cello, piano, photography, number theory, and topology.

Crystallizing Experiences

The teachers did not report Crystallizing Experiences on the part of their students. Although this finding was unanticipated, we can offer an explanation in retrospect. In the biographies, crystallizing experiences were most frequent in precisely those cases where there was little or no teaching or where there was an early discovery of the domain before teachers had been contacted. Even in those cases where crystallizing experiences occurred relatively late, the individuals were frequently alone and engaged in self-instruction when it happened. It may also be that individuals themselves do not recognize a crystallizing experience fully at the time that it happens; only in retrospect do individuals become aware of it. Finally, crystallizing

experiences are by their nature intensely personal and private: adolescent students may be reluctant to share these with others, even trusted parents and teachers.

Although the teachers did not observe crystallizing experiences in their students, most of them reported them in discussing the development of their own careers:

> Photographer: When I was growing up I had very little exposure to art; we visited the Metropolitan Museum maybe once. Then, in the navy, I was lying in my bunk reading the book Lust For Life, the novelization of VanGogh's life, and I noticed that the pictures in the back were in the Museum of Modern Art in New York, and since we were in dry dock in the Brooklyn Naval Yard at the time, I jumped up and went to see them.
>
> I remember that day like yesterday -- the weather, the people on the street. I guess you could say it was an "epiphany." When I left the Navy, I tried to get a job as a guard in an art museum because I had been a payroll guard in the Navy..
>
> Topologist: My father was an interesting person mathematically. He had a great deal of facility although he was no mathematician. He had worked out for himself a number of interesting "tricks" and I can give you an example of one. You would write a number and he would write after it immediately another number. When you added the two, the answer was divisible by 37. I remember him doing this kind of trick and being very impressed by it and being very curious about how it could work. I was attracted to this because it was acompletely unposed problem, not a problem in a book. He did this trick, and he didnt' have any training -- how did he figure it out?
>
> I think that kind of experience was probably very important to me at the time.

These two experiences are quite different in terms of drama and immediacy. And yet they share a common quality -- they serve as a reference point in the individual's perception of his development as an artist or mathematician. For the photographer, the situation involved the first contact with the world of art.

Its impact was quite immediate and profound, and we might suppose that he was "prepared" in some way for this experience. In the second case, what was crystallized was the topologist's appreciation of mathematics as a field of inquiry. As a field, mathematics contains many problems that have no solution; problems posed in texts, on the other hand, inevitably do have solutions and their study is not representative of the highest and most creative aspects of the field.

The teachers also discussed a phenomenon that might also be interpreted along "crystallizing" lines -- choosing the instrument in the domain (e.g., violin, photography, or topology). We found that the teachers described this choice as if it were "predetermined" in some way -- as if they had to discover the instrument that was most appropriate for them. This suggests that talent may be tuned not only to a domain, but, more specifically, to a particular approach within that domain. For example:

> Violinist: I have found that it is not just enough to be musical; there has to be some orientation toward the actual physical process of playing around <u>that</u> particular instrument. For example, when I started musi, I wanted to play the flute. But then my idea changed around 6 or 7. My mother said that I would begin the piano, but by that time I wanted to play the violin, but she insisted on the piano as a "basis." It was very clear to me as a child that I was not primarily interested in piano even though I learned it easily and well. I really wanted to play the violin, and through my subsequent study it was that way: I <u>knew</u> the violin was ... me.
>
> We would listen to the radio, we heard classical music... I had in my mind this very warm and very beautiful violin sound. When I began to play the violin and it was in my hands, I could feel a lot more directly the control of the sound. I think that appealed to me.
>
> It is quite the opposite for other people. I have a friend who is a wonderful pianist; she is very

talented. She took up the cello and she told me that she could never play in tune on the cello. She is the despair of her cello teacher. She is a wonderfully talented pianist, and yet somehow she didn't click with the cello. She liked it and she wished she could do well on it, but it just didn't suit her.

Pianist: It often happens that somebody is extremely talented on the violin and starts on the piano, for instance, and does very poorly. Some of my colleagues have told me that they have done that.

I personally encourage the children to start a general education in music with the rhythms of dance and playing with different kinds of instruments of very simple types. So they have a chance after a year maybe of that to decide with their teacher which instrument is best. They play those simple recorders and pitch pipes and drums and string instruments and keyboard instruments. They may gravitate toward one of them. That is the more natural way.

