

1. Synthesis of the senses- A historical review of synesthesia & its connection to creativity by Tanya Mehta & Purbasha Mazumdar, Lady Shri Ram College for Women

Introduction

Synesthesia, from the ancient Greek *syn* "together," and *aisthēsis*, "sensation," is a neurologically based condition in which an otherwise normal person experiences sensations in one modality when a second modality is stimulated. A person experiencing this phenomenon is called a "synesthete". For example, a synesthete may experience a specific colour whenever she encounters a particular tone (e.g., E-sharp may be green) or may see any given number as always tinged a certain colour (e.g., '7' may be blue and '6' may be red). It isn't known with surety when first this quirky phenomenon was recognized as being a human trait. However, speculations abound. It has been surmised that Newton experienced this phenomenon. Multiple artists have been known to exhibit this condition.

Synesthesia was first documented systematically and studied scientifically by Francis Galton. In 1892 Galton published a small article dedicated to this oddity in the prime science journal *Nature*. This was one of the lesser known articles authored by the great scientist and was more or less ignored by the scientific community. Since then, it has been the norm for scientists to brush this condition aside as a mere neurological anomaly. However, there are a band of scientists today who are convinced that this is a real phenomenon and indeed an extremely important one, a phenomenon that provides valuable insights into the most intriguing aspects of the human mind, and posits to answer questions about what makes us uniquely human.

Synesthesia might have lacked supporters in the scientific field through the 19th and 20th centuries but the present story isn't quite as gloomy, a host of brilliant researchers have taken up the study of synesthesia and it is a blooming field of study. Richard Cytowic was one of the first neurologists who pioneered the study of this phenomenon as being something "real". He wrote two books about it: *Synesthesia : A Union of the Senses* (1989) *The Man Who Tasted Shapes* (1993/2003). Other key scientists involved in synesthesia-related research include V.S. Ramachandran, Ed Hubbard, Baren-Cohen, Campen, Domino etc.

General Description

Synesthetes are normally functioning in the conventional sense. They appear bright and clinically, seem mentally balanced with their MMPIs scores being unremarkable except for non-stereotypical male-female scales. Standard neurological exams are also yield normal results. However, they do have excellent memories because of their parallel sensations for different stimuli, saying for example, "I know it's 2 because it's white." Synesthetes perform in the superior range of the Wechsler Memory Scale. They also have superior but uneven cognitive skills. They may have dyscalculia or subtle mathematical deficiencies such as lexical-to-digit

transcoding and right-left confusion (allochiria).

Synesthesia is also sometimes reported by individuals under the influence of psychedelic drugs, after a stroke, during a temporal lobe epilepsy seizure, or as a result of blindness or deafness. Synesthesia that arises from such non-genetic events is referred to as "adventitious synesthesia" to distinguish it from the more common congenital forms of synesthesia. Adventitious synesthesia involving drugs or stroke (but not blindness or deafness) apparently only involves sensory linkings such as sound → vision or touch → hearing.

Estimates of the prevalence of synesthesia vary dramatically. Cytowic (1989; 1997) estimates that it occurs in 1 in 20,000 people, while Galton (1880) placed the prevalence at 1 in 20. More recent, systematic, studies have estimated that synesthesia occurs in 1 in 2,000 people (Baron-Cohen et al., 1996). Ramachandran's estimates suggest that as much as 1 in 200 could possess this condition (Ramachandran et al., 2001). Some of this variability is likely due to differences in definitional criteria used by different researchers, but some of this might also be due to the different subtypes examined by different investigators. It has also been found that women synesthetes predominate with Cytowic (1989) finding a female to male ratio of 3:1 in the U.S. and a ratio of 8:1 in the U.K. (Baron-Cohen et al. 1993).

The study of synesthesia becomes more challenging due to the idiosyncratic nature of synesthetic experiences. However, some scientists also contend that the most intriguing aspect of this condition is the variability inherent to it. There are multiple types of synesthesia and also individual differences within these types (e.g., vividness, spatial extent, affective components).

