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On Understanding Language

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Abstract. This essay attempts to offer the bare bones outline of a complete physical theory of language.

Language: - The entire system of formal units used by a nation, people, race, or other common breeding group to communicate.

Communicate: - To pass from one to another by clear signs [knowledge, information, feelings, ideas]. (Definitions adapted from OEUD).

Preface. What a language does, as communication, is to switch or evoke changes in internal states of a system. A switch does that, but its function does not thereby represent a language. We will propose that, in order to qualify as a language, it is necessary that the switching or invoking function has to occur between complex entities - systems, which each have to involve a great number of internal states. You, the reader, of course generally start with the notion that the entities using language are human. We propose to offer you a physical generalization in which the entities are any system of complex matter-energy units. What is to be gained by this extension is the possibility of grasping a general and unified notion of language, its function and purpose, and how it comes about in a real physical universe. The presentation in no way is meant to be metaphoric; instead it is a new physical introduction to an otherwise mystifying subject.

Physical introduction. Our general systems' model (a homeokinetic physics of complex systems - see Soodak, Iberall, 1978) is that of a bounded ensemble of nonevanescent atomistic units ('atomisms') engaged in physically interactive play in a real matter-energy universe. While physically there are solid and fluid state systems, our general interest is in fluid state systems. The atomisms are not locked into fixed spatial configurations.

The major physical prototype for such a fluid field description is the so-called Navier-Stokes equations (N-S) of hydrodynamics-thermodynamics. That set of equations describes the essential variables in any flow field, subject to its boundary conditions and constraints. It describes the configuration and flow in space and time of energy, of movement (e.g., momentum), of matter density. Augmented for example by electromagnetic theory, it also describes the flow of the electrical constituents that make up the material-energetic properties of the units in the field. The range of application of such equations is enormous. They are used in cosmology, in galactic fields, in stellar fields, in the atmospheres, hydrospheres and fluid lithospheres of planets, in the geology, geochemistry, and biology of those planets, in the flows and processes within molecular, atomic, and nuclear constituents. Further, believe it or not, we have been engaged - in years of association with ISCSC - in the application of the ideas behind these sort of equations to an applied physics for society (see, for example, Iberall, 1974; Iberall, Soodak, Arensberg, 1980; Iberall, 1984; Iberall, 1985; Wilkinson, Iberall, 1986; Iberall, Wilkinson, 1987; Iberall, White, 1988; Iberall, 1991-92).

Such modelling for social processes would not be complete if it could not get around to the things that make you think of human societies as unique or specific, namely as systems displaying extensive memory, constructive capabilities, culture, language, communications (equally common, the opposite in miscommunication or dysfunctional communication), emotional or affective processes, as well as the 'mere' act of living and dying. In this essay, we wish to give you a sense of how language enters into such complex systems' descriptions.

Ordinarily, the N-S equations in physics are applied to what we call simple fluid systems. However, do not let the word usage 'simple' mislead you. These applications conceal some of the most difficult problem applications of modern physics. In their simplest prototype, relatively permanent ball-like atomistic units bang into each other and share and distribute their motional-energetic properties (we presume, for example, that you showered or washed, ate and breathed this day. Those media display the processes). The mechanistic play of physics consists of the principled capability of describing that motion in terms of invariant measures of that motion, and conservations associated with the interactive motion. In each paired atomistic collision, invariably matter, energy, and momentum are conserved. That elementary basis is never relinquished even when the nature of the interactive units change in a hierarchy of such systems, even as the application of our physical laws is augmented by a description of interactions that become more complex. Beyond the gravitational force (Newton's originating contribution), which with particle unit collisions already provide attractive and repulsive forces (e.g., drop a ball and watch it bounce), formally introducing the attractive and repulsive electrical force produces the unit interactions of chemistry. The units (molecular) may break up (into atomic constituents) and recombine. Chemistry, the making, breaking, and exchanging of force-bonded units, takes place physically because of the electric force (electrostatic and electrodynamic quantum exchange force). Further, at very fine scale, we also find nuclear forces acting at the more primitive scale of fundamental matter unit particles. With these few forces (discovered in 300 years of study), we have apparently reached exhaustively all the forces which affect movement and change.

Action in systems, simple and complex. The net effect of combining these few forces is to lead to more complexity in the higher ordered atomistic units that become possible, and in their possible unit interactions. We identify and distinguish a complex system of such atomistic units by the fact that they exhibit an extremely long time delay in another component measure of their physical energy conservation, the energy associated with their internal action, as compared to the scale of their external collisional actions. Actions - from which we observe the normal linguistic use of the word activity - are the things that a unit or system does. Technically, action is the energy-time product of a dynamic process engaged in by a unit. By the fact that complex atomistic units in ensemble have and repeat a characteristic long time delayed process compared to their pair-by-pair external interactions, which we can identify, we know that such complex units exist. Physics is an experimental science. In our physical construct for complex systems, which we call homeokinetic physics [homeostasis, or homeostatics representing the regulation of the interior, independent of external vicissitudes; homeokinetics is the physical dynamic processes that lead to such apparently persistent regulation], we refer to that internally repeated process as the "factory day" of the atomistic units organized into a system. Why? Because the interior resembles a factory in its complex of operating processes. And also because that repeated process has some such unitary time scale as its 'day'. Effectively almost by definition, a complex unit exhibits a great number of dynamic processes, e.g., a 'heterarchy' of many processes, but also a hierarchy of organization, the persistent existence of some such unit is to be found in that nested spectrum of temporal processes. One senses - e.g., the reader ought to - the existence of a large spectrum, a cascade of physical processes.

