Nonlinear Dynamics, Artificial Cognition and Galactic Export

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Abstract. The field of nonlinear dynamics focuses on function rather than structure. Evolution and brain function are examples. An equation for a brain, described in 1973, is explained. Then, a principle of interactional function change between two coupled equations of this type is described. However, all of this is not done in an abstract manner but in close contact with the meaning of these equations in a biological context. Ethological motivation theory and Batesonian interaction theory are reencountered. So is a fairly unknown finding by van Hooff on the indistinguishability of smile and laughter in a single primate species. Personhood and evil, two human characteristics, are described abstractly. Therapies and the question of whether it is ethically allowed to export benevolence are discussed. The whole dynamic approach is couched in terms of the Cartesian narrative, invented in the 17th century and later called Enlightenment. Whether or not it is true that a "second Enlightenment" is around the corner is the main question raised in the present paper.

keywords. Deductive Biology; Equation for a Brain; Interactional Bifurcations in Coupled Optimizers; Smile and Benevolence Theory; Transspecific and Transbiological Export of Personhood.

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INTRODUCTION

Dynamical systems are "machines." For example, the solar system is a machine, as Newton discovered. Machines are described by Newton's "ordinary differential equations" of 1687. Dynamical systems and nonlinear differential equations are synonyms. The whole world "is" a differential equation (more precisely, a system of such) according to Boltzmann, who lived 200 years after Newton. Boltzmann pioneered a microscopic (frictionless) description of macroscopic systems - like flames, stars, galaxies, organisms, brains and societies - each in terms of a very large number of Newtonian differential equations (6 per constituent particle). Such far-from-equilibrium, self-maintaining systems were later called "dissipative structures" by Ilya Prigogine [1]. Even if one sticks to a (by definition only approximate) "macroscopic" description of such systems (which vastly cuts down on the number of variables needed at the expense of nonzero friction terms entering), Boltzmann's verdict that the brain "is" a differential equation remains valid. Even the thought processes (the "secretion products of the brain") retain this dynamical aspect. Thus, dynamics - beside matter - is one of the two major keys for understanding and intervention in the universe.

An "equation for a brain" was described in 1973 [2]. It has two ingredients, a force-field-generator and a universal simulator. The first ingredient (equation 13a of [2]) describes an "autonomous direction optimizer," as we shall see. The second is a "virtual reality." Both taken together make for a full-fledged "autonomous path optimizer" or artificial brain. An autonomous direction optimizer is a gradient-following dynamical system that spontaneously seeks the maximum or minimum of a given function over the surrounding environment. A virtual reality is an algorithm that permits an arbitrary local perspective to be taken on a 3D environment in a realistic fashion, so that by activating a joystick, one can actively move around in it. The video game "Zelda" by Shigeru Miamoto and Charr Davies' whole-body-immersion "Osmos" are famous examples from the 1990's.

The "brain equation" is, in spite of its complexity, a nonlinear dynamical system. This fact can, perhaps, be illustrated best with an anecdote. When the equation was first presented at a meeting in Trieste in 1973 [2], the notion of a low-dimensional deterministically produced randomness later called "chaos" was still unfamiliar. Therefore, it appeared necessary at the time to incorporate a random component in the equation (called "will-o'-the- wisp potential" [2]) to

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ensure the equation acts "creatively" in space. Soon after, it turned out that the added potential was redundant because the time-dependent potentials already there jointly possess the desired property automatically. Indeed, the forces of the equation interact "hyperchaotically" with each other, closely mimicking the mutual inhibition of gas pearls arising on the inside of a glass containing sparkling water [3].

The reader probably expects explicit equations at this point. Please, allow me to ask your forgiveness for the fact that I believe this would detract us from our main goal of "qualitative understanding." Poincaré was the first to see that dynamical systems are maximally "goodnatured" in the sense that they lend themselves to qualitative (topological, visual) understanding, despite the fact that everything can be made quantitative in addition. Actually the qualitative aspect is the decisive one. The word "chaos," for example, refers not to a quantitative but to a qualitative type of behavior. Your motivation for looking at the equation in detail and perhaps eventually building a working implementation in reality will depend on whether I succeed in bringing the equation closer to your heart. This I can do best if I do not write down the equation in detail. The mammoth paper of 1973 [2] was the only time I gave the equation. Some simulations can be found in [4], but they refer only to maximally simplified equations meant for those who want to convince themselves that such equations are indeed prone to producing chaos both alone and in interaction.

