shall be outlined, meter is so neatly attuned to the functionings of the brain itself, it can serve as a stimulant and reinforcer of those mental capacities that together contribute to and compose what we term understanding, in the fullest sense of the word. The first section of this essay presents an analysis of the primary characteristics of the human nervous system. We then summarize our findings concerning the meter and line of poetry as it is practiced in all cultures that we have analyzed. The third part of the essay is a description of human hearing and a discussion of its temporal organization. The conclusion of this essay will be devoted to the subjective experience of poetry as it is read or heard and an integration of the three preceding areas of study into a working description of the functional benefits of metered poetry in the brain and in the culture at large.

The radically interdisciplinary nature of this essay is not simply a consequence of the need to seek explanations across the boundaries of different fields. It also represents a commitment and a belief on the part of its authors. We are convinced not only that this type of study will cast light on its specific subject (poetic meter), but also that the scientific material will be reciprocally enhanced in value, taking its place within a framework which gives it a greater predictive power. We further believe that "understanding" itself consists of just such a union of knowledge with global significance.

At this point, it might be helpful to review the major characteristics of human cortical information processing as it has been determined by studies in perceptual psychology, brain chemistry, psychology, brain evolution, brain development, ethology, and cultural anthropology.[2] Individually, the characteristics of human brain activity listed below are commonplace and undisputed for the most part; collectively, they constitute a new and complex picture of the human mind.

Human information processing is, on the crude level of individual neurons, *procrustean*. That is, it reduces the information it derives from the outside world to its own categories and accepts reality's answers only if they directly address its own set of questions. In the macrocosm, human perception of electromagnetic radiation cuts out all but heat and the visible spectrum; in the microcosm, a given neuron in the visual cortex will fire only if certain characteristics – e.g., a moving vertical light contrast – fall upon the retina. The neuron will ignore all impertinent information. We possess, as it were, a certain domineering and arrogant quality in our dealings with sensory information, and our brain will "listen" only to replies to its own inquiries. In quantum physics, the familiar procrustean questions – Is light composed of rays or particles ? Is this ray of light polarized north-south or east-west ? – force reality into a certainty and definition which it did not originally possess, and this insistence on unambiguity is rooted in our neurons. Thus, we may say that human information processing is, secondly, *determinative*. With its insistence upon certainty, it overrules the probabalistic and indeterminate nature of the most primitive and archaic components of the universe.

Third, and in contrast to the "conservative" tendency we have described, the human nervous system seems designed to register differences; it is *habituative*. It tends to ignore repeated and expected stimuli and responds more eagerly to the new and unexpected. Although it frames the questions, it is more interested in odd answers than ordinary ones. Spatially, it sees contrasts and borderlines; temporally, it sees movements and hears changes. At this point in the essay, we are beginning to notice the seamless interfaces of poetic meter with the information-processing faculties of the brain; the variations within a given metrical system, which were used so often by Shakespeare and upon which Wordsworth elaborates in his preface to *Lyrical Ballads*, are tuned to the habituative capacity of the auditory nervous system.

Fourth, human nervous activitiy is fundamentally *synthetic* in its aim. It seeks form even when it is not there, and there is a serious ontological question as to whether definable form comes to exist when we postulate it.

It is (5) *active* rather than passive: the nervous system constructs scenarios to be tested by reality, vigorously seeks confirmation of them, and painfully reconstructs them if they are contradicted. The brain is at least as much an organ of action as it is an organ of knowledge.

It is thus (6) *predictive*: the patterns it extrapolates or invents are patterns that involve specific immediate expectations and, in the more distant future, expectations which await satisfaction and are tested by the senses. So dominant is human adaptation to predictive calculation that it might be said that the human senses exist to check our predictions rather than, as in most animals, triggers for appropriate behavior.

Human information processing is, moreover, (7) *hierarchical* in its organization. In the columns of neurons in the sensory cortex, a plausible reconstruction of the world is created by a hierarchy of the cells, the ones at the base responding to very simple stimuli and passing on their findings to cells programmed to respond to successively more complex stimuli. Likewise, motor decisions are passed down a long command-chain of simpler and simpler neural servomechanisms.