There are various forms of synesthesia, for example:

1) Grapheme → color synesthesia : Individual letters of the alphabet and numbers (collectively referred to as graphemes), are "tinged" with a certain colour and individuals usually do not report the same colors for all letters and numbers, studies with large numbers of synesthetes find some commonalities across letters. In study of 172 "colored letter" synesthetes alone, by Sean Day, 43% perceive the letter A as red; of 123 synesthetes, 57% perceive the letter O as white. The letter I holds interest: of 119, 38% perceive this letter as white, 28% as black, and 12% as gray; that is, 78% perceive it as non-hued; likewise, 75% perceive the letter O as non-hued. Of 93 synesthetes, 44% perceive Y as yellow. This is only a simple example that demonstrates the multivariate nature of synesthetic experiences.

2) Sound → color synesthesia : In this form of synesthesia, environmental sounds such as clattering dishes or dog barks trigger color and firework shapes that arise, move around, and then fade when the sound ends. For some, the stimulus type is limited (e.g., music only, or even just a specific musical key); for others, a wide variety of sounds triggers synesthesia.

3) Number form synesthesia: A number form is a mental map of numbers, which automatically and involuntarily appears whenever someone who experiences number-forms thinks of numbers.

4) Ordinal Linguistic synesthesia: In this form ordered sequences such as days, weeks, months appear as distinct personalities. This is the most ignored form of synesthesia.

There are various other forms of synesthesia but researchers have looked most intricately into grapheme-colour synesthesia which has also been proposed to be the most commonly experienced form of synesthesia (Day, 2001). For the purpose of our present review, we have also generally discussed this form of synesthesia.

First Hand Accounts

There are/have been many famous personalities who have/had synesthesia. Here we highlight a few most-intriguing and curious accounts. The world renowned composer Franz Liszt (1811-1886) was a synesthete. He is said to have made the following to his orchestra in Weimar(1842),who were, needless to mention, astonished.

“O please, gentlemen, a little bluer, if you please!
This tone type requires it!” Or: “That is a deep violet, please, depend on it!
Not so rose!”

Vladimir Nabokov (1899-1977), the very controversial and extremely talented author of *Lolita* was one of the most famous people to possess this condition. In Nabokov’s memoir *Speak, Memory*, Nabokov details how his synesthesia has affected him in his life. He writes “The long ‘a’ of the English alphabet . . . has for me the tint of weathered wood, but a French ‘a’ evokes polished ebony. This black group also includes hard ‘g’ (vulcanized rubber) and ‘r’ (a sooty rag being ripped). Oatmeal ‘n’, noodle-limp ‘l’, and the ivory-backed hand-mirror of ‘o’ take care of the white. . . . Passing on to the blue group, there is steely ‘x’, thundercloud ‘z’ and huckleberry ‘h’. Since a subtle interaction exists between sound and shape, I see ‘q’ as browner than ‘k’, while ‘s’ is not the light blue of ‘c’, but a curious mixture of azure and mother-of-pearl.” (Cited in Lemley, 1999)

Luria diagnosed Shereshevskii with an extremely strong version of synesthesia, fivefold synesthesia, in which the stimulation of one of his senses produced a reaction in every other. For example, if Shereshevskii heard a musical tone played he would immediately see a colour, touch would trigger a taste sensation and so on for each of the senses. The images that his synesthesia produced usually aided him in memorizing. For example, when thinking about numbers he reported:

“Take the number 1. This is a proud, well-built man; 2 is a high-spirited woman; 3 a gloomy person; 6 a man with a swollen foot; 7 a man with a moustache; 8 a very stout woman—a sack within a sack. As for the number 87, what I see is a fat woman and a man twirling his moustache.”

“Whenever Francesca closes her eyes and touches a particular texture, she experiences a vivid emotion: Denim, extreme sadness. Silk, peace and calm. Wax, embarrassment. She sometimes feels subtle nuances of emotions. Grade 60 sandpaper produces guilt and grade 120 evokes ‘the feeling of telling a white lie’”. From *The Tell-Tale Brain* by V.S. Ramachandran.

