THE FIFTH INFLUENCE

Michel Cabanac
Département de physiologie, Université Laval
Québec
Canada

Rémi Cabanac
Institut d'astrophysique, Centre national de la recherche scientifique
Paris
France

Harold T. Hammel
Department of Physiology and Biophysics, Indiana University
Bloomington, IN,
U. S. A.

Summary. This article is a theoretical consideration on the role of sensory pleasure and mental joy as optimizers of behavior. It ends with an axiomatic proposal. When they compare the human body to its environment, Philosophers recognise the cosmos as the Large Infinite, and the atomic particles as the Small Infinite. The human brain reaches such a degree of complexity that it may be considered as a third infinite in the Universe, a Complex Infinite. It follows that any force capable of moving such an infinite deserves a place among the forces of the Universe. Physicists have recognized four forces, the gravitational, the electromagnetic, the weak, and the strong nuclear forces. Forces are defined in four dimensions (reversible or not in time) and it is postulated that these forces are valid and applicable everywhere. Pleasure and displeasure, the affective axis of consciousness, can move the infinitely complex into action and no human brain can avoid the trend to maximize its pleasure. Therefore, we suggest, axiomatically, that the affective capability of consciousness operates in a way similar to the four forces of Physics, i e. influences the behavior of conscious agents in a way similar to the way the four forces influence masses and particles. However, since a mental phenomenon is dimensionless we propose to call the affective capability of consciousness the fifth influence rather than the fifth force.

Key words: consciousness evolution force pleasure/joy

1. Introduction

In the Seventeenth Century the Mathematician-Philosopher Blaise Pascal (1670-1672), considering the world of his time, recognized anxiously that the human was balanced between two abysses: the infinitely small abyss of atomic particles, *raccourci d'atome*, and the infinitely large abyss of the cosmos, *l'univers* . In our times, the Pascalian anguish would have worsened with the knowledge accumulated since the Seventeenth Century. Both the small and the large infinites have gained several orders of magnitude since Pascal's time. However, in the mid Twentieth Century the Palaeontologist-Philosopher Pierre Teilhard de Chardin, in his attempt to reconcile Biology with Physics and Astronomy (It is often considered that Teilhard's main thrust was an attempt to reconcile science and faith, however in this precise book his aim was indeed what we state here), removed the Pascalian anguish. His reconciliation was the result of his reckoning that the human phenomenon represents also an infinite. He considered that matter is organised in living beings and, as a rough estimate of this organisation, he counted the number of atoms co-ordinated in autonomous entities such as the human body. In this organism the number reached 10^{25}, i.e. a number similar to the magnitude of the positive and negative exponents for the size of the Cosmos and the atom measured in centimetres (Teilhardde Chardin, 1965) (Fig. 1).

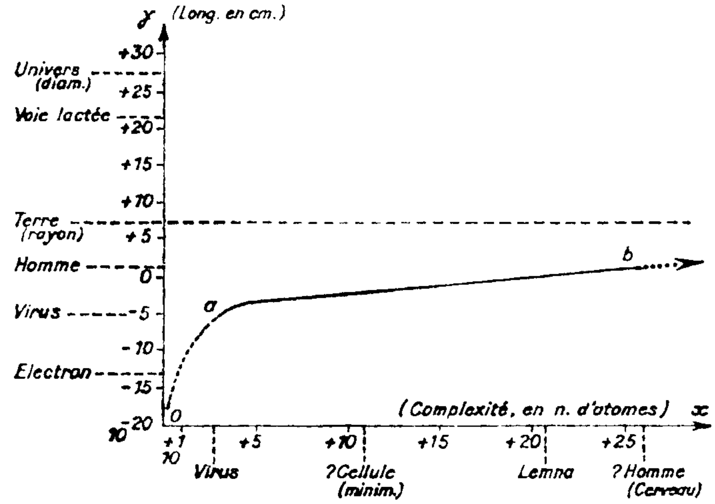

Figure 1. Teilhard de Chardin's natural curve of complexity. In ordinates the length of identifiable entity-objects measured in centimetres *(long. en cm.)*. *Homme*, human; *Terre (rayon)*, Earth (radius); *Voie lactée*, Galaxy; *Univers*, Universe. In abscissa complexity *(Complexité, en n. d'atomes)* as estimated in number of atoms. *Cellule*, Cell; *Lemna*, water lentil (duckweed);*Homme (cerveau),* Human (brain). *a*, appearance of Life; *b*, appearance of *Homo* (from Teilhard de Chardin, 1965, with permission).