Such sensing is correct. For example, it leads us to one of the key augmenting notions of physics known as quantum mechanics.

To illustrate with a small amount of physical depth the character of a governing principle in the physics of quantum mechanics, we will point out an early form of quantum mechanics, Bohr's first attempt at it, which has not proved to be generally valid, but which gives some of the key flavor of what quantum mechanics succeeds in doing. We write compactly the expression:

$$\int_{t_0} pdq = \int_{t_0} Edt = nh$$

This is completely opaque to a social scientist audience, but its translation is not too difficult. It states that the summation ($\int$ is the symbol of integration or summing) over a cycle of dynamic performance ($\int_{t_0}$ represents a sum over that temporal cycle) of the product of momentum (p) and motions of displacement (dq) or of energy (E) and time change (dt) [out of its relativistic character, energy E is a "fourth dimension" of momentum p; time is a "fourth dimension" of space q - thus the two statements are equivalent] is measured by a small number (n represents that small number) of characteristic units of action (h - Planck's constant - is a fundamental action constant of nature).

Translated more sweepingly, the quantum concept states that characteristic actions of fundamental atomistic particles are measured by a small number of a universal measure of action. A fundamental atomistic particle is one of those particles that are found at the lowest hierarchical level in all of nature - in nuclei, atoms, molecules, cosmic rays. The parsimonious existence of a handful of fundamental constants and invariants in nature is remarkable. For example, one attempts a great deal of unified scaling in all of the universal processes within cosmology by the use of h - Planck's constant of action, C - the velocity of light in vacuum, e - the electric charge of the proton or electron, m, m_p - the mass of the electron and proton, G - the constant of universal gravity, R - the scale of the universe, and H - Hubble's constant, which is related to the age of the universe.

Complex systems. Illustrative of an exercize in biophysics, Iberall (1973b) was able to scale metabolic action in all mammals, from 3 gr shrews to 100,000 kg whales, by an action scaling not much different from Bohr's relation. The left hand of the relation remains the sum over all elementary actions of the mammalian body $\int pdq$ or $\int Edt$; the right hand is $\Sigma H_i = H_o$, where H_i is the action (energy-time product) of the major characteristic modes of the adult mammalian members of a species (Σ is the sum over i characteristic modes, 1,2,3, .. to some peak number i), which in toto comprises H_0 the total factory day action of that mammalian species. What was shown is that the characteristic action H_0 scales with the 4/5ths power of adult body mass (because of the gravitational force). Believe it or not, but because of the existence of some such relationship, people know how much to feed themselves and other animals that they involve themselves with.

For the human, the daily "factory day" energy consumption measure is about 2000 kcal/day (e,.g., the chemical energy of perhaps 20 slices of bread). To stress its universality, that number is now plastered on almost every item of food which one buys in American supermarkets. The action H_o is thus about 2000 kcal-days/factory day. It is interesting to compare H_o with Planck's constant h. In comparable units, H_o is 7×10^{18} erg-sec (per factory day); h is 7×10^{-27} erg-sec. Thus H_0 is 10^{45} larger. Loosely speaking, this is a measure of how many fundamental units (units really of fundamental action) one finds in a human. (The number of cells in a human is perhaps 10^{11}. Each cell in its own right is also a complex unit). That extremely large number indicates how large the measure of complexity may be in complex systems - here the human - in the universe. As a complex unit, the measure is a measure of the amount of internal action going on in the interior.

It is no surprise in physical science that the N-S equations of fluid motion do provide room for such internal action measures. First, beyond the purely 'macroscopic' mechanical processes (encompassed by what are known as the Euler equations of motion), as a result of their simple atomistic or microscopic interactions, there are atomistic particle-to-particle transactions - transfer actions, known as transport processes, by which matter, energy, and momentum are partitioned out (spread out) among all members and space-time reaches of the field. The transports are known as diffusivities. In addition to the transports of mass, energy, and momentum, there are the transport of electrical measures, including those that make up chemical processes - the chemical reaction rates representing the so-called making, breaking, and exchanging of chemical (electrical) bonds. But there is also the diffusion of the internalized actions among and from within the atomistic units. Here is from where complex systems processes and properties emerge. That measure - as we have shown - is the long internal time delay in internal atomistic interaction [characteristic exemplars: if two simple units interact, they exchange momentum; if two complex atomistic units interact, there is a long time delay in exchange of internal action. You eat a cookie and it takes 4 hours before that energetics shows up as externally available, say, to get you to work. Or, two people meet to get married, or to rob a bank. You spell out the consequences of those actions].

Catalysis and language. It is very clear that in simple atomistic systems, all of the field action in the system takes place by the continued pair-by-pair interaction of atomisms. We refer to their macrofield action as occuring by modes. The number of modal types of action are few. They can be exhaustively identified as propagative, diffusive, and convective modes. In simple systems, they are minimally energy, momentum, and density diffusion, momentum wave propagation, and momentum convection (e.g., heat energy spreads around by diffusion; start a fluid moving by local stirring and that movement also spreads by diffusion; on the other hand a faster component of the movement can propagate at the speed of sound; and the fluid movement may mechanically carry or sweep a load of materials by convection). Such field phenomena are found as smooth (laminar flow), turbulent, or chaotic flows, also the rest state. The coupling among these modes is quite direct. Most commonly, their format is joined via the external boundary conditions determined by such things as walls, storage depots, and other temporal processes out there.