Perceptual Reality of Synesthesia

Synesthesia is still brushed under the carpet by many in the scientific community with the label of being an anomaly. As has been mentioned earlier, this standard stance was ignored by Cytowic, who is considered a pioneer in this field of research. Cytowic proposed that the phenomenon was a kind of evolutionary regression to a more primitive brain state wherein the senses hadn't quite separated and were being mingled in the emotional core of the brain. "MWs cortical metabolism dropped so low during synesthesia that he should have been blind, paralyzed, or shown some other conventional sign of a lesion. Yet his thinking and neurological exam were unimpaired. Such a depression of cortical metabolism during a distinct behavioral state disturbs traditionalists, who regard the more recently-evolved cortex as the seat of higher analysis and reason, while assigning the limbic system (the sub-cortical ring of tissue that encircles the brainstem and is much older in evolutionary terms) to handle the more "primitive" functions of emotion, memory, and attention." From *Synesthesia: A union of the senses*. This idea of an undifferentiated primitive brain hasn't settled well with contemporary scientists, for if Cytowic's claims are to be taken seriously one would assume that the senses would just blend into each other creating a blurry mess. However, this is in exact contradiction to the experiences of synesthetes who claim to have very distinctive experiences.

A second explanation that is often posed is that synesthesia arises out of previously formed memory associations. Scientists in favour of this theory propose that the condition merely results out of, for example, associations that form in childhood while playing with refrigerator magnets or coloured blocks. Hence, synesthetes when experiencing the phenomenon are merely "remembering" these associations vividly, akin to how "normal" people recall the smell of a rose or the taste of curry. This theory has major pitfalls. For instance, it doesn't explain why only some people remain stuck with such vivid sensory memories. Moreover, V.S. Ramachandran has also been able to identify a colourblind synesthete who has never experienced colours in "reality" that he is able to "see" during his synesthetic experiences (Ramachandran and Hubbard, 2001).

The more accepted explanation by contemporary neurologists is that synesthesia has a neurological basis and isn't merely a result of childhood memories nor is it people being exaggeratedly metaphorical or tangential in their speech in order to gain attention.

Genetic Basis of Synesthesia -

In spite of the variability in estimates of its prevalence, almost every study of synesthesia has agreed that synesthesia seems to run in families. Initial family studies showed that the trait seemed to be passed along the X-chromosome, and that it may have been dominant (Bailey & Johnson, 1997). However, the researchers weren't able to identify the exact genetic loci and preliminary results from a molecular genetic study of synesthesia indicates that synesthesia may not be solely X linked (J.E. Asher). When large-scale random sample studies are carried out, there is no gender bias, suggesting that early studies suffered from an under-reporting by male subjects (J. Simner). Other recent findings, including a pair of mono-zygotic twins who were discordant for synesthesia (Smilek et al., 2002) and data suggesting that synesthesia can skip

generations (Hubbard and Ramachandran, 2003) are hard to reconcile with dominant transmission. In sum, recent data suggest that the genetic mechanisms underlying synesthesia may be more complex than the straightforward X-linked dominant account proposed by early researchers. It has been proposed that synesthesia is most likely a polygenic condition since it involves various types. It has also been put forth that certain varieties of synesthesia could have an epigenetic basis.

Synesthetic Associations are Stable over Time –

Scientists have proposed and subsequently proved empirically that synesthetically induced colours are consistent across months or even years of testing (Baron-Cohen et al., 1993). Baron-Cohen et al. asked nine synesthetic subjects and nine controls to give colour associations for a list of 130 words. Control subjects were told that they would be tested one week later, while synesthetic subjects were retested one year later and were not informed prior to testing that they would be retested. Synesthetic subjects were 92.3% consistent, while control subjects were only 37.6% consistent. The color associations of synesthetes also tend to be highly specific (Baron-Cohen et al., 1993, 1996; Mattingley et al., 2001).

Cognitive Studies of Synesthesia – Although studies of consistency are useful in differentiating between synesthetes and non-synesthetes, they are too superficial to allow exploration of the underlying cognitive, perceptual, and neural bases of synesthesia. Consistency suggests that there is some difference between synesthetes and non-synesthetes, but it does not educate us of exactly what that difference is. Recently there has been an explosion of studies examining these questions with more sophisticated behavioral techniques. With modified Stroop interference paradigms, recent research has shown that synesthesia is automatic and perhaps obligatory (Dixon et al., 2000; Mattingley et al., 2001; Mills et al., 1999). In the standard Stroop paradigm, color names are presented in colored ink, such as the word RED printed in either red or green ink. An incongruence is evoked in the subject by printing the word RED in green ink which consequently yields a larger response time. Similarly in the Synesthetic-stroop paradigm, the synesthete is first tested on some preliminary tests in order to identify what the specific colours experienced by the synesthete are.