2. The Brain And The Infinite Complexity

Our purpose is not to confirm or support Teilhard de Chardin's philosophical point of view. Moreover, it may seem irrelevant to compare numbers with different dimensions. However, we acknowledge Teilhard de Chardin's philosophical breakthrough when he recognized infinite complexity as a relevant feature of Nature. Common language use the word 'infinite' more liberally than Mathematicians or Physicists. Infinity is the acknowledgement of an immensity in comparison with the usual human environment. For the physicist, infinite is nearer to the mathematical definition, i.e. • ∫ 1/0. When physicists find an infinite, they mean they reached the end of their model. Infinite is therefore a sign of incompetence that they are reluctant to acknowledge. In this article, we use 'infinite' in its common rather than its mathematical acceptation.

The size of the *observable* universe is the distance of the farthest object the light of which reaches us i.e. the causal horizon (sphere of light since the beginning of the universe); at greater distance no information can be gathered, the universe is unknown. This distance is now estimated of the order of 3000 Megaparsec. Expressed in metres, the unit of the Système International closest to the size of the human body, the size of the observable universe turns out to be of the order of 10^{26} m. Elementary particles are defined by their energy equivalent rather than their radius; yet, the radius of the atom of hydrogen is about 1 Å and that of the proton constituent of this atom's nucleus is about 10^{-15} m; the electron is estimated to be less than 10^{-18} m. The three quarks, constituents of a proton, have the same radius as the proton. Expressed in meters the sizes of the smallest identified particles turn out to be of the order of 10^{-18} m. These figures are the present state of our knowledge; they do not change Teilhard de Chardin's message.

Gell-Mann (1994) has underlined the difficulty of defining and, furthermore, quantifying complexity. The quantitative comparing of biological complexity to the dimensions of universe and quarks makes little sense in terms of numbers because complexity has no dimension and therefore cannot be compared to units of length. However, it is of interest to obtain numbers to illustrate the astronomic complexity reached in living beings. The number of atoms in the human body, used by Teilhard de Chardin as a gross estimate of complexity can no longer be accepted; the number of atoms organised in a Sequoia or a whale is much larger than in a human body and nothing indicates that these entities are more complex than humans. As suggested by Teilhard de Chardin himself, the number of atoms is not the best index of complexity. Among other candidate indexes of complexity, such as the genetic code, the central nervous system is more likely to be the locus of the highest and most organised complexity in nature. The human central nervous system is generally accepted as containing about 10^{11} to 10^{12} neurones organised in a single whole entity. Each neurone is capable to communicate synaptically with other neurones. Rather than the raw number of cells contained in the brain, synapses are a better indicator of the brain complexity. It is possible to make a rough estimate of the number of synapses accumulated in the human central nervous system (Kandel and Schwartz, 1985). The number of synapses per neurone is extremely variable from 2 in the highly specialised bipolar retinal cells, to 150 000 in Purkinje cells. A conservative figure may be estimated *ca.* 10 000 as the average number of synapses per neurone. The resulting number of synapses would thus reach *ca.* 10^{15}. This is a conservative estimate since 10^{14}-10^{15} was proposed as the number of synapses in the human cortex only (Changeux, 1983). Such a number defies the imagination, but can be compared to other phenomena to illustrate its magnitude: if the universe is 10-20 billion years old, the number of synapses in a human brain is the same as the number of minutes since the big bang. Yet, this is not the ultimate of brain complexity. Although the synaptic transmission of an action potential is an all or nothing phenomenon, a synapse is capable of modulating information in a far more complex way than this simple Boolean computation. The mechanism involves neurotransmitter vesicles that operate as quanta of synaptic transmission. The number of vesicles in a given synaptic button is variable but may be estimated conservatively as 10^2. In turn, the index we have selected to estimate complexity reaches now 10^{17}. This figure is given to illustrate the brain complexity. Other criteria would provide numbers of similar or higher magnitude e.g. Penrose estimated that the brain is able to perform 10^{24} operations per second. Thus, Teilhard de Chardin's solution to Pascal's anguish may be transposed from the human body to the single human brain, the complexity of which may be considered as a third infinite, the infinite complex. A somewhat similar line was developed in what is commonly designated as the Anthropic principle (Barrow and Tipler, 1986; Bertola and Curi, 1993; Breuer, 1991). However, the argument defended in the present article is independent of the anthropic principle. In this article we address the question of the 'how' agents are brought into motion, not the question of the 'why' they are motioned. We may now consider what can move this infinite complex, what force can induce the brain, taken as an individual whole entity, to behave.