In complex atomistic systems, while the field action still takes place by continued pair by pair interactions and is still diffusive, propagative, and convective, most of the modal action is internalized and hierarchicalized within the complex atomisms. The number of modes is much more extensive, and they form classes of recognizable phenomena arrayed hierarchically. Now the issue of modal election of action becomes complex. It is no longer so direct. That process of hierarchicalization is what has confused humans for millenia to accept and distinguish the 'natural' sciences from the 'humanistic'. Both types of phenomena are 'natural'.

The problem one has to solve here is by what sort of process, e.g., a so-called governance or command-control process, can the election of modes of action take place in a complex system; (a) in any complex system; (b) in all complex systems? In the first place, the question has to be answered whether complex systems exist, and whether there is a measure for that complexity.

It turns out that there is a physical measure within the N-S thermodynamics of fluid systems which casts light on the subject. Within the diffusive transports among atomistic components - in addition to mass, energy, and momentum (measured by their diffusivities of mass, of thermal conduction, and of shear viscosity - the latter measuring how movement is transferred in a fluid, say, as you stir or otherwise introduce momentum into a system), there is another diffusive transport known as the bulk or associational viscosity. Since the shear viscosity exhausts the mode of external transport between atomisms (how they transfer momentum by external collision), it turns out, by residual exhaustion, that the bulk viscosity measures the transfer of action into internal modes. What justifies our notion that the bulk viscosity is the measure of complexity is the following: Physical theory demonstrates that the ratio of bulk to shear viscosity is the ratio of internal action in the atomistic units to the external action between those units. Recall that the shear viscosity is the measure of diffusivity of momentum among atomistic units. As diffusivities, the bulk and shear viscosities have the same physical measure [a diffusivity measures the mean square spatial range into which a property "diffuses" per unit time. In the peopling of the Earth, population, and the practice processes of metallurgy, ceramics, agriculture diffused on the Earth's surface]. Action, physically, is measured by the product of energy and time in all modes that a system operates. If the bulk to shear viscosity measures their internal to external action, and - the essence of the matter - since their (the atomistic units) internal and external energetics are comparable (all the interior dissipative energetics has to come from the exterior, e.g., the cookies you eat), then that ratio is the ratio of internal time delay in action to the external time delay in collisional interaction.

Now recall that we defined a complex atomistically based system as one whose internal action is long time delayed. Thus, very large bulk viscosity systems are complex. However, there are two requirements - one that they exist, and two, that their long internal action time constitutes a more or less repetitive cycle, what we have called the factory day. Examine the latter. First, what would constitute a long time delay internally and how does it come about physically?

It comes about because of the hierarchical atomistic nature of matter-energy systems that exist, and because of their considerable diversity at each level. Thus, the interior of a complex atomism is really a complex fluid dynamical field made up of many subcomponents. We call it a factory, and because of the physical nonevanescent character of those subcomponents, there is a complex factory day (a complete cycle of its functional operation). Actually, because of the hierarchical nature of organization, there is an entire nested sequence of time delaying processes in which the factory day is only one of the limiting, more embracing measures. In a simple system, the operation more or less only centers on one or a few external time delay processes, and at most a few internal time delay processes, e.g., an internal vibration or rotation. In the physics of simple systems, we find three states of matter - the gaseous, the liquid, and the solid states. For example, in a simple gas system, the salient process is the long free flight time associated with atomistic mean free path of flight between collisions. In a simple liquid, there is the local hammering collisions among the flock of closely nested atomisms associated in a local liquid cell. An additional force component of attraction, largely from an electrical foundation, comes into play as well as the repulsive force which drives them apart. However, as internal complexity is found in molecular type unit atomisms, the bulk to shear viscosity (internal to external time delays) begins to rise. A considerable number of the time delays begin to serve as so-called thixotropic or memory functions. For example, as we combine simple gases, with more reactive components, and with water in both a liquid and vapor form, within a considerable variety of nonlinear processes at planetary scale, we find ourselves confronting a complex system, the atmosphere, whose *storminess and diversity of states serves quite generally as a prescription of how complex systems develop or evolve.* Or, to introduce a more quantitative depiction of bulk to shear viscosity ratio, consider loosely a macromolecule of DNA, with millions of atomic pairs, running off a model of itself; another example, some catalytic chemical enzyme in a cell expressing a program to duplicate the millions of steps required to synthesize a protein. Its bulk viscosity is measured by the millions of steps of such syntheses; its shear viscosity remains measured by its water-like characteristics, whose momentum-driven action is millions of times less.

The ratio of bulk to shear viscosity is zero for a monatomic gas (like helium, neon, argon, etc., e.g., effectively no internal structure); about one for a diatomic gas (like oxygen, a measure deriving from internal vibration), for organic liquids it may be in the hundreds. As we get to thixotropic materials (memory-possessing fluids, like paints, inks, sewage), the ratio rises. However, our concern, when memory storage becomes appreciable, is in ratios above 10,000, e.g., in the millions, billions, trillions, and perhaps beyond. As you can see, the problem of switching internal modes thereby really becomes significant.