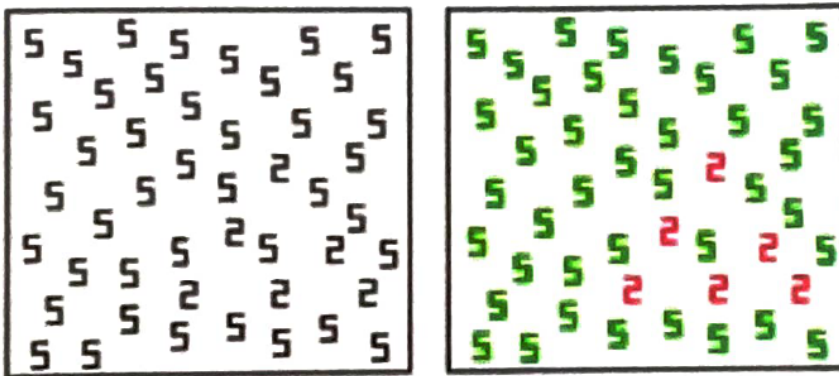
Knowing this, thus, two varying conditions can be created in the Stroop test which are likely to yield varying response times akin to the Stroop test conditions employed for non-synesthetic Stroop subjects. In one of these conditions the colour of the word is made to match the automatic synesthetic colour experienced by the subject, this is known as the congruent condition. In the other condition, called the incongruent condition, the word is written in a colour that does not match the automatic synesthetic colour evoked naturally in the subject. Responses in the incongruent condition are typically much slower than in the congruent condition. The consistent finding that synesthetes are slower in the incongruent condition than in the congruent condition demonstrates that synesthetic colors are automatic and not under voluntary control. Subsequent research has shown that synesthetic Stroop interference can be induced simply by thinking about or imagining the eliciting stimulus when it is the solution to a math problem (Dixon et al., 2000; Jansari et al., 2005) and can be eliminated by masking the target grapheme before presenting a colored grapheme (Mattingley et al., 2001).

McCollough Effect –

The most exciting finding in the field concerning the automaticity of synesthesia has been the reported result that projected photisms evoked through synesthesia can induce the McCollough effect (Blake et al).

Pop – out Effect –

Synesthetically induced colours are known to produce pop-out. Subjects were presented with displays composed of graphemes (e.g., a matrix of randomly placed, computer-generated '2's). Within the display, a shape had been embedded, such as a triangle, composed of other graphemes (e.g. computer-generated '5's; (see fig.a). Since '5's are mirror images of '2's and made up of identical features (horizontal and vertical line segments), non-synesthetic subjects found it hard to detect the embedded shape composed of '5's. Synesthetes, on the other hand, were able to identify the '2's as one colour and the '5's as a different colour, so they claimed to see the display as (for example) a red triangle amidst a background of green '2's. When their performance was measured, it was found that they were significantly better at detecting the embedded shape than non-synesthetic control subjects (Ramachandran & Hubbard, 2001), making it clear that they were not confabulating and could not have been 'faking it'. Perceptual grouping and pop-out are often used as diagnostic tests to determine whether a given feature is genuinely perceptual or not (Beck, 1966; Treisman, 1982).