The coordination of these hierarchical systems, in which many kinds of disparate information must be integrated, requires a neural pulse within which all relevant information is brought together as a whole. For instance, in the visual system, many levels of detail – frequency, color, and depth – must be synchronized, or we would not be able to integrate the various features of a visual scene (I.Rentschler 1981, 1982, personal communications). Thus, brain processing is (8) essentially *rhythmic*. That these rhythms can be "driven" or reinforced by repeated photic or auditory stimuli to produce peculiar subjective states is already well known.

More controversial in detail but, in general, widely accepted is the proposition that the brain's activities are (9) *self-rewarding*. The brain possesses built-in sites for the reception of opioid peptides, such as enkephalin (the endorphins), as well as other pleasure-associated hormones. The brain controls the manufacture and release of these chemicals, and it has been shown that behavior can be reinforced by their use as a reward. The brain, therefore, is able to *reward itself* for certain activities which are, presumably, preferred for their adaptive utility. Clearly, if this system of self-reward is the major motivating agent of the brain, any external technique for calibrating and controlling it would result in an enormously enhanced mental efficiency. We would, by the utilization of such a technique, be able to harness all our intellectual and emotional resources to a given task. Indeed, as we will later argue, this is exactly what an aesthetic education, including an early introduction to metered verse, can do. It is, we believe, precisely this autonomous and reflexive reward system which underlies the whole realm of human values, ultimate purposes, and ideals, such as truth, beauty, and goodness.

Associated with the brain's capacity for self-reward is (10) that it is characteristically *reflexive*. It is, within broad limits, self-calibrating. Unlike a computer, it seems to have a capacity to convert software into hardware – short-term memory into long-term memory, for example, and vice versa. The brain can examine by introspection its own operations so that its hardware can become its input or even its program, if we extend this analogy. We might define consciousness, itself, as the continuous, irresolvable disparity between the brain as observer of itself and the brain as the object of observation.

The human nervous system cannot be separated from the human cultural system it was designed to serve, and it is for this reason that we say its operations are essentially (11) *social*. It is not only specific skills and communicative competences that are learned in a social context, but also the fundamental capacities of arousal, orientation, attention, and motivation. Clearly we possess genetic proclivities to learn speech, elementary mathematic calculation, and so on, but it is equally clear that we require a socio-cultural context to release that potential. Human society itself can be profoundly changed by the development of new ways of using the brain. Illustrative are the enormous socio-cultural consequences of the invention of the written word. In a sense, reading is a sort of new synthetic instinct, input that is reflexively transformed into a program, crystallized into neural hardware, and incorporated as a cultural loop into the human nervous circuit. This "new instinct" in turn profoundly changes the environment within which young human brains are programmed. In the early stages of human evolution, such new instincts (speech must have been one) had to wait for their full development while sexual selection established the necessary elaborate vocal circuitry in the cortex. Later on, we were able to use our technology, which required much less time to develop, as a sort of supplementary nervous system.

One of the most exciting propositions of the new brain science is that human information processing is (12) *hemispherically specialized.* While the jury is still out debating the consequences of these findings, we must caution against the popular view that the right hemisphere of the brain is emotional and the left hemisphere is rational and that artistic capacities, being emotional, are located in the right brain. More plausible is the position of Jerre Levy (chapter 9), who characterizes the relationship between right and left as a complementarity of cognitive capacities. In a brilliant aphorism, she has stated that the left brain maps spatial information into a temporal order, while the right brain maps temporal information into spatial order. In a sense, understanding largely *consists* of the translation of information to and fro between a temporal ordering and a spatial one – resulting in a sort of stereoscopic depth-cognition. In Levy's view, the two "brains" alternate in the treatment of information according to a rhythm determined by the general brain state and pass their accumulated findings on to each other. The fact that experienced musicians use their left brain just as much as their right in listening to music shows that their higher understanding of music is the result of the collaboration of both "brains," the music having been translated first from temporal sequence to spatial pattern and then "read," as it were, back into a temporal movement. The neurobiologist, Günter Baumgartner (chapter 7), suggests that the forebrain acts as the integrating agent between specialized left and right functions, and it is in this integrative process that we would locate the essentially creative capacities of the brain, whether artistic or scientific. The apparent superiority of the isolated right brain in emotional matters may well simply reflect the fact that emotions, like music, are temporal in nature, and their articulation requires the sort of temporal-on-spatial mapping that is the specialty of the right cerebral hemisphere.