Physically, the domain of not-very-large bulk to shear viscosity range, e.g., from perhaps 3-10 to tens of thousands, lies commonly in a very difficult physical study known as rheology. Engineers and scientists find this in inks and paints, in silly putty, asphalt, and some other exotic materials. In contradistinction, what we have pioneered in is the very large range in which the extensive memory function of "meteorological" systems is found. Thus suppose we consider the Earth's atmosphere. Its dynamic temporal range is as extensive as a "dust devil", perhaps near 0.1-1 sec, to the 100,000 year scaling of major meteorological processes such as the warming and cooling ages that socially trouble people today. That scale itself represents minimally a bulk to shear viscosity ratio of about 10^{13}. This is a reasonable intermediate measure of complexity when compared to the human's possible 10^{45} measure.

What we have uncovered, as a general process, is some essential facts about how these large bulk viscosity systems operate. At each internal complex hierarchical level, we find a double track of chemistry (chemistry - the making, breaking, and exchanging of bonds) going on. One track is the track of power chemistry. This is where the major thermodynamic energy flows (for example, the simple reaction of fuel plus oxygen giving rise to carbon dioxide and water and byproducts plus heat energy). But parallel to that track is a second track of catalytic chemistry. This is a small power track which provokes or retards the power chemistry. Its ingredients are not used up, but they are put in and out of storage bins, i.e., they satisfy the definition of being catalysts. This second track is and defines the language of that system level. Language is a catalyst that evokes or switches modes. The catalytic flow track used may make use of chemical, mechanical, electromagnetic processes (e.g., acoustic, chemical as in pheromones, or as light or radio waves). Among engineers, it represents what is called the communicational engineering aspects of their systems.

What is necessary for a catalyst, particularly for a system of catalysts, is that they can be stored and not used up. Thus in living systems, the use and storage of enzymes constitutes such a system of catalysts. Or clouds and water pools and Earth processes in meteorological systems store a number of catalytic measures.

At any simple system level, there is no reasonable way to regard it as a language-possessing level. There may be a few modes of action and switches that control those changes, but the system program is not extensive enough to constitute a language.

What sort of systems are complex and language possessing? It is useful to have a general idea of the systems that do possess languages. We will illustrate. Quite generally, they are "meteorological" and exhibit many "faces", commonly ranging around "storminess" and "placidity". They are changeable in their character. And, of course, they are catalyzable. The meteorology of an atmosphere (the Earth's atmosphere), of a hydrological system (like the oceans and rivers and lakes and clouds), of the mind (the electrical patterns in the brain), of the living organism, of a living society, of a star or solar system, of a galaxy, of the universe itself, are some major examples. Note that they are all fluid systems. Solid state automobiles or rigidly formed (hard wired, hard molded, hard geared) factories are not complex systems regardless of how many switches are installed. It isn't until all of the inconsistences, the instabilities, the paradoxes of incompatible states, the misdirected or mistakes in catalytic coding can be self resolved within the system, which will continue to operate, that we have a complex language using system. Literally, in a complex system, the walls and all other architectonic features also have to flow and turn over.

The switching-evoking content of language. What does a language, as catalyst, deal with? Obviously, the modal business of the system. And what can that be? Since it is a physical system, it can only deal with the beings and becomings of the system, the fact that the system can only be in one of a few physical states - gas, liquid, solid, or combinations, and operating with a limited number of processes. That sort of idea became clear philosophically to the classical Greeks in philosophy (e.g., as the problem of being and becoming), to more ancient humans in discovering the spiritism-animism of magic-religion, and in current people's discovery of science. To characterize the processes in a scientific sense, rather than concentrating on the states of being, we can refer to the actions we observe as aggress, defend, and maintain modes. We will deal with some of the scientific issues a little later on. But first, it will be of use to grasp the hierarchy of language usage in such a complex system like a human, us.

Exemplifying a language hierarchy. Reaching down to our lowest systems level, we - as in all physical systems - are comprised at a low level of leptons and quarks. At that lowest level, they "use" a "language". Do we understand it? Very vaguely, effectively almost not at all. It proceeds among those objects, these bosons and fermions as they conduct their business with the vacuum of nature. For example, by the very limited way and localized environment in which the quarks communicate with each other, they constitute that social universe that we find making us up. To beat a metaphor literally to death, their forces, no different from Chomsky's deep structures, give us their noun phrases and verb phrases; thereby they catalyze the nuclear constituents out of the vacuum that we perceive as reality. Perhaps some day, if and when we develop a grand unified theory, a theory of everything, in physics then we will better understand that language.

At a level above, we encounter the language of nuclear elements or species. This is perhaps understood a little better than the lower level. As a level above, where nuclear elements join, we come to the more ordinary "chemical" language of atoms, ions, molecules. At present, there is a community - chemists - who are capable of addressing this language level in pidgin form. With newer laboratory techniques, the language comprehension is growing. It is one of the few levels with which humans can claim any modest familiarity, a familiarity acquired in 200-300 years of study. In the laboratory, the chemist 'speaks' to those units, and conversely in the human's own laboratory, those chemical units 'speak' to the human any time he or she performs any action (For example, try 6 oz of alcohol, or test your nicotine addiction).