Before going further we must acknowledge that the brain is the locus of the second emergence of Evolution. After emergence of life from matter, thinking and consciousness emerged from complex nervous systems. We should not be arrogant enough to shun the possibility that other forms of thinking complexity may exist in the cosmos but, in the present state of our knowledge, the human brain is the most advanced locus of thinking. In the following we shall restrict the infinite complex to the thinking brain and shall concentrate on its emerging properties, sensation and consciousness.

3. Pleasure And The Philosophers

Moralists have always recognized that the seeking of pleasure is the motor of action. Here is what but a sample of a few thinkers wrote: "mankind have nothing better under the sun than to eat and drink and rejoice" (Ecclesiastes 900 B.C.); "one may also think that, if all humans seek pleasure, that is because they desire to live" (Aristotle, 4th century BC); "nature gives us organs to inform us through pleasure about what we should seek and through pain what we should avoid" (Condillac, 1754); "pleasure is the spring of action" Bentham (1742-1832) in (Bowring, 1962); "pleasure is always useful" (Dostoievski: Alexis Ivanovitch, The Player); "the Creator[...] gave us the inducement of appetite, the encouragement of taste, and the reward of pleasure" (Brillat-Savarin 1825); "pleasures and pains represent the sole genuine basis for understanding human motives" (Jevons, 1871); "from every point of view the affective process must be regarded as motivational in nature" (Young, 1959). Finally, the Fathers of the American Constitution, also, acknowledged that the pursuit of happiness is the main aim of the human life. In the following, it will be argued that the seeking of pleasure is the motor of human behaviour. We do not claim that the seeking of pleasure and the avoidance of displeasure explain brain function, but that they explain behaviour as foreseen by Philosophers. Yet, this knowledge now will be based, not on intuition, like the Moralists of the past, but on scientific evidence. We acknowledge that proximal explanation of behaviour may seem unnecessary when examined from the point of view of natural selection. However, proximal explanations of behaviour must be provided. In addition, the emergence of thinking, consciousness, and awareness must, and can be viewed from an evolutionary perspective (Cosmides and Tooby, 1992). The problem is not that we can understand evolution phenomenologically without consciousness, the problem is that consciousness is there, we must deal with it, and understand its role in nature.

4. Physiological Role Of Pleasure

The starting point of the chain of reasoning is the observation that sensory pleasure tags stimuli that are useful for optimal physiological functioning and survival and, obversely, that sensory displeasure indicates useless or noxious stimuli (Cabanac, 1971; Cabanac, 1979).