Finally, human information processing can be described as (13) *kalogenetic* (Turner), a word coined from the Greek *kalos* (beauty, goodness, rightness) and *genesis* (begetting, productive cause, origin, source). The human nervous system has a strong drive to construct affirmative, plausible, coherent, consistent, concise, and predictively powerful models of the word, in which all events are explained by and take their place in a system that is at once rich in implications beyond its extant data and, at the same time, governed by as few principles or axioms as possible. The words that scientists use for such a system are "elegant," "powerful," and often "beautiful"; artists and philosophers use the same terms and also "appropriate," "fitting," "correct," and "right," all of which can be translations of the Greek *kalos*.

If this tendency is a true drive, then according to the theory of reinforcement, it is an activity for which the brain rewards itself. If these were techniques by which the endogenous reward system could be stimulated and sensitized, those techniques would enable us to greatly enhance the integrative powers of our minds.

Such a technique would have to meet certain qualifications. First, it would have to be culturally universal, since it would be based on neural and biochemical features common to all human beings.[3] Second, it would be very archaic, identifiable as an element of the most ancient and the most primitive cultures. Third, it would most probably be regarded by its indigenous practitioners as the locus of an almost magical inspiration and as a source of wisdom; it would have the reputation of having significantly contributed to the efficiency and adaptiveness of the societies in which it is practiced. Fourth, it would be associated with the social and cultural activities that demand the highest powers of original thought and complex calculation, such as education, the organization of large-scale projects, like war, cooperative agriculture, and the rituals that divert for social uses the dangerous and valuable energies implicit in sexuality, birth, death, sickness, and the like.

Metered poetry, the use of rule-governed rhythmic measures in the production of a heightened and intensified form of linguistic expression, nicely fulfills these requirements. In nearly all cultures, metered poetry is used in crucial religious, social, and economic rituals, and it has the reputation of containing mysterious wisdom; the learning of major poetic texts is central to the process of education in nearly all literate traditions. Much work – farming, herding, hunting, war, sailing and even mining – has its own body of poetry and song. Objective and universal traits can be identified across the whole range of poetic practice throughout the world and as far back into the past as we have records. From these universal characteristics, we can construct a general definition of metered poetry that applies to the ancient Greeks as well as to the Kwakiutl, Racine, and the Polynesians.

The fundamental unit of metered poetry is what we shall call t h e l i n e. This fundamental unit, while not designated by a written convention such as a line-break in all cultures, is recognizable metrically and nearly always takes from two to four seconds to recite, with a strong peak in distribution, according to the data we have collected, between 2.5 and 3.5 seconds.[4] The line is nearly always a rhythmic, semantic, and syntactical unit as well – a sentence, a colon, a clause, a phrase, or a completed group of these. Thus, other linguistic rhythms are accommodated to the basic acoustical rhythm, producing that pleasing sensation of appropriateness and inevitability, which is part of the delight of verse and an aid to the memory.

The second universal characteristic of human verse meter is that certain marked elements of the line or group of lines remain constant throughout the poem and thus indicate the repetition of a pattern. The 3-second cycle is not marked merely by a pause, but by distinct resemblances between the material in each cycle. Repetition is added to frequency to emphasize the rhythm. These constant elements may take many forms, the simplest of which is the number of syllables per line. Other poetic traditions arrange patterns of stress and cadence. Still other patterns are arranged around alliteration, consonance, assonance, and end rhyme. Often, many of these devices are used together, some prescribed by the conventions of a particular poetic form and others left to the discretion and inspiration of the individual poet. No verse convention dictates *all* the characteristics of a line, so every poem contains an interplay between prescribed elements and free variation.[5]