At a next level, within living organisms, we come to the level of organelles and cells. There is a lesson to be learnt here. There are many unicell organisms that are fairly proficient in that - their - language level. On the other hand, it is one which is really not well understood yet by humans. At the next level, the organ level, humans hardly have even a pidgin form of comprehension. Can you intelligibly communicate with your liver, or spleen, or stomach (e.g., by

Rolaids?)?

It is only at the next level, the organism level, that we begin to have any comprehension of that language. It is part of the overweening hubris of humans that tends to identify this as the "only" level of language, and at that human, and only spoken. Before dwelling on that issue, we can complete the litany of languages, and attend to the one above, the cultural and legal societal language of the species, and finally above that the common language of all organized systems in the universe.

By this time, we think it becomes obvious that each of these language levels is an interacting constraint system of "law". The uppermost level of such "law" is the physical law system of the universe. It is the catalytic system that dominates all of the universe. In that context, the lesser levels are the level of human social law, and then the lawful constraints of organismic language which govern their behavior,

For example, we have begun to work on the physiological linguistics of all motor-sensory behavior in mammals. While you perform that language, and are constrained physiologally by that "legal" system, you only "speak" it in very pidgin form. You "generate" it easily, but you don't "speak" it. Actually in our comprehension of it, we have been able to figure out its phonemic structure; we are just beginning at its semantic structure (see, Iberall, 1992). These phonemes of behavior take on their repetitive time scale of about 6 seconds - as an "attention" scale, and represent the stream of about 15,000 units per day. As "linguistic" units, they comprise a stream of perhaps a few hundred "sentences" each day, and that represents our total "volitional action content" each day. It is those messages which we inscribe on the winds of each day. It has been possible to show that the action spectrum of body action modes themselves satisfy language distribution characteristics.

But the purpose of this paper is to introduce the foundations by which we generate "our" language, that catalytic system which we repetitively and intensively invoke internally, which we use to communicate between our "selves" and our internal parts, and which we also externalize and communicate with organisms like ourselves. To a lesser extent, we use it as a pidgin language with other organisms, and we even attempt to use it in more incomprehensible form - as animism leading to religion - with other components of nature in the universe. We hardly take note of the fact that other organisms are also communicating.

Language systems in mammals. With this very long but necessary introduction (we are not sound bite driven politicians), we can turn our attention to animal organisms with nervous systems, more particularly to mammals, even more particularly to primates, up to hominoids, hominids, Homo, and even us.

In animals with nervous systems, we find cells and organelles specialized for long distance "fast" communication (read H. Chandler Elliott, 1969 for an excellent introduction to brain and nervous system function; also Llinás, Iberall, 1977). Evolutionarily, before the development of electrically conducting cellular transport systems [electricity here is basically ionic conduction promoted by chemistry], the communication system was much slower chemical transport, e.g., by hormone-like actions. With nervous systems, multicellular animals had two communicational systems - a slow to-whom-it-may-concern diffusive system, and a fast "wired" system. Fast, here, means transport at about the 0.03-0.1 second level. Some such internal communication system is found in all nervous subsystem animals.

When we move to the level of humans, we even find an additional modification. Not only can the communication take place internally and emerge as an internal rapid command-control system [please don't let any of a large number of "hunting" creatures attack you if you think you are the only species capable of such fast intercommunication], another layer or level of catalytic communications emerges wherein as much rapid external communication can take place as inside. Thus a 6 second phoneme, found in all mammals, is itself a complex process - a cognition, of many fast perceptions produced by nervous elements.

[As a marvelous thought, consider the largest nerve possessing animals - the largest species of whales and of dinosaurs. They both reach about 100 feet (30 meters) in length. The slow nervous conduction system is about 0.2 seconds per meter. Multiplying 0.2 sec./meter by about 30 - 3 ft units, gives 6 seconds. Thus these enormous animals can also provide 6 second behavioral phonemes. A possible conjecture is that 100 ft length is a limiting size for nerve possessing animals]. Thus all nervous system organisms have an internal sensory-motor system behavioral language. That language is studied by ethologists, who intuitively know it as a language, but not consciously, not intellectually - yet (except for the one study we have encouraged at UCLA. However, it is fair to say that there are some ethologists who we believe are effectively close up to the themes we address here. See, for example, Eisenberg, 1973)].

So we finally come to the language level that humans use, which we can explain loosely how it may have arisen. Language, as you can now surmise, directs and evokes the stream of action of an organism. In nerve-possessing organisms, it uses the chemistry, electrochemistry, of connected nerve cells for the fastest form of that catalytic action. In order to be an extensive enough system to comprise a language, it must encompass a considerable nervous net capable of being manipulated at a great number of low energetic catalyzable states.

It is our conjecture that what made human language possible was the interposition of one additional interneuronal level in the higher nervous system. What is very important of nervous systems is that they operate by the apparent negative process of inhibition. Namely, if a pathway is to be excited, lateral inhibition is required to shut off extraneous pathways. If and when all pathways are excited, one confronts a process like epilepsy, nervous spreading from a focal center, or the jitter attributed to Parkinson's disease, and the like (If one examines, say, an outstretched arm, one finds a general movement of tremor that originates from chemical causation without nervous excitation. However, it is of small amplitude).