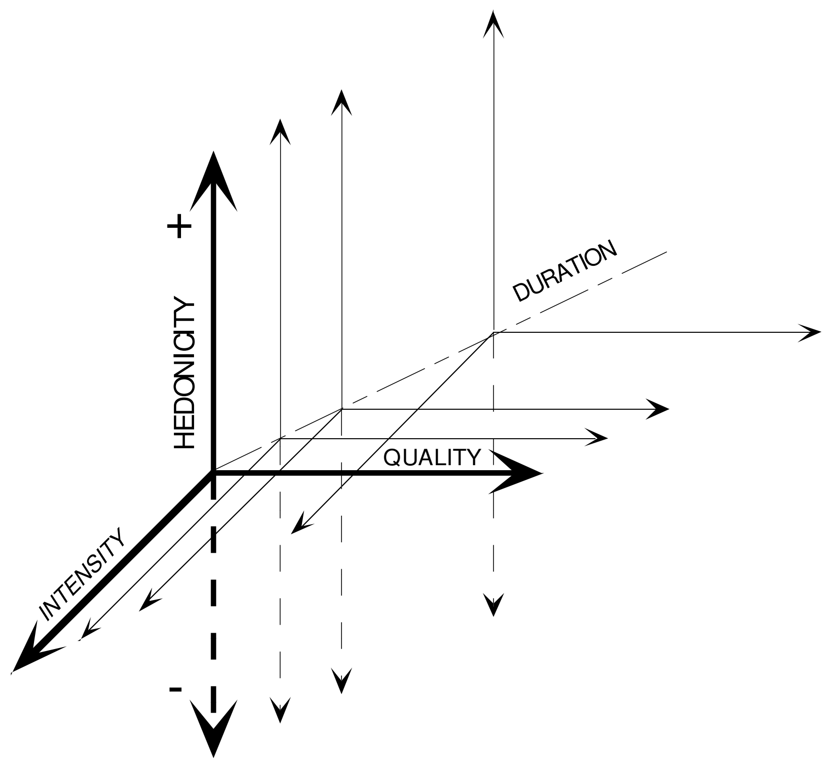

Figure 2. Sensation seen as a multidimensional event in response to a stimulus. Quality, describes the nature of the stimulus; quantity, describes the intensity of the stimulus; affectivity (pleasure or displeasure), describes the physiological usefulness (survival value) of the stimulus. Duration is added to the three other fundamental axes of sensation. It is argued, here, that this model describes equally sensation and consciousness (from Cabanac, 1996, with permission).

Sensation is the mental representation of a stimulus that reaches a sensory organ. Whenever a stimulus excites a sensory ending, the sensation aroused is a four-dimensional phenomenon (Fig. 2). The first dimension, the quality of the sensation indicates the nature of the stimulus. The second dimension, the intensity of the sensation, indicates the magnitude of the stimulus. The third dimension, the affectivity of the sensation (pleasure/displeasure), indicates the potential usefulness of the stimulus. The fourth dimension, the duration of the sensation, indicates the duration of the stimulus. Let us examine the third dimension. The word alliesthesia was coined to describe the fact that a same given stimulus can feel pleasant or unpleasant according to the internal state of the subject and that the resulting sensation can move up and down the affectivity axis. This is especially obvious in the determinism of thermo-regulatory behaviour (Attia, 1984), and of the control of food intake (Fantino, 1984; Fantino, 1995; McBride, 1997). When a subject is hypothermic, a warm skin feels pleasant and a cool one unpleasant. When the subject is hyperthermic a warm skin feels unpleasant and a cool one pleasant. The efficacy of this mechanism is almost limitless: already, the simplest behaviour, such as the seeking of pleasure by a hyperthermic subject who immerses only his hand in stirred 20°C water, can extract as much as 70 W from the hand, i.e. as much as the subject's basal heat production (Cabanac *et al.*, 1972). The adaptation of sensory pleasure and displeasure to physiological need is such that very similar equations describe thermal preference (Bleichert, 1973; Cabanac, 1972), and the autonomic regulatory responses, evaporative heat loss (Stolwijk *et al.*, 1968) or chemical thermogenesis (Nadel *et al.*, 1970) . In addition, thermal pleasure and displeasure is adapted to the defence not only of core temperature but to the difference T_{set}-T_{core}, the error signal of temperature regulation. The case of alimentary pleasure is similar, with pleasure occurring from food stimuli when applied to hungry subjects and displeasure when applied to satiated subjects (Fantino, 1984; Fantino, 1995). The similarity with temperature regulation was recognized when alliesthesia to sweet stimuli disappeared in subjects whose body weight was reduced with dieting, and recovered when body weight returned to control value. A last example of the functional role of pleasure may be found in postural adjustments: the most precise gestures are reached with the help of the affective capability of musculo-articular sensation (Rossetti *et al.*, 1994).

Sensory pleasure is thus the axis of sensation that allows optimisation of behaviour, as seen from the physiologist point of view, that of immediate improvement of physiological function, and survival of the subject.