The third universal characteristic of metrical verse is *variation*. Variation is a temporary suspension of the metrical pattern at work in any given poem, a surprising, unexpected, and refreshing twist to that pattern. Here we must point out that variation can only be an effective or even a definable technique within the context of a prescribed metrical pattern, a pattern which cannot be abandoned. Meter is important in that it conveys meaning, much as a melody does in a song. Metrical patterns are elements of an analogical structure, which is comprehended by the right cerebral hemisphere, while poetry as language is presumably processed by the left temporal lobe. If this hypothesis is correct, meter is partially a method of introducing right brain processes into the left brain activity of understanding language. In other words, it is a way of connecting our much more culture-bound linguistic capacities with the relatively more primitive spatial pattern recognition faculties, which we share with the higher animals.

In the context of this hypothesis, we wish to introduce the major finding of this essay, which explains, we believe, the extraordinary prevalence of the 3-second line in human poetry. If we ask the question, "What does the ear hear?" the obvious answer is "sound". What is sound? It is mechanical waves in the air or another medium. This answer is not very enlightening. We can, for instance, perceive mechanical waves by the sense of touch: it would be as incorrect to say that a deaf man "heard" a vibrating handrail with his fingers as it would be to say a blind man "saw" a fire with the skin of his face. What characterizes hearing as such is not that it senses mechanical waves, just as what characterizes sight is not the perception of electromagnetic waves, but the perception of distinctions between electromagnetic waves.

For vision, those distinctions (except for color) are spatial distinctions, but for audition, they are mainly temporal. To put it directly: what the sense of hearing hears is essentially *time*. The recognition of differences in pitch involves a very pure and highly accurate comparative measurement of different frequencies into which time is divided. The perception of timbre, tone, sound texture, and so forth, consists of the recognition of combinations of frequencies. The recognition of rhythms necessitates the recognition of frequencies taking up longer periods of time.

Audition is not only a marvellously accurate instrument for detecting differences between temporal periods, but also an active organizer, arranging those different periods within a hierarchy as definite as that of the seconds, minutes, and hours of a clock. These different periods are also uniquely appraised. Pitch is an arrangement of that hierarchy into laws of harmony. New discoveries by Ernst Pöppel's group in Munich have begun to elucidate the role of the auditory hierarchy in the structure and function of the brain. This has led to a comprehensive understanding of the general hierarchical organization of the human sensory-motor system and a fresh approach to the production and understanding of language. We shall first briefly outline the auditory hierarchy.

Events separated by periods of time shorter than about three thousandths of a second (0.003 s) are classified by the auditory system as simultaneous. If a brief sound is presented to one ear and another sound is presented to the other ear less than 0.003 s later, the subject will perceive only one sound. If the sounds are a little more than approximately 0.003 s apart, the subject will experience two sounds. However, he will not be able to tell which of the two sounds came first until the interval between them is increased roughly ten times. Thus, the lowest category in the hierarchy of auditory time is *simultaneity*, and the second lowest is mere temporal *separation*, without a preferred order of time. The most primary temporal experience is timeless unity; next comes a space-like recognition – space-like because, unlike temporal positions, spatial positions can be exchanged. One can go from New York to Berlin or from Berlin to New York; but one can only go from 1980 to 1983, not from 1983 to 1980. Likewise, the realm of "separation" is a nondeterministic, acausal realm; events happen in it, perhaps in patterns or perhaps not, but they cannot be said to cause one another because we cannot say which came first.

When two sounds are about three hundredths of a second (0.03 s) apart, a subject can experience their *sequence*, accurately reporting which came first. This is the third category in the hierarchy of time, subsuming separations and simultaneities and organizing them rationally with respect to one another. At this stage, however, the organism is still a passive recipient of stimuli. We can hear a sequence of two sounds one-tenth of a second apart, but there is nothing we can do in response to the first sound before the second sound arrives.

We are helpless to alter what will befall us if the interval between the first signal and its sequel falls within this range. Events follow each other recognizably, but we cannot intervene.