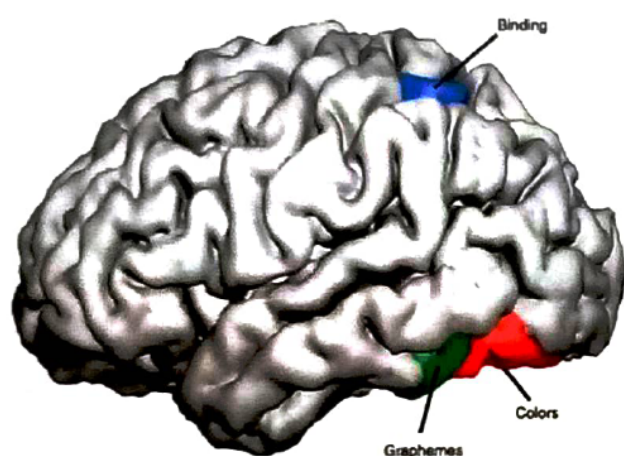


The Cross Activation Hypothesis

Synesthetes were initially considered to be crazy or at best “acid junkies” or “pot-heads”. As mentioned before, these conjectures are not accepted by the scientific community today. Synesthesia has been accepted as being a neurological and automatic condition, shaped by learning. However, the underlying cause of synesthesia is still open to hot debate. The most competent hypothesis regarding the etiology of synesthesia is the “cross-activation” hypothesis which has been around for about a century, but more systematic work in shaping and elaborating this theory has been done by Ramachandran and Hubbard (Ramachandran and Hubbard, 2001). The key insight comes from anatomical, physiological and imaging studies in both humans and monkeys, which show that colour areas in the brain (V4; Lueck et al., 1989; Zeki & Marini, 1998 and V8; Hadjikhani et al., 1998) are in the fusiform gyrus. It has been found that, remarkably, the visual grapheme area is also in the fusiform (Allison et al., 1994; Nobre et al., 1994; Pesenti et al., 2000), especially in the left hemisphere (Tarkiainen et al., 1999), adjacent to V4. This has led Ramachandran to speculate (Ramachandran and Hubbard, 2001) that synesthesia arises out

of cross-wiring between these two areas. Since synesthesia runs in families, Ramachandran (Ramachandran and Hubbard, 2001) suggests that a single gene mutation causes an excess of cross-connections or defective pruning of connections between different brain areas. Consequently, every time there is activation of neurons representing numbers, there may be a corresponding activation of colour neurons.

One potential mechanism for this would be the observed prenatal connections between inferior temporal regions and area V4 (Kennedy et al., 1997; Rodman & Moore, 1997). In the immature brain, there are substantially more connections between (and within) areas than are present in the adult brain. Some of these connections are removed through a process of pruning, and others remain. It has been shown that there is a much larger feedback input from inferior temporal areas to V4 in prenatal monkeys. (Kennedy et al, 1997). Hence, if a genetic mutation were to lead to a failure of pruning (or stabilization) of these prenatal pathways, connections between the number grapheme area and V4 would persist into adulthood, leading to the experience of colour when viewing numbers or letters.



Synesthesia and Creativity- Art, whether it is in the form of poetry, painting, sculpture, or music, requires one to make mental leaps and relate seemingly unrelated concepts. In this way, creation of art is not very different from synesthetic experiences and it is purported to be more common in artists, poets and novelists (Dailey et al., 1997; Domino, 1989; Root-Bernstein & Root-Bernstein, 1999). Many famous artists, novelists, musicians are/have been known to have synesthesia for example Vladimir Nabokov, Alexander Scriabin, Wassily Kandinsky, Franz Liszt etc.

In 1989 Domino published a study reporting that in a sample of 358 fine-arts students, 23% experienced synaesthesia. This figure was much larger than any reported for the general population suggesting that synesthesia is more prevalent in artists and creative people than it is in the general population. Domino also tested 61 of the self-reported synaesthetes and 61 control subjects (equated on gender, major, year in school and verbal intelligence) on four experimental measures of creativity. He found that, as a group, synaesthetes performed better than controls on all four experimental measures of creativity.

Evidence also suggests that creative individuals have access to primary process modes of thought and they engage in both synesthetic and physiognomic perceptions involving a unity between different sensory modalities and a fusion of affect and perception. Mednick & Mednick

(1967) used the Remote Associates Test to measure creative potential. Similarity judgments were made between auditory stimuli (pure tones and pure vowel sounds) and colors to measure synesthetic-like phenomena. Colors were rated using adjectives with emotional connotations to measure physiognomic perception. Results showed that more creative participants exhibited significantly stronger associations between colors and pure tones, vowels, and emotional terms.

In another experiment, involving 210 participants, the relationship between self-reported synesthesia and verbal creativity was explored through the Remote Associates Test and pun generation and a significant correlation between scores on Synesthesia and Verbal Creativity was obtained. (Sitton and Pierce, 2004)

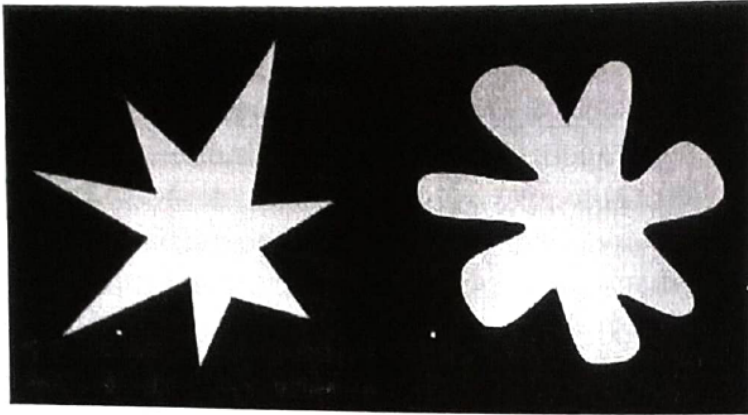
How can the cross-wiring hypothesis explain these results?