5. The Common Currency

One of the basic postulates of Ethology is that behaviour is the product of natural selection and thus is optimal (Baerends, 1956; Tinbergen, 1950). However, Ethologists seldom question the proximate cause of behaviour and optimisation of behaviour. McFarland and Sibly (1975) have theorised that since behaviour is a *final common path* there must exist a common currency within the brain-mind to allow trade-offs between motivations and thus rank them by order of priority (McFarland, 1985; McFarland and Sibly, 1975; McNamara and Houston, 1986). Over the last twenty years a series of experiments led to the conclusion that pleasure is this common currency (Cabanac, 1995). More generally, the common currency is the affective axis of consciousness. The rationale was as follows.

Since there is need for a common currency, if sensory pleasure/displeasure is the mental signal that allows us to produce useful behaviours adapted to their physiological goals, then pleasure/displeasure could be this common currency. This was confirmed in several experimental conflicts of motivations involving physiological functions such as temperature regulation, fatigue aroused by muscular exercise, and taste. Useful behaviours were selected by the subjects who simply maximized the algebraic sum of pleasures/displeasures aroused simultaneously in both sensory modalities involved. The same mechanism works with purely mental motivations. When subjects were placed in situations where a motivation involving a sensory modality (e.g. thermal discomfort, or hunger) was confronted with a purely mental motivation (e.g. the pleasure of playing a video-game, or the displeasure of losing money) they behaved in the same way. They maximized the algebraic sum of pleasures/displeasures aroused simultaneously in both sensory and mental modalities involved. The principle of their decisions can be described by figure 3. Finally, it was demonstrated in rats that motivations for acquiring rewards as different from one another as intra-cranial electrical stimulation and the sweet taste of sugar, activated the same area of the brain (Shizgal, 1996). Thus, pleasure was also a common currency in animals.

	Resulting hedonic experience	Action
Behavior 1	a ------> A	yes
Behavior 2	B ------> b	no
Behavior 1 + Behavior 2	a + B-----> A + b	yes

with, a < A, and B > b
and with a + B < A + b

Figure 3. Mechanism by which a behaviour (behaviour 2) that produces displeasure (B to b) can be chosen by a subject if another behaviour (behaviour l) that produces pleasure (a to A) is simultaneously chosen. The necessary and sufficient condition for the behaviour 2 to occur (action) is that the algebraic sum of affective experience (pleasure) of the yoked behaviours is positive ($a+B<A+b$). Capital letters B and A indicate larger pleasure than respective small letters a and b (from Cabanac, 1992, with permission).

6. Consciousness

The paramount role of pleasure and displeasure can be recognized not only in sensation and physiology but in the whole real of consciousness (McKenna,1996; Warburton, 1996). An evolutionary psychology perspective (Cosmides and Tooby, 1995; Cosmides *et al.*, 1992) is useful here to extrapolate from sensation to consciousness, and leads to a postulate. It may be postulated that consciousness evolved from sensation (Cabanac, 1996). A corollary of this postulate is that when consciousness evolved from sensation, consciousness inherited the properties of sensation, i.e. figure 2 describes not only sensation but also the four-dimensional structure of all conscious events.

We may accept the above conclusions as a result of mere introspection: I can analyse any thought I have and recognise a quality, an intensity, an affectivity, and a duration. However, the postulate entails its corollary according to the following steps:
1) The affective axis of sensation, pleasure and displeasure, is the sign of the physiological usefulness of a stimulus. Pleasure is both the tag of a useful stimulus and the force that orients behaviour to approach and eventually consume this stimulus.
2) Since behaviour is a final common path, the brain needs a common currency to rank the motivations for access to behaviour in a time-sharing pattern (McFarland and Sibly, 1975; McNamara and Houston, 1986).
3) Since maximisation of sensory pleasure is the motivation for behaviours adapted to physiological goals and since motivations with physiological goals compete with other motivations such as playing, aesthetic, and social ones for access to the behavioural final common path, pleasure is this common currency (Cabanac, 1992). In the same way as sensory pleasure tags the usefulness of a stimulus, joy tags the usefulness of any other conscious experience[1].
4) The affective axis is thus the motivational capability of consciousness.
5) If consciousness possesses the affective axis, then the other axes of sensation also were inherited by consciousness.