What is unique in human nervous systems is that the connected wiring extends and mixes into all channels. Thus rather than the direct excitation of a reflex, or early formed wired connections, e.g., a food signal discharged by a food action, etc., or a conditioned reflex - transfer of excitation from one channel to a second conditioned channel, there is a spreading capability into all channels, e.g., any signal can be transduced into another signal channel - food, sex, smell, mental imagery. That required even more careful lateral inhibition control.

The essence of that control spreading is the development of abstraction. Abstractions are identifications which are not direct, but that can be fixed epigenetically. Example: The poet asks "How do I compare thee to a summer's day?"

With uprightedness and facile handedness, the primate, evolving to hominoid on to hominid, began to develop specific locally extended nets. This occured in the visual system, the vocal system, the upper body attention system, and the brachiating system. The body as a whole had such a net, but these were more localized coordinated nets. Our conjecture is that they each involve about 25-50 degrees of local freedom. With some discrimination in states in each of these degrees of freedom, extensive languages can be created. But if they are low energy, they can be conducted at neural rates, that is at tenth second unit discrimination. For example, human speech phonemes are used at about 5 per second.

But it is a mistake to think that it is guaranteed that human language started with speech. If you consider the known historical occurences of human language, you must grasp that any of the extensive nervous system nets might have been used as a "first" language. For example, humans have evolved handed language independent of speech, written language, Morse code language, Braille language, currently we can detect that a full-fledged computer language is in process of development.

Let us also characterize other more obscure languages. A pilot command-controls a multiengined airplane, communicates with the plane and its natural meteorological environment. (Why a language? Because if it weren't, the pilot could be replaced by an autopilot which would control the entire system by mechanistic switches. No one, we believe, is yet ready to accept such open command-control, even for a model airplane). A community of physicists, over 200 years, have developed a language of nature. Other disciplines also attempt their languages, their jargons, their pidgins, or people attempt to inscribe a language of law for their societies). But a hunting animal also communicates with nature and the animals he or she hunts or hunts with. An animal attending to all aspects of an environment is using a language. All of these exhibit the capability of nervous system languages. So with these clues, we can now approach the topic of human languages, including speech.

First, in general, what is the subject of language? For example consider the doctrine of animism. It asserts that spirits exist and that spirits move or cause motion. Or, linguistically, one asserts noun phrase and verb phrase. Or, jumping to a first attempt at a complete natural law and language, we have Newton's law of motion, $F = ma$. Forces make systems move by accelerating them. Thus as solutions of that general law, we have the dynamic resultant pair for any state, e.g., x, dx/dt (position, velocity). All of these pairs represent state and rate of change of state, prototypes for being and becoming.

Now the linguist knows that it doesn't remain that simple. There are all sorts of modifiers that we develop as pilot linguist, as verbal linguist, as physicist linguist, as hunter linguist, but they are minor, modifications of the fundamentals of being and becoming. However, we will suggest we now have a basic sufficiency to embark on a fundamental theory of language.

A first scenario. How might the human languages, with human nervous capability, gotten started? We do not have to make the point again that humans as complex systems had languages, had all of the internal physical-chemical stormi-ness of complex systems. But we want specific contexts within which the specialized human languages might have started. Unless we were there, we could hardly know. So we will offer you physical conjectures, scenarios if you will, of how such languages might have started. They are and have to be evolutionary, which is still an incompletely developed field of physics.

Language is communal. It involves communal linking. So why not imagine and conjecture communal situations involving humans in which language could have been invented. We offer you the hominid attention mode, hunting, and the communal activity of the hearth, the camp, and the band fire. We want to link human motor-sensory activity and internal brain capability in those kinds of activity.

Human ability to associate signal from any channel with response in any other channel, rather than merely associating in one additional channel - as in the conditioned reflex - is the beginning of human type abstraction. It overcomes the loss of generality of the lateral inhibition. Note that without lateral inhibition in the nervous system, the entire system would be excited (as in epilepsy, or Parkinsonianism). That sort of response is a "linear instability". A system flooded with excitatory signal cannot function. The system is confronted by too many conflicts. Thus the existence of lateral inhibition, representing a loss of the ability to produce a general excitation, stabilizes the system into selecting nonlinear control of modes of action. It offers selective control as a substitute for general excitation. Selective capability to associate in all channels, yet under some epigenetic control, restores some of that generality lost by automatic inhibition, but at a slower rate.

As one may surmise, the complex living organism really is flooded in the environment by a bewildering number of inputs, a flood of signals. How do we know that? One, when we go into a number of new and strange environments, we are immediately so struck. So it is much the familiarity of most circumstances that lets us proceed with a moderately volitional set of elections (We turn down our detectional gain systems, rather automatically). We can "choose" to direct our attention and avoid great conflicts. But that is only most of the time. Almost any human can be triggered into confusing situations, in which the indicator of rapid eye movement indicates the nonlinear confusion. A second probe at the instability of flooding is very simple to show. Amplify or intensify the input signals in any environment. Then, like any overamplified electronic receiver, you will find the system going into a very noisy jittery and disturbed response. Or, conversely, turn down all input signal. The compensation characteristics of the organism's nervous system will itself turn up the response gain and the system will go into a mode of instability from no signal.