Similarly, in art school, students are exposed to a vast array of media, from oils to watercolor to goldsmithing to videotape:

Photographer: Just as I talk I remember a student who came here to be sculptor, and then went down the the photography department, just to learn enough photographic technique to photograph his sculpture, and he found that he really was a <u>photographer!</u> It happens all the time. (Art school) is a smorgasbord and you have to find how you operate and then find the medium that is most appropriate... Film, photography, woodworking, printmaking, every kind of sculpture you can imagine -- it is not just a coincidence that art schools are the places that apeople go to become artists.

These early experiences at "choosing an instrument" can be considered fine-tuning in the domain -- finding a niche within the field; in this case, the teacher serves as an important aid in this search for the instrument. In fact, the teachers report that an important part of their job is to provide the rights kinds of experiences that help their students choose wisely. At the same

time, however, several of these experiences sound very much like "crystallizations" in themselves. In these cases, the teacher does not play an important role. Both Yehudi Menuhin and the violinist in our interviews reported that the sound of the violin was different for them as young children, before any formal instruction. In these cases, hearing the violin crystallizes the sense of the individual as a musician at a time antecedent to formal training. We consider these types of revelations to be legitimate examples of crystallizing experiences.

These examples of choosing an instrument recall our distinction between initiating crystallizing experiences and refining experiences. That is, the choice of the instrument does not serve to crystallize the youngster to the domain per se, but rather to the way in which that child will enter the domain. So, it is a crystallizing experience at the time that we usually find the initiating experiences, but it has more of the flavor of the refining experiences generally found later on.

The issue of talent

As a part of our interest in crystallizing experiences, we talked to teachers about how they judged the talents of their students -- what specific things made some students special, how quickly could the teachers make such a distinction, what specifically marked the differences among students, and so on. We were particularly interested in determining whether the teachers

would report simply that children <u>are</u> talented, or whether such differences were merely a matter of hours of practice.

The answers prove quite instructive. On the one hand, the teachers described, quite articulately, differences among their students that may be attributed to differences in talent. At the same time, those teachers often denied outright that there was such a quality that operated independent of their teaching. For example:

> Violinist: You can notice the very great musical feeling sometimes from the very beginning. A student can play a little Bach duet, just beautifully, with such grace and taste and (still) be quite elementary (in terms of technique). I heard a tape recently of an 8-year old girl who plays so beautifully, so musically. Now, she is not particularly advanced for 8 years old by our standards today, but in her playing there is such a feeling of her whole being; and just so free, and such expression in it, that I thought on hearing the tape, "Hmm, this is a remarkable child."

> Photographer: Some of those ways of being in the world seem somehow more nutritious and salubrious to us than others. Those are the people we think of as having talent. And they have some of the characteristics of being clear, and vulnerable, and graceful in a potent way. I suppose that is really the magic that you are talking about (with respect to "talent"). I don't know where it comes from.

> Topologist: (In talking about a former student) He was very, very bright. Throughout his period here as a graduate student we regularly recognized his grasp of things. He was always ahead of the other graduate students.

> (Question: Are there things in mathematics that are untaught or unteachable?)

> I don't know what it is and I wish I could tell what it is that makes someone good at mathematics. It is very hard to <u>teach</u> somebody mathematics when you don't know how to start. When you do mathematics, you rather

> naturally "see" certain kinds of relationships and you don't have to be told what they are, and you get the drift. And when you get somebody (in class) who doesn't see the world that way, it is extremely different. I can't figure out why it is that I can't explain to them why 2+2 is 4!

At the same time the teachers also said:

> Cellist: I think that one of the most important things is cultivating a love of music in the young person. If you start them very young and train and develop them slowly, then you have the time to set up the technique but at the same time to develop the love of playing and the love of music, and that in the long run will make for a child who want to play well... who will develop a musical soul from that.
>
> Number Theorist: (Question: In mathematics, what can't be taught?) Anything can be taught! The difference is strictly in terms of motivation. To be a mathematician you have to "do math" 16 hours a day.

These quotations suggest two different perspectives on eventual success in a domain -- a special quality, aptitude, or predilection in the learner versus a disciplined motivation derived in part from well-managed teaching. The two views were not stated as contending points of view; instead, they comprised an inconsistency within a single point of view. That is, we found several teachers who reported both perspectives in the same interview. Of course, the two perspectives are not logically contradictory; success in a field could result from a combination of natural aptitude and good teaching. However, the teachers did not appear to embrace this compromise position and maintained instead either one pole or the other. Since a primary goal of the interviews was to determine how teachers conceptualize the notion of "talent" in their students, we must consider this result in some detail.