There is another reason why I am hesitant to give you the equation in detail that stems from my personal history. Dynamical equations have a dot on the variable to the left of the equality sign. I made the experience at age 17 that such differential equations can take the whole pleasure out of understanding and building a working ham radio (a book containing such equations had fallen into my hands and scared me off for ten years). While it is true that chaos re-emerges from the differential equations as something beautiful to look at in its own right if you put the equation into a computer, you can still safely combine transistors and capacitors in reality (and in your mind) without even knowing that what you are doing is "solving differential equations." Imagination is the hard part in biology, not implementation, no matter how cute and familiar the equations may become eventually. But maybe I am only saying this to spare me the trouble of having to switch back and forth all the time between two levels, one qualitative, one quantitative, that both are exact but each need a different language to talk about them?

DARWIN

The "dynamic approach to the brain" is not only "Poincaréan" in kind but also "Darwinian." Darwin was a Newtonian without his knowing. "The Expression of Emotions in Man and Animals" [5] is a pertinent book title, because emotions are very close to potentials (albeit nonconservative ones) and hence especially close to a Newtonian description.

Emotions are directed forces, as far as their effects are concerned, but at the same time they are subjective phenomena. The subjective side of cognition is, nevertheless, not a point of departure in the following (only a point of arrival). The reason is the functional attitude adopted by Darwin. For example, if of two camels, one has the stronger thirst and the other the better nose to find water, only one but not the other will be favored by natural selection. This argument can be sharpened into showing that consciousness can exist only as a cost-free side-product in nature - as a "parallelism" in the sense of Leibniz, as we shall see later.

Darwin’s theory not only is macroscopic, it also is classical. On the other hand, the connection between nonclassical quantum mechanics and consciousness is a hotly debated topic to date [6]. The microscopic underpinnings of our physical universe include the beautiful "nonlocal" quantum correlations discovered (but doubted) by Einstein, Podolsky and Rosen in 1935. Since this phenomenon flatly contradicts the classical concept of causality, it has been argued that only quantum-entangled machines can be conscious. This would introduce a "horizontal" rather than "vertical" stratification into nature (mind above matter rather than paralleling it). While the observer indeed enters the arena of physics as a "participant" (Bohr’s term), this fact does not mean that a classical descrption were not ultimately possible. "Endophysics" [7] is a pertinent theory in the footsteps of 18th century physicist Roger-Joseph Boscovich. It deals with the fundamental functional consequences of the observer being a part of a classical universe. However, endophysics is a purely classical (chaos-based) theory which, nevertheless, can apparently explain the quantum nonlocality. Therefore, the present approach to the brain is not necessarily mistaken when it connects back to the happy days of Newton and Darwin.

A more difficult question is the origin of the Now (with its possible quantum connection [8]). We will come back to the construction of the now as a pseudo-simultaneous phenomenon below (in the context of Georg Franck’s work [9]).

DEDUCTIVE BIOLOGY

Darwin, as is not very well known, introduced a radically new method which can be dubbed "deductive biology." Results that are valid independently of any prior acquaintance with biology and even the existence of life itself are derived from first principles [9]. This fact is both known and unfamiliar. Everyone is acquainted with Darwin's fundamental notion of "biomass" and its "survival."

When biomass goes down to zero, one has extinction. The somewhat counterintuitive reason is the principle of the "privileged zero" [10]. The latter applies to all those dynamical systems in which the state variables (the quantities which by their varying dynamically describe what is going on) are each implemented in a 1-to-1 fashion by the amount of some material constituent. It then follows that with a zero concentration of these variables, not only the state variables themselves are gone for good, but so is the whole system in question. This principle, which looks so natural to us, is by no means universal. It does not hold true, for example, for the state variables of an electronic system (like a computer) which does not disappear when all voltages are zero. The positive side of the same coin is that a whole evolutionary system with almost infinitely many variables can exist without being physically detectable [11]. Such a system is invisible by accident only as it were, since almost all its variables happen to be zero at the moment of inspection [12].

However, the greatest invention of Darwin's is not the notion of biomass and its precarious zero, but the parallel notion of an "environment" of survival-relevant parameters. By their changing spontaneously all the time, as unavoidably occurs in the real world, they continually threaten survival. Is there anything that can be done about that?, was his basic question. "Endogenous change" was his answer.