If the temporal interval is longer than three-tenths of a second (0.3 s), however, we have entered a new temporal category – response. Three-tenths of a second is enough time for a human subject to respond to an acoustic stimulus. If we play two sounds to our subject one second apart, the subject could prepare to deal with the second sound in the time given him after hearing the first. The perceiver is no longer passive. For response to exist, there must be a temporal separation, and a further element, which might be characterized in a primitive sense as a purpose. The response to a given stimulus will differ according to the function of the responding organ and the purpose of the organism as a whole.

At several places in this analysis, it has been pointed out that a given familiar temporal relationship – chance, pattern, cause, purpose – only becomes possible when there is enough time given for it to occupy. The idea that an entity needs time to exist in has become commonplace recently. An electron, for instance, requires at least 10 to the negative twenty seconds (10^{-20}s, its spin period) in which to exist, just as surely as it requires 10 to the negative ten centimeters of space (10^{-10}cm, its Compton wavelength). The corollary to this observation is that entities that consist only of spatio-temporal relations are not necessarily less real than material objects, for spatio-temporal relations are a prerequisite for the existence of material objects, also. Although a given period of time may be sufficient for a given relation – chance, cause, function – to be recognized, it is not sufficient for the concept of the relation to be formulated. It takes much less time to recognize or speak a word once learned than it takes to learn the word in the first place. Many examples of the sequence or response relation between events must be compared before a causal or purposive order can be formulated and recognized in individual cases. However, comparisons require discrete parcels of experience between which the comparison can be made, and, since the entities being compared are themselves temporal in nature, these parcels of experience must exist in equal periods of time. The next lowest time division beyond the three-second response frequency must be sufficiently long to enable the completion and recognition of the temporal relations to be compared. The comparison of experience takes more time than experience itself; the recognition of a melody takes more time than the perception of the single notes.

This fundamental "parcel of experience" is about three seconds. The three-second interval, roughly speaking, is the length of the human present moment. (At least it is for the auditory system, which possesses the sharpest temporal acuity of all the senses. The eye, for instance, takes much longer than the ear to distinguish temporal separation from simultaneity.) The philosophical notion of the "specious present" – the present moment of a given organism – finds here its experimental embodiment.

A human speaker will pause for a few milliseconds every three seconds or so and, in that period, will decide on the precise syntax and lexicon of the next three seconds. A listener will absorb about three seconds of heard speech without pause or reflection and then stop listening in order to integrate and make sense of what he has heard. (Speaker and hearer are not necessarily "in phase" for this activity; this observation will be of importance later.)

To use a cybernetic metaphor, we possess an auditory information "buffer," whose capacity is three seconds' worth of information. At the end of three seconds, the "buffer" is full, and it passes the entire accumulated stock of information on to the higher information-processing centers. In theory, this stock should consist of about 1,000 simultaneities, 100 discrete temporal separations, and 10 consecutive responses to stimuli. In practice, however, the buffer has a smaller capacity – about 60 separations and 7 responses (the length of a local telephone number).

It appears likely that another mechanism is involved here, too. Different types of information take different amounts of time to be processed by the cortex. For instance, fine visual detail takes more time to be identified by the cortex than coarse detail. Some sort of pulse is necessary for all the various information to arrive at the higher processing centers as a bundle, correctly labelled as belonging together. At the same time, the sensory cortex "waits" for the "slowest" information to catch up with the "fastest" so that it all can be sent off at once. This three-second period constitutes such a pulse.

Beyond the two horizons of the present moment exist the two periods that together constitute *duration*, which is the highest or "longest frequency" integrative level of the human perception of time. Those two periods, the past and the future, memory and planning, constitute the widest arena of human thought.

It should be obvious from all of this that a remarkable and suggestive correlation exists between the temporal organization of poetic meter and the temporal functions of the human hearing mechanism. Of general linguistic significance is the fact that the length of a syllable, about 1/3 of a second, corresponds to the minimum period within which a response to an auditory stimulus can take place. To be efficient, speech must be as fast as possible, while, to be controllable, it must be slow enough for a hearer to react to a syllable before the next comes along.

Of more specific significance for our subject is the very exact correlation between the three-second line and the three-second "auditory present." The average number of syllables per line in human poetry seems to be about ten, so human poetic meter embodies the two lowest frequency rhythms in the