There is an explanation for the apparent inconsistency in the teachers' point of view. Good teachers have a high investment in the act of teaching and in its role in the process of the development of the mature artist or mathematician. They believe -- they must believe -- that teaching makes a difference. At the same time, however, they actively seek out those students who display unique qualities or talents within the field, even before the instruction has begun. This is equally important to the teaching process: for one thing, students with these special qualities are more likely to achieve success, but perhaps more importantly, they are more likely to continue the development of their talent over a longer period of time. The teachers, and perhaps especially those in music, consider the time they spend in instruction as an investment in a particular student, and they are very careful to select those students who will not squander that investment. They make this choice on the basis of motivation and aptitude. Consequently, the teachers can discuss aptitude in detail and they can articulate specific skills and behaviors that they look for as indicators of aptitude. These concerns lead to the paradoxical situation where the teacher can, on the one hand, claim that anything can be taught to anyone who is properly motivated, while at the same time actively seeking out certain kinds of students to receive that teaching.

In choosing students, the teachers look for several very specific traits that in their experience are related to eventual success. For instance, the number theorist described one such attribute he had observed in successful mathematicians:

Number Theorist: Yet another interesting trait is

> "artful dodging." Some people, when they run into a problem, persistently remain there even if they are getting no closer to a solution. This is counter-productive. Others, if they are "artful dodgers," know enough to try something else, or to drop the problem, or to contrive the skill that they lack. This is much more adaptive and productive.

And the cellist who described the need for "love of playing" earlier, also looked for the following skills in young children:

> Cellist: The talented generally have strong, flexible fingers. This is a real key to the whole of playing. The child has to be strong enough to push the string down, but at the same time the hand is still flexible so that you can get a beautiful sound. I can just tell when a student comes in, in the first month of lessons, I can tell by the feel of their hand whether it is going to be easy or hard for them.

The music teachers also mentioned the ability to handle different kinds of problems (e.g., key, rhythm, fingering) at the same time, as well as the ability to process information quickly (especially in sight reading). The mathematicians mentioned the ability to identify and focus on one particular quality of a problem. So, even as they talked in general terms about "lyricism" or "insightfulness" or "vulnerability," the teachers also talked about specific skills like intonation, craft, and problem-solving. It does not appear that "talent" as described by these teachers resides strictly in either the mysterious intangibles nor does it reside in the technical faculties. Rather, talent comprises both factors and perhaps they cannot and should not be separated.

Motivation is yet another feature to which teachers pay careful attention -- the love of playing in a young musician, or the desire to "do mathematics 16 hours a day." To some degree, motivation is outside

the direct control of the teachers and so they are very careful to evaluate motivation in their students; but at the same time, they feel that motivation can be instilled and to this degree they can affect it. In contrast, talent, as defined in our culture, is entirely outside the control of the teachers, and again, this probably is responsible in part for the unenthusiastic response of the teachers to the construct "talent."

While teachers claim that it is important to have motivation, and that this is within the students' (if not the teachers') control, the theory of multiple intelligences suggests a different perspective. Specifically, turning the usual formula on its head, we propose that individuals are, or become, motivated to the extent that they have some facility within a particular domain. That is, a talented mathematician would be more likely to do "mathematics 16 hours a day" because of a basic understanding of the domain and the intriguing problems that it presents than the person who does not have that talent and does not understand the domain in that way. Motivation then would be the consequence of talent rather than the explanation of it.

In sum, then, the teachers described differences among their students along several lines. They articulated general differences -- the love of playing, the insightfulness, the vulnerability; and they talked about specific skills and attributes that contributed to this success, such as flexible fingers, facility with manipulating symbols, rapid processing of information, and so on. This is quite compatible with the incidence of childhood talent found in the biographies and the specific skills displayed by those subjects when they were children. Taken together, the two sources of data provide a more complete picture

of the early development of talented children.

When asked specifically about this talent, however, the teachers responded in two nearly contradictory ways. While they described differences among their students, they often denied that these differences were independent of teaching and insisted instead that they were the product of external factors such as "motivation." This response was quite unexpected since there is nothing similar in the biographical literature. We interpret it as a reflection of an educational philosophy that emphasizes the potential of each student rather than the constraints posed by limitations in talent.