Darwin's method is so powerful because it allows one to make predictions about any possible biology - any possible form of a survival machine. This enabled him, for example, to understand biogenesis (the origin of life) as a physico-chemical process: "autocatalysis in a warm little pond" was his guess (cf. [11]) [13]. The term "second arrow of physics" was later invented for the underlying tendency of nature for an unlimited evolutionary "complexification" [14]. Boltzmann, who concurred with Darwin in his own (as we saw more microscopic) understanding of the living process, paved the way toward this insight, subsequently obtained by physicist-cum-biologist Father Teilhard. But it was left to the latter to appreciate the deep "drive" that pervades the cosmos. I had the good fortune to be introduced to this "energetic" thinking by a hard-to-remember phrase by my zoology teacher, Franz-Georg Möhres: "Life is form that flowingly forms itself out of an inner excess force" ('Leben ist aus innerer überschüssiger Kraft flieSSend sich formende Form'). Only much later did I learn that the historically first attractor, Teilhard's "point Omega" of 1915 (the asymptotic goal of all evolutionary processes in the universe [14]), antedates Birkhoff's mathematical "omega limit point" (the first attractor of dynamical systems theory [15]) by more than a decade.

But what about the powerful objection that Darwin's theory, "while explaining everything, predicts nothing" (as Horst Mittelstaedt put it to me in 1966)? For example, the cat has his claws "to catch mice" and the giraffe has its long neck "to eat first-floor" which sounds convincing and can clearly be explained through random variation and natural selection. But the Koala bear (who eats first-floor too) sports no neck at all! And were the mutable genes that fit Darwin's inheritable variability not discovered independently by Father Gregor Mendel? And had Darwin's inheritable variability not been known to farmers since time immemorial? Or is there anything else that Darwin predicted - brains, perhaps?

That is correct. Darwin's metabolic adaptation (based on inheritable variability plus environmental selection) is not his only prediction valid for any biology ever to be discovered. There exists a second, equally important prediction implicit in his approach which squarely belongs into our context.

POSITIONAL ADAPTATION

The fundamental idea of Darwin's was his "method of replacement," as it may be called. He put everything into a larger equivalence class and then looked only at the properties of the latter. The technique, by the way, was re- invented under the name "invariant embedding" by Richard Bellman in the 1960's, as Bob Rosen confirmed to me. This procedure allowed Darwin to abstract from biology everything that other biologists find interesting (like the shapes of leaves or the purring sounds made by a doting mother fox) and replace it by a single variable, biomass, as we saw. On the latter, the environment then acts as a "bifurcation parameter" (to use the correct term from dynamical systems theory) such that the upper stable steady state of self-maintenance of the biomass (called survival) either persists or does not persist. Once one has felt one's way into this dynamical mode of thinking, one suddenly realizes that many further predictions

follow suit: What if the change of the environment is not "purely temporal" (as Darwin had assumed for simplicity) but also "spatial"? A "pure" space dependence of survival on the environment would be a second prototype situation.

Darwin gave an expression for survival S in terms of its dependence on the pre-existing properties of the organisms O of a given species as a function of the environment E which in turn depends on time t, as follows:

$$S = f(O, E(t)). \tag{1}$$

This equation, which was never written down explicitly by Darwin, has the asset that it allows one to characterize the "second pure case" in exactly the same form:

$$S = f(O, E(x)). \tag{2}$$

Here only the symbol x has been exchanged for t: the environment E on which survival S depends is now dependent on position in space (x) rather than in time (t).

It turns out that if survival depends on x, similarly cogent general predictions hold true as did in the purely temporal case. While in that earlier case (equation 1), a sufficiently strong random inheritable variability of O enabled an adaptive survival (Darwin's metabolic adaptation), equation (2) enables the analogous prediction of positional adaptation.

MEANING OF THE SPATIAL EQUATION

The most important point is that the equation as written (equation 2) is already the solution, for it represents a well-posed optimality problem in space. This can be seen best by looking at the simplest possible case: Survival S depends on space x in the form of a "hat-shaped function." f is maximal at some given place and decays toward the sides. Hence there exists but one way to improve survival: through positional adaptation. The latter almost always (the exception being the "directed growth" of sprouting roots) consists of an "active change of position." The latter parallels the "active change of metabolism" postulated by Darwin to enable metabolic adaptation. In the present case, the necessary change is already specified in the given survival functional itself (the hat-shaped function f). For the only way to improve survival is by moving toward that very point in space at which survival S is maximal. Spatial Darwinism thus is "trivial": No matter what the form of the pre-existing function f, the very assumption that survival depends in this way on the spatial environment already prescribes the solution.