The reader will have recognized in these five steps the same rationale as used earlier. The behavioural final common path, and the common currency, lead to the challenging conclusion that all conscious events bear the structure sketched in figure 2. It follows that affectivity might be the general motivation for any behaviour and that all the properties of sensory pleasure also would belong to the affective axis of consciousness. Joy is, in consciousness, congruent with pleasure, in sensation. Sensory pleasure possesses several characteristics: Pleasure is contingent, pleasure is the sign of a useful stimulus, pleasure is transient, pleasure motivates behaviour (Cabanac, 1971; Cabanac, 1979). Therefore, it follows from the same premises that joy keeps with global consciousness the same properties as pleasure with sensation. Joy possesses the same characteristics as sensory pleasure: joy is contingent, joy is the sign of a useful thought, joy is transient, joy motivates behaviour (Cabanac, 1986; Cabanac, 1996; Warburton, 1996).

It follows that pleasure/joy is the ineluctable motor of action of the human mind and bears the properties of an impelling force, the application of which will actuate the human being. This conclusion does not exclude that animals are susceptible to obey also the law of maximization of pleasure; interested readers will find elements of discussion in Griffin (1992) and Dawkins (1993). The evolutionary advantage of sensory pleasure, for the animals that first had it, is that it saved the nervous system from storing astronomical numbers of potentially useful or noxious stimulus-response reflexes. Sensory pleasure added flexibility to the

---

[1] This was recently confirmed in a series of experiments where pleasure/joy tagged efficacious mentalactivity (European Psychologist, 1997, 2:226-234), facilitated mental calculus (submitted), and was the key to decision making (Neuropsychobiology, 1998, 37:205-210). See also McKenna, F. (1996) Understanding risky choices. In D. M. Warburton & N. Sherwood (Eds.), Pleasure and Quality of Life (pp. 157-170). Chichester: John Wiley & Sons Ltd.

behavioural pattern of those which possessed it and passed it to their offspring. Similarly joy saves the brain from storing an infinite number of rules of thumb, and provides a formidable advantage both in amount of information stored and in flexibility of the behavioural responses. The major advantages of affective decision process as compared to rational (or reflexive) pre affective decision process (in living or inanimate agents) is to facilitate the ranking of priorities and to add flexibility to this process. The affective dimension of consciousness may be what makes a conscious agent different from an algorithmic Türing machine, as pointed out by Penrose (Penrose, 1994).

7. Conclusion And Proposal: The Fifth Influence

Historically, the Physicists have defined as a Newtonian force an *influence* operating on a body so as to produce an alteration, or tendency to alteration. Later, they have recognized four influences defined in a different framework but with similar conceptual results, the gravitational force, the electromagnetic force, the weak, and the strong nuclear forces (Table I). The gravitational force is the weakest of all interactions but exerts its influence most noticeably in the cosmos. Its range is infinite and all non-zero-mass particles are submitted to its influence. The electromagnetic force is much stronger than the former, it also exerts its influence over infinite distances but on charged particles only. It is accepted that the universe is neutral and only hot and dense regions in galaxies (stars, planets, plasma), and high-temperature clouds of gas in clusters of galaxies are submitted to the electromagnetic force. Photons and electromagnetic waves, so conspicuous in our everyday life, result from the electromagnetic force. The weak and the strong nuclear forces exert influences at atomic and sub-atomic level. They cause radioactivity and nuclear reactions in star cores. Unlike the other forces, the strong force increases with separation of the quarks. All forces have in common the property to actuate the bodies and particles on which they are exerted.

Table I. The four fources recognized by the Physicists and
the fifth influence proposed in the present paper

INFLUENCE	FIELD	RANGE	MACROSCOPIC MODEL
gravitational	cosmos	infinite	planetary systems
electromagnetic	charged particles	infinite	earth magnetosphere
weak	subatomic	atom	beta decay, neutrinos
strong nuclear	subatomic	atom	nuclear reactions
fifth influence	brain	infinite (behaviour)	human

Proposal

Having recalled that complexity is a relevant feature of the world, and that the brain is the locus of the highest known organised complexity;
having recalled that the affective capability of consciousness is the ineluctable motivation for behaviour;
and having finally recalled what a force is, we can now reach a conclusion with a proposal:

we suggest that the affective axis of consciousness, pleasure/displeasure and joy/distress, operates in conscious animals in a way similar to the way the four forces of Physics influence masses and particles, i.e. influences their behavior.