CONCLUDING REMARKS

It is important to indicate certain limits intrinstic to our study. To begin with, there are limitations in theory. While the perspective of multiple intelligences can, loosely speaking, be considered a theory, it clearly lacks axioms, postulates, a set of testable hypotheses, and other paraphernalia of a theory in the hard sciences. By the same token, the construct of crystallizing experiences does not follow in any lock-step fashion from the treatment of giftedness in MI theory. As we have seen, there are individuals of indisputable achievement who lack crystallizing expereinces, and, without a doubt, there are other individuals who experience some, or even all, of the features of a crystallizing experience without achieving notable success in any domain. What

lends our study urgency is the need for a construct which is consistent with the major assertions of MI theory and which at the same time helps to explain, if sometimes in a post-hoc fashion, major findings concerning the genesis and realization of talent. It is in this spirit that we have formulated our construct of crystallizing experiences and examined it in the light of biographical and interview testimony. To the extent that the consruct has proved its utility (and we believe it has), it is now opportune to initiate more systematic studies, which would include control groups, and perhaps experimental manipulations as well.

With these caveats in mind, we offer the following summary of our findings. In the biographies, we found that crystallizing experiences do occur frequently, but that there are noticeable and probably important differences across individuals and across domains. For one thing, the nature of a crystallizing experience depends on the age of the subject. The experiences of younger subjects are closely related to unmediated or "raw" intelligence; we called these "initiating crystallizing experiences." The anecdote from Galois in the Introduction illustrates this; Menuhin provides another example. With older children and young adults, the crystallizing experience reflects a mediated contact with the domain, in which some training in the materials of the domain is presupposed -- Debussy's reaction to Wagner or Hardy's response to his Cambridge mathematics professor illustrate what we called "refining crystallizing experiences."

Our results also suggest that crystallizing experiences differ across domains as well. They are more prevalent in

mathematics and music than in the visual arts, for instance. Perhaps in the visual arts, individuals are "crystallized" over a longer period of time, through repeated visits to museums for instance. In that case, the memorable experience of Renoir stands as an exception and the more gradual development of Cezanne as the rule. Or it may be that visual artists are less willing to share their experiences with teachers and appreciate the crystallizing experience only in retrospect.

The domains also differed with respect to the early appearance of talent. Music and mathematics were both characterized by a large number of talented children, while the visual arts were not. Similarly, music and mathematics appear to require disciplined training during childhood while the visual arts do not. We have considered the possibility that these differences may reflect contrasting cultural values about the various domains (e.g., early mathematics being valued more than early visual art in our culture), but they may also reflect the differences intrinsic to the domain (the degree to which the domain is cut off from others and can be negotiated in a manner independent of real world experiences).

Some of these findings from the biographies were affirmed by our interviews with the teachers: the requirement of early training or learning in mathematics and music but not the visual arts; the personal experiences of the teachers in discovering their own talents; the manner in which training keeps pace with the general move from "raw" intelligence to mediated intelligence. However, other points emerged during the interviews that did not

appear in the biographies. For instance, the teachers spoke a great deal about motivation in contrast to talent. This perspective can be seen either as a challenge to the theory of multiple intelligences, or, as we have described previously, a call for supplementary data. Also, aside from the choice of the particular instrument, the teachers reported no observations of crystallizing experiences in their students, although they did report them from their personal development. We have offered several retrospective explanations for this apparent discrepancy.

How, then, does our perspective fare in accounting for the phenomenon of crystallizing experiences? Our analysis strongly suggests that crystallizing experiences are a genuine phenomenon, although one that is not immune to differences across domains. It would be difficult to maintain that these experiences are accidental or artifactual, since this implies that they should occur in the same fashion and with the same frequency across domains and across developmental levels. Second, it appears that the crystallizing experience is a fragile phenomenon that occurs principally when circumstances combine inborn talert, self-teaching, and proper exposure to a set of materials in a particular way. Finally, in those circumstances where there is a strong predisposition to excel with a given material, and where there are some but not exceptional opportunities, crystallizing experiences are most likely to occur.