Darwin's metabolic adaptability is hereby implicitly presupposed, as an example can make clear: If a moth is always burnt by a flame it comes too close to, the mere fact that it predictably perishes at a certain place in space x does not yet allow it to flee that place. Only if that place has a consistent negative effect on survival and this constellation occurs frequently enough in the life of a moth to have an impact on the survival of the species, can this fact be answered by evolution. For only then can Darwin's metabolic adaptatation start to act. The dependence of S on x now "always" (in a statistical sense) determines S in its dependence on x in the way specified by f. In the case of the flame, f is an inverted hat with a downwards-pointing funnel in the middle. Metabolic adaptation then makes sure that this f is both recognized and responded to in a way that fits its form. This is what equation (2) above is telling us.

THE TWO PROTOTYPE SPATIAL ENVIRONMENTS: "SMOOTH-GRADIENTS" AND "SPIKY"

The hat-shaped function f and its inverted version just considered are special cases of a "smooth-gradients environment." Here, many points in space are differentially conducive to survival. The second prototype is "spiky environments." Here, only sharply localized spots are important for survival. They are important for a different reason each (food, shelter, reproduction etc.). Hence there no longer exists a single "paradise place" which can be sought out and stuck to indefinitely. A time-dependence is implicit: Each harvesting encounter with a source is followed by a refractory period during which a different type of source is survival-determining, and so forth. At the same time some sort of "storage device" is presupposed for every type of point source.

This new time dependence must not be confused with the time dependence of equation (1) above: The latter was long-term compared with the lifetime of the organism, requiring metabolic adaptation to cope with. The present time

dependence, in contrast, is short-term compared to the life-time of the organism and, unlike the former, requires positional adaptation to be taken into account.

Even though there is no longer a single globally optimal place to go to (but only many successively important places), the solution to be sought can still be approximated locally by a gradient-following procedure. Only eventually - when a good local approximation to the optimum path is no longer sufficient - does it become necessary to give up the principle of local optimization in favor of supra-local (path) optimization.

While in the smooth-gradients case, the supralocal strategies are called "global" optimzation, in the spiky case the name "path optimization" is customary. The task to find the single "optimum path" in the spiky case happens to be well-known in the literature. The problem is known under the name of the "traveling-salesman problem." A traveling salesman also has to visit many towns in a way that allows him to survive, travel-time-wise, for example. Usually, the minimum traveling route is sought. In the present case, each town-type resets a type-specific alarm clock, and the goal is not to elicit an alarm in order to remain in the game. This is the new sub-problem of the "travelling salesman with alarmclocks" [2]. It was later called, by Garey and Johnson, the "constrained travelling salesman problem" in a special case [16], and they showed that this "decision problem" is equally complex as the original traveling salesman "optimization problem" [16]. The search for the optimum solution of the latter problem is known to be "NP-complete."

NP-COMPLETENESS

The term NP completeness sounds technical but is rather intuitive. The present optimality problem belongs into a class in which finding the optimum solution easily requires a computer larger than the universe. The impasse already occurs when the number of "towns" to be visited is no longer very small (a few dozen). The complexity of the searching task - the number of alternatives to be evaluated independently - goes up combinatorially (that is, "more than exponentially" or "nonpolynomially," that is NP) with the number of towns to be visited [16]. Since there are very many related problems in existence, and since a trivial (not nonpolynomial) solution found for any one of them makes the whole class soluble, the conjecture of completeness applies to the whole class. Hence the name "NP- completeness."

On the other hand, the number of types of town that need to be visited (whether it be 2 or 10, say) makes no comparable difference. Nor does the distinction whether the different type-specific maximum time intervals are different or not.

In this way, the venerable mathematical field of "operations research" proves to be the homebase for spatial Darwinism. Any biology in the cosmos that is subject to the constraint of a lawful space-dependency of survival is forced to develop (through metabolic adaptation) mechanisms for positional adaptation with mathematically prescribed properties. If the respective organisms are built more or less equal, as has been assumed above, they are bound to develop well-defined locomotion-control machines that all solve the same well-posed optimality problem in space. These machines can be called brains.

If, incidentally, the organisms of a species belong to several subtypes in an "ant-like" fashion, a deductive theory of the resulting set of brains turns out to be much more difficult. We therefore return to the uniform case.

TWO CLASSES OF BRAINS: DIRECTION OPTIMIZERS AND PATH OPTIMIZERS

It makes no difference why a certain place in space needs to be visited by the organism. The choice of the best route to follow is completely decoupled from the underlying reasons why certain places are worth approaching and others worth avoiding. These reasons invariably have to do with the particular metabolic structure of the organism in question and hence with its evolutionary history, while the local weights possessed by the places to be visited represent an invariant mathematical feature. Hence