It is very clear, e.g., among, say, mammals, that the total modal behavior patterns constitute a language (see Iberall, McCulloch, 1969, for the character of human modes). More particularly, that "body" language can in fact be largely translated by human abstractions into common language, but likely in that form it does not immediately serve as the basis for a fast symbolic language. So it is the basis by which fast low energy catalytic action languages might be developed that we are searching for. We turn to more specialized nerve governed patterns.

It is our conjecture that much of the socialized response of the organism is shaped early on by the mother in the mother-child relationships. These relationships help both to individualize and socialize the character of future responses that the organism's historical development patterns in the nervous system.

There is very little doubt that animals such as mammals (and birds) imprint and do conduct linguistic exchanges in mother-child relationships. But in the human, it is protracted, and it develops much more extensively. One notes that it is a language involving a complex of facial movements, body movements, hand movements, and - in time - oral utterences. They all involve nervous system complexes.

A second kind of social nervous complex where rapid response is needed is found in hunting - found also in many hunting animals, but the added complex of tool evolution going back 2-3 million years "speaks" of additional complexity. A tool is neither self nor outer world, but some material-energetic assemblage which can be 'manipulated' between self and outer world to influence action. As such, it is also a linguistic, catalytic element. It is clear that hominid ancestors exhibited that capability, and - by findings - it dates back that long. It probably began with Homo habilis or Australopithecus, more likely the former, namely in the Homo line. At any case, it indicates likely that some transformation in hominid brains made that kind of epigenetic cultural startup possible. Note that the break from anthropoid apes is now dated at about 6 million years. In an evolutionary sense, this begins to increase the selection pressure on the emergence of hominid tools to within relatively a few millions of years.

The early startup, as pebble tools, is not a tremendously remarkable transformation. It is difficult even to distinguish the findings, in individual cases, from simply "found" objects. But the persistence of the findings, their number, and their evolutionary character in time, e.g., differences between 2 and 1 and 1/2 million year old tools, indicate their cultural epigenetic character. Yet some brain size and wiring changes had to make the evolution of such abstractions possible. As we said, we opt for an extra interneuronal level in addition to the increase of hominid outer cortical brain size in the Pliopleistocene era. This is the weak evidence that supports the commonality of tool evolution and biological and social evolution. Handedness evidence turns from basically none in chimpanzees (personal communication from J. Goodall), to almost none in Neanderthalers, to its appearance 40,000 years ago in Cro-Magnon, modern humans.

Given that type of hard and fixed bioevolutionary change, an emergence of interorganismic communication at relatively rapid neural rates was possible. That is, we are saying that communication systems more extensive than are found currently among, say, primates, even anthropoid apes, became possible among those hominid transitions. As lower limits, we can ascertain how mammals, e.g., dog-dog, human-dog, human-cat, etc. communicate, on more particularly on up to primates, and further on to apes. In humans, we find full languages at or up to 5-10 Hz (e.g., phonemic signals up to 5-10 per second. See Kelso, Tuller, 1984). That is very close to nervous system limits. and we find the support basis for such language in nervous memory systems, in the exponentiation of a few 'handfuls' of signals. Typically, with such a level of discrimination, we find a potential pool of language units up to the order of 2^{20} (e.g., a million) [the OUED, for example, has a half million words alone]. The limit is memory albeit in a society of many individuals.

On the other hand, let us indicate another test of that sort of discrimination in an apparent nonlinguistic task. The human memory can distinguish and hold about 500 faces in memory banks (or hunter-gatherers can identify a similar number of different plants). How many units of discrimination are required to distinguish a face? There are about 10-20 features. These have perhaps 10 discriminable states each. Thus 10x20x500 = 100,000. Thus we may perceive that catalytic memory pools may have that range of perhaps up to 10^5 to 10^6 units of linguistic discrimination units in memory bank, as we range from individuals to groups, and in the human case discriminate rates up to 5-10 Hz.

How does such a catalytic abstract parallel linguistic system emerge and evolve? It emerges chemically, electrically, as the components of a social pressure made up of an electrochemical bulk viscosity. It emerges as a social pressure able to match environmental stresses (a pressure is a particularly directed stress.

It is an in-out component. See, Iberall, Soodak, Arensberg, 1980; also Iberall, in a forthcoming article on the operation of the brain - in review in Eco. Psych.).

Now for potential scenarios of evolution. Those, we suggested, are hominid, likely Homo mother-child configurations, hunter-gatherer social action configurations, and - perhaps above all - the communal fire. Since young children after a modest age of 2-5 years, commonly have extensive use of language, we may surmise that the first configuration is also important. The communal fire we can put back either in Homo erectus history, perhaps 1 Mya, and quite certainly Homo sapiens neanderthalensis 1/4 Mya.

To a hunting animal, a body language of thousands of signals is easily developed from birth on up. Please do not indicate a parochial blindness that cannot sense such languages. Watch any insect, bird, or mammal, and perceive immediately that you have only the faintest pidgin sense of their hunting languages after they have each passed some early development and enculturing stage, typically from parents.

So here we have arrived, finally, at what has seemed to us to be the richest source of abstract imagery, the nightly campfire. One of us drew inspiration originally from Fustel de Coulanges' The Ancient City. Given the developing Homo brain, and the entire Pleistocene age, with the appearance and development of tool abstraction as a linguistic adjunct to the actions of life, the darkness of night, the richness of the tool use of fire, it seems almost obvious that the operational circumstance would help force and direct the development of language. How? By what appears to be the major provoked imagery, the social pressure exerted by the communal fire.