For the purposes of this chapter, we have stressed the kinds of experiences that may befall individuals of indisputable talent and that help to set them on their life course. In conclusion,

we would like to raise the question about whether crystallizing experiences are indeed just a purview of the most gifted, or whether they may occur in more mundane ways with individuals who are closer to the norm. The present study casts no light on this question. Still, it would seem to be good pedagogy -- if not just good common sense -- to treat all children as if they have the potential for crystallizing experiences, and to expose them at an early age to materials that may motivate them to explore a domain. It may turn out that there are far more "gifted" children than could have been anticipated from the unplanned encounters that until now have been the chief locus for crystallizing experiences.

Table One. The Musicians

Joseph Haydn 1732-1809, Austria
Childhood Talent: Talent did not appear during childhood. Sang in the Vienna Boys' Choir

Crystallizing Experience: None reported.

Wolfgang Amadeus Mozart 1756-1791 Austria
Childhood Talent: First composition at 5 years. First symphony at 9. First opera at 13.

Crystallizing Experience: None reported.

Ludwig van Beethoven 1770-1827, Germany
Childhood Talent: Concert at 9. Assistant organist at 14. Began study of composition with Haydn at 22.

Crystallizing Experience: None reported.

Felix Mendelssohn 1809-1847 Germany
Childhood Talent: Debut at 9. Began studying composition at 10. Mastered counterpoint and figured bass at age 12.

Crystallizing Experience: None reported.

Richard Wagner 1813-1883 Germany
Childhood Talent: Talent did not appear during childhood.

Crystallizing Experience: As an adolescent, he heard a famous singer in Fidelio and was greatly moved. He wrote the singer a letter in which he dedicated his life to music, delivered it to her hotel room, and then "ran out into the street, quite mad." (Wagner, 1911, p. 44)

Claude Debussy 1862-1918 France
Childhood Talent: Entered Conservatoire at age 9. Won the prize for piano at age 14.

Crystallizing Experience: Transcribing the opera Tannhauser described in the Introduction.

Gustav Mahler 1860-1911 Czechoslovakia

Childhood Talent: Played the concertina at 4. At 15, he auditioned for Julius Epstein who sent him immediately to the Conservatory in Vienna where he was described as "the new Schubert."

Crystallizing Experience: None reported.

Igor Stravinksy 1882-1971 Russia

Childhood Talent: Talent did not appear as a child.

Crystallizing Experience: As a child, he attended the theater weekly, and notes that he was greatly moved by the "sound of Glinka's orchestra and the compositions of Tchaikovsky" (White, 1966, p. 23)
Although he was generally uninterested in the skills of composition as a college student, his eventual career as a composer was fixed in his mind during his five-year app-enticeship with Rimsky-Korsakov.

Arthur Rubinstein 1887-1982 Poland

Childhood Talent: Auditioned for the violinist Joseph Joachim at the age of 3. Began lessons with Joachim at 10 and gave his first concert the next year.

Crystallizing Experience: Rubinstein reports that when the family purchased a piano, "the drawing room became my paradise." He learned to play by ear and to name the notes in dissonant chords within a matter of months.

Yehudi Menuhin 1916 - United States

Childhood Talent: Debut at the age of 9.

Crystallizing Experience: He was taken to concerts of the San Francisco Symphony regularly when he was 3 years old. Upon hearing the sound of the orchestra, and in particular L uis Persinger's violin, he said, "I asked for a violin for my fourth birthday, and Louis Persinger to teach me to play it." (Menuhin, 1977, p.22) He got both.

Pierre Boulez 1926 - France

Childhood Talent: His talent did not appear during childhood.

Crystallizing Experience: At the age of 19, when studying composition, he heard for the first time the music of Messaien and recognized the 12-tone style as a new language, "a revelation."

Table Two. The Mathematicians

Carl Friedrich Gauss 1777-1855 Germany

Childhood Talent: Original mathematics produced at the age of 15 when he derived certain principles regarding the laws of prime numbers.

Crystallizing Experience: During his first year at the University, Gauss discovered a method for constructing a 17-sided polygon with only Euclidean tools. He announced the discovery proudly in the advance notices in a mathematics journal saying it was "a discovery (with) special interest" because it made a signficant advance upon the work of Euclid. If there had been any doubt in his mind about his eventual career as a mathematician, it was removed with this discovery. (Hall, 1970, pp. 21-24)

Evariste Galois 1811-1832 France

Childhood Talent: Self-taught in mathematics. Original publications beginning at age 17.

Crystallizing Experience: Reading the geometry textbook of Legendre, cited in the Introduction.