Ramachandran has pioneered the research concerning the link between creativity and this curious condition. He utilizes the cross-activation hypothesis to propose a unifying theory which deems to explain both these phenomena. One thing that artists and synesthetes have in common is a remarkable facility linking two seemingly unrelated realms in order to highlight a hidden deep similarity (Root-Bernstein & Root-Bernstein, 1999). When Shakespeare writes 'It is the East and Juliet is the sun', our brains instantly understand this. One doesn't say, 'Juliet is the sun. Does that mean she is a glowing ball of fire?' . Instead, our brain instantly forms the right links, 'She is warm like the sun, nurturing like the sun, radiant like the sun' and so on. (Ramachandran and Hubbard, 2001).

It has often been suggested that concepts are represented in brain maps in the same way that percepts (like colours or faces) are. One such example is that of the concept of number, a fairly abstract concept, for which neurologists have been able to identify the specific brain regions (the fusiform and the angular) which are involved. Perhaps many other concepts are also represented in non-topographic maps in the brain. If so, Ramachandran suggests (Ramachandran and Hubbard, 2001) one can think of metaphors as involving cross-activation of conceptual maps in a manner analogous to cross-activation of perceptual maps in synesthesia. If this idea is correct then it might explain the higher incidence of synesthesia in artists and poets. If mutation-induced cross-wiring selectively affects the fusiform or angular gyrus someone may experience synesthesia. However, if this mutation is more diffusely expressed it may produce a more generally cross-wired brain creating a greater propensity and opportunity for creatively mapping from one concept to another.

Are we all synesthetes in a sense?

Inferring from the above mentioned lines it can be put forth that synesthesia is best considered as an example of subpathological cross-modal interactions which can be a signature of creativity. But it can also be seen that normal everyday language is replete with synesthetic metaphors and even in nonsynesthetes, a great deal of what goes on in their minds is a result of normal crossmodal interactions that are nonarbitrary. Hence, there is a sense in which all of us are synesthetes. To illustrate this Ramachandran used the Buba-Kiki experiment which had been initially devised by Köhler in 1929. The Bouba/Kiki Effect is a non-arbitrary mapping between speech sounds and the visual shape of objects. This experiment first conducted on the island of



Tenerife, Köhler showed forms similar to those shown below and asked participants which shape was called "takete" and which was called "baluba". Data suggested a strong preference to pair the jagged shape with "takete" and the rounded shape with "baluba".

In 2001, Ramachandran and Hubbard repeated Köhler's experiment using the words "kiki" and "bouba" and asked American college undergraduates and Tamil speakers in India "Which of these shapes is bouba and which is kiki?" In both the English and the Tamil speakers, 95% to 98% selected the curvy shape as "bouba" and the jagged one as "kiki", suggesting that the human brain is somehow able to extract abstract properties from the shapes and sounds. Recent work by Daphne Maurer and colleagues has shown that even children as young as 2.5 (too young to read) show this effect. The reason proposed for this effect is that the gentle curves and undulations of the amoeba-like figure mimic the gentle sound of the word "bouba". On the other hand, the sharp wave forms of the sound kiki and the sharp inflection of the tongue on the palate mimic the sudden changes in the jagged visual shape.

This has led Ramachandran to suggest that such nonarbitrary crossmodal neural activity hold important keys to understanding uniquely human traits such as language, metaphorical thinking and creativity.

Conclusion

Synesthesia has been able to intrigue a band of talented scientists in fields ranging from linguistics to cognitive sciences to neurology. This sudden interest in this age-old phenomenon is due to the fact that increased understanding of this oddity has led scientists to believe that it may hold answers to the most perplexing questions that have been ever posed such as the riddles of consciousness, creativity and language origin. Thus synesthesia provides possible answers for not only the ivory tower-like academic concerns of specialist scientists but it also perhaps provides a window into the soul that each of inherit through language and literature.