Of course, it wasn't until a few years ago, in our California social physics group (to which both authors belong), that our anthropologist colleague, Alexander Moore, USC, made sufficiently clear to us the significance of the hearth fire as an enculturating device for the human hunter-gatherer group, so that a causal connection to language became apparent.

To our minds, the major images which become entwined are the "causal" animistic spirit of the flickering flame, the personage of the keeper of the flame, the giver of the flame, and the spirit of the ambulatory living and dead who carry the spirit of the camp. Symbol, flickering image, spirit, the fluctuation of life-death, god or gods - in time, these perceptions become enmeshed in the mind. We can't tell when such an idea originated. That, physically, is an experimental question - some time between tool origins among Homos 2 or so Mya (million years ago) to the appearance of very definite cultural abstractions of 35,000 to 20,000 years ago. It has to parallel, in some way, the evolution of Homo-hominid culture.

What sort of language might evolve in those social circumstances, e.g., around a nightly fire? Any abstract symbolizing form associated with a rich enough pooled cache of nervous elements. Did it have to be speech? No. As estimated earlier (Iberall, 1973), spoken language could not have emerged until there was brain disymmetry as indicated by handedness, and a pharynx. Thus, that paper attributed speech to Homo sapiens sapiens, about 40,000 years ago. At present, we cannot tell whether so-called archaic Homo sapiens sapiens of perhaps 100,000 years ago had that kind of handedness. But with facile tool making going back to 2.5 Mya, and very elaborate tool making among Mousterian Neanderthals, we cannot preclude complex hand signalling with or without handedness. We would still vote for brain disymmetry, but no longer as convincingly. It is only the cultural artifacts of 35,000 years ago that provide a certain lower limit, but no longer an upper limit. So some time, at or before 40,000 years ago, any of a number of signalling systems may have proven advantaged and pushed social-biological evolution of a rapid language system. What did it represent? Signalling abstractions for beings and becomings; in physical language symbols denoting state and rate of all kinds of systems, and later other 'linguistic' modifiers. As it developed, a language of physical systems, as a universal language, and the language of the complex system of humans, more specifically, continued to develop in parallel in abstract content.

[The facts known in perhaps 1980 from Middle Paleolithic findings in Israel suggested the presence of Neanderthalers to about 50-60, now even - in Spain - as recent as 30 kybp (thousands of years before present), and the appearance of Homo sapiens sapiens (H.s.s) about 40,000 ybp. A broadening of calibrating measuring techniques have reassessed that data, McDermott et al, 1993. It now appears that the date that can be assigned to that earlier Neanderthal data (Tabun) is about 110 kybp as averaged from two measuring techniques (uranium, and electron spin resonance), and 116 kybp (with the addition of thermoluminescence); that the H. s. s. data (Qafzeh) averaged about 101 from 2 types of measurements, and 107 from three types. The H.s.s. data from Skhul appears to range from young 45 kybp data for two types of measurement to oldest of 88; from three types of measurement these numbers change to 52 and 90. Such changes are not capricious; they represent 10 years of hard measurement research. Even more recent findings add additional information into the range up to and beyond 100 kybp].

We can't tell you what the nerve governed phonemes of emergent hominid-Homo-human languages might have been. It might have been vocal, or handed, or grosser body movements, or motor patterns of attention. Even slightly advantaged individuals could have led the evolution. With this growth of understanding of the problem, it is now clear that such genetic selection, breeding selection only of point mutations, could have evolved a language in less that a few millenia. We use other breedings as yardsticks - the breeding of dogs, the breeding of domesticated plants, social evolution of cultural forms and institutions, Auel's fairy tales, these all become analogous measures of a similar process. Many of us older folk are now watching the speed with which children are beginning to pick up on computer 'languages'.

Coda. We know that you expected us to write down the more likely coding for the history of a universal human spoken language. At this point, we don't think physics or our physics can go much further in creating historical languages. Physics is an experimental science. We have helped give you a theoretical Rosetta stone, a first clue for deciphering our linguistic hieroglyphics. Now, we would be more comfortable sitting down with linguists or paleolinguists, or ethnolinguists, or physiologists, etc. and beginning to think experimentally and compare notes. The discourse - from our side - would relate to information flow theory, to the efficiency of languages, to various physical, chemical, physiological, social physical limitations and constraints. We have made our first contribution in pointing up the roles of a mother-child relation, the role of the hunter, the shaman, other ambulatory memory roles of the elders, the weaving of the day and night in the flickering fantasies and reveries of mind (Iberall, 1972). Beyond the space and time and energetic manipulation in space and time, and the logics of naming, counting, and geometricizing, that paper pointed out the existence of the switching logic of "reverie". Here now, we need to create proper social experimental situations for creating the historical content of the plausible fragments of reverie. This is a task similar to deciphering, decoding of ancient fragments. Of course we know that there is you and I, and we and they, and the beings and the doings and the changings. Fot those who are ready, it is time to start. Our place, or your place?

Arthur Iberall, Cri-de-Coeur Press; David Wilkinson, UCLA

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