Henri Poincare 1854-1912 France

Childhood Talent: His talent appeared during adolescence when he won a mathematics context without taking notes during lectures. In the examination for the Polytechnique his examiner suspended the examination for an hour in order to construct an especially difficult question for Poincare. He answered it correctly and received the highest grade.

Crystallizing Experience: None reported.

David Hilbert 1862-1943 Germany

Childhood Talent: Hilbert received outstanding grades in mathematics during school but was not a prodigy along the lines of Gauss or Poincare. He stated later that he did not concentrate on mathematics during his school years because he "always knew he would do that later." (Reid, 1970, p. 7)

Crystallizing Experience: After an uninspired dissertation, he spent several years traveling and studying with mathematicians like Klein, Poincare, and Hermite. He made no major contribution until at the age of 27 he published the solution to Gordon's problem; in this proof, he demonstrated that a solution was impossible. Although first criticized by the establishment as "unearthly", this technique was shortly accepted by the mathematical community and secured

Hilbert's position as a leader. (Reid, pp. 28-28)

G.H. Hardy 1877-1947 England

Childhood Talent: Although an outstanding student throughout school, Hardy was not a child prodigy.

Crystallizing Experience: He did well in school mathematics without developing any "passion" for the subject. When he began study at the University with Professor Love, however, he said, "I learned for the first time what mathematics really meant. Fromthat time onwards, I on my way to becoming a real mathematician with sound mathematical ambitions and a genuine passion for mathematics." (Hardy, 1969, p. 24)

Srinivasa Ramanujan 1887-1920 India

Childhood Talent: Ramanujan was almost entirely self-educated. He never finished the first year at the University and yet when he sent some of his original work to Hardy in England, his genius was immediately recognized and Hardy obtained a fellowship for him to work and study at Cambridge.

Crystallizing Experience: Reading the tutorial manual, Carr's Synopsis fo Pure Mathematics, described in the text.

Norbert Wiener 1894-1964 United States

Childhood Talent: Tutored by his father, he graduated from high school at age 10, and from Tufts College at 14. He obtained a Ph.D. from Harvard by the age of 18.

Crystallizing Experience: None reported.

John von Neumann 1903-1957 Hungary

Childhood Talent: Tutored in mathematics through high school, he published original work at the age of 16. He won a nation-wide mathematics contest at 18. By 22 he had obtained two doctorates.

Crystallizing Experience: None reported.

Table 3. The Visual Artists

Rembrandt van Rinj 1606-1669 Netherlands

Childhood Talent: Rembrandt came from a modest background and turned down an opportunity to study at the University in order to pursue a career in art. After a four-year apprenticeship, he established his own shop at the age of 19 and began giving art lessons. Constantine Huygens, a scholar visiting Leyden, described Rembrandt at this time as having great promise even though his "teachers were insignificant" (Brown, 1911, pp. 59-60).

Crystallizing Experience: None reported.

J.M.W. Turner 1775-1851 England

Childhood Talent: As a schoolboy, Turner gained a reputation as someone who would rather draw than work. He began study at the Royal Academy at age -- and finished at 18. He immediately took on commisions and was exhibited at the Royal Academy at the age of 22; he was elected A.R.A. at 24.

Crystallizing Experience: None reported.

Paul Cezanne 1839-1906 France

Childhood Talent: His talent did not appear during childhood.

Crystallizing Experiences: None reported.

August Renoir 1841-1919 Paris

Childhood Talent: His facility with the paintbrush earned him a full adult wage while an apprenctice porcelin decorator.

Crystallizing Experience: He found a beauty in the Statue at the Fountain des Innocents in Paris that he had not anticipated in his consideration of art as an aesthetic rather than decorative medium. (Introduction)

Paul Klee 1879-1940 Switzerland

Childhood Talent: His talent did not appear until early adulthood.

Crystallizing Experience: He studied art briefly at the Academy in Munich after which he began a tour of Italy. In Naples he visited the Aquarium where he found that "the silent creativeness of Nature challenged man's fantasy to indulge in as much freedom." (Haftman, 1954,

p. 30) This experience, when combined with his careful observation of the galleries of Florence and Rome, caused him to give up the formal study of art and return instead to his home in Switzerland. There he spent the next ten years experimenting.

Joan Miro: 1893- Spain

Childhood Talent: His talent did not appear until early adulthood.

Crystallizing Experience: None reported.

Mary Cassatt 1844-1926 United State

Childhood Talent: Talent did not appear until adulthood.

Crystallizing Experience: None reported.

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