Since pleasure can move the infinitely complex into action, and since no thinking brain can escape the trend to maximize pleasure/joy, pleasure deserves to be ranked as the fifth 'force' of the universe[2]. However, since a

---

[2] The Physicists have hypothesized that matter was under the influence of a unified force in the beginning of the universe. As the energy density went down with time, the unified force separated, through symetry breaking, into gravitation and great unified force (GUT), then GUT separated into strong and electro-weak forces, then electro-weak forces separated into electro-magnetic and weak forces. It may be of interest to speculate on the emergence of the fifth influence from matter as the last symetry breaking of the forces; thus,

mental phenomenon is dimensionless we propose to consider the affective capability of consciousness, as the fifth influence rather than the fifth force. The above proposal is an axiom, and as such should not require demonstration. Yet, the experiments on which it is based were as many attempts to falsify it. This article is not the place to discuss when in phylogenesis, presumably among higher vertebrates, consciousness and the fifth influence emerged. Yet, we may accept that its early action was to actuate behaviours oriented toward the survival of individuals. With the advent of consciousness and humankind, the fifth influence led individuals to experience that not only biological behaviours but social ones are rewarding as well. Therefore, the fifth influence may be considered as just starting to drive the world towards increasing complexity by organising the more and more complex system of links that humankind weaves between individuals, the network that Teilhard de Chardin called "noosphere" (TeilharddeChardin, 1955).

Acknowledgements.
We wish to thank our colleagues C. Barrette (Dept. Biology) and J. R. Roy (Dept. Physics) for their kind improving earlier versions of the present article.

References

Aristotle 4th century BC. *De anima* (Fr. Transl.). Librairie philosophique J. Vrin, Paris.

Attia, M. 1984. Thermal pleasantness and temperature regulation in man. *Neuroscience and Biobehavioral Reviews* , **8**: 335-343.

Baerends, G. P. 1956. Aufbau des tierischen Verhaltens. In *Handbuch der Zoologie*. (Edited by Kükenthal W and Krumbach T) De Gruyter & Co, Berlin, p. Teil 10 (Lfg 7).

Barrow, J. D., and Tipler, F. T. 1986. *The Anthropic Cosmological Principle*. Oxford University Press, Oxford.

Bertola, F., and Curi, U. 1993. The Anthropic Principle: *Proceedings of the Second Venice Conference on Cosmology and Philosophy*. Cambridge University Press, Cambridge.

Bleichert, A. Behling, K., Scarperi, M., and Scarperi, S. 1973. Thermoregulatory behavior of man during rest and exercise. Pflügers Archiv, **338**: 303-312.

Bowring, J. 1962. *The works of Jeremy Bentham published under the superintendance of his executor John Bowring* 1833-1844. Russell & Russell inc., New York.

Breuer, R. 1991. *The Anthropic Principle. Man as the Focal Point of Nature*. Birkhäuser, Boston.

Brillat Savarin, A. 1828. *Physiologie du Gout*. Sautelet & Cie., Paris.

Cabanac, M. 1971. Physiological role of pleasure. *Science* , **173**:1103-1107.

Cabanac, M. 1979. Sensory pleasure. *Quarterly Review of Biology* , **54**:1-29.

Cabanac, M. 1986. Du confort au bonheur. *Psychiatrie Française* , **17**:9-15.

Cabanac, M. 1992, Pleasure: the common currency. *Journal of Theoretical Biology* , **155**:173-200.

Cabanac, M. 1995, *La quète du plaisir*. Liber, Montréal.

Cabanac, M. 1996. On the origin of consciousness, a postulate and its corrollary. *Neuroscience and Biobehavioral Reviews* , **20**:33-40.

---

eventually, in biological times, pleasure emerged from complexity as the last 'symetry breaking', resulting from a critical level of complexity reached by animal brains.

Cabanac, M., Massonnet, B., and Belaiche, R. 1972. Preferred hand temperature as a function of internal and mean skin temperatures. *Journal of Applied Physiology*, **33**:699-703.

Changeux, J. P. 1983. *L'homme neuronal*. Fayard, Paris.

B. de Condillac, E. 1754. *Traité des sensations*. (2nd ed.) Arthème Fayard, Paris.

Cosmides, L., and Tooby, J. 1995. From evolution to adaptations of behavior. In *Biological Perspectives on Motivated Activities*. (Edited by Wong R) Ablex Publ. Co., Northwood, New Jersey, p. 11-74.

Cosmides, L., Tooby, J., and Barkow, J. H. (1992) Introduction: evolutionary psychology and conceptual integration. In *The Adapted Mind*. (Edited by Barkow JH, Cosmides L, Tooby J.) Oxford University Press, New York, p. 3-15.

Dawkins, M. S. 1993. *Through our eyes only*? W. H. Freeman & Co, Oxford.

Fantino, M. 1984. Role of sensory input in the control of food intake. *Journal of the Autonomic Nervous System* , **10**:326-347.

Fantino, M. 1995. Nutriments et alliesthésie alimentaire. *Cahiers de Nutrition et de Diététique* , **30**:14-18.

Gell-Mann, M. 1994. *The Quark and the Jaguar*. WH Freeman & Co, New York.

Griffin, D. R. 1992. *Animal Minds*. University of Chicago Press, Chicago.

Jevons, W. S. 1871. *The theory of political economy*. MacMillan, London.

Kandel, E. R., and Schwartz, J. H. 1985. *Principles of Neural Science*. Elsevier Science Publ Co, Amsterdam.

McBride, R. L. 1998. On the relativity of everyday pleasures. In *The value of pleasures and the question of guilt* (Edited by Warburton DM, Sherwood N) John Wiley & Sons Ltd., Chichester, (in press).

McFarland, D. J. 1985. *Animal Behaviour*. Pitman, London.

McFarland, D. J., and Sibly, R. M. 1975. The behavioural final common path. *Philosophical Transactions of the Royal Society*. London, **270**:265-293.

McKenna,F. 1996. Understanding risky choices. In Pleasure and Quality of Life. (Edited by Warburton DM, Sherwood N) John Wiley & Sons Ltd., Chichester, p. 157-170.

McNamara, J. M., and Houston, A. 1986. The common currency for behavioural decisions. *American Naturalist* , **127**:358-378.

Nadel, E. R., Horvath, S. M., Dawson, C. A., and Tucker, A. 1970. Sensitivity to central and peripheral thermal stimulation in man. *Journal of Applied Physiology* , **29**:603-609.

Pascal, B. 1670. *Pensées* (réedit. 1972) Librairie Générale Française, Paris.

Penrose, R. 1994: *Shadows of the Mind*. Oxford University Press, Oxford.

Rossetti, Y., Meckler, C., and Prablanc, C. 1994. Is there an optimal arm posture? Deterioration of finger localization precision and comfort sensation in extreme arm-joint postures. *Experimental Brain Research* , **99**:131-136.

Shizgal, P., and Conover, K. 1996. On the neural computation of utility. *Current Directions in Psychological Science* , **5**:37-43.

Stolwijk, J. A. J., Saltin, B., and Gagge, A. P. 1968. Physiological factorsassociated with sweating during exercise. *Aerospace Medicine* , **39**:1101-1105.

TeilharddeChardin, P. (1955) *Le phénomène humain*. Éditions du Seuil, Paris.

TeilharddeChardin, P. 1965. *La place de l'homme dans la nature*. Éditions du Seuil, Paris.

Tinbergen, N. 1950. The hierarchical organization of mechanisms underlying instinctive behaviour. *Symposia of the Society for Experimental Biology* , **4**:305-312.

Warburton, D. M. 1996. The functions of pleasure. In *Pleasure and Quality of Life*. (Edited by Warburton D M, Sherwood N) John Wiley & Sons, Chichester, p. 1-10.

Young, P. T. 1959. The role of affective processes in learning and motivation. *Psychological Reviews* , **66**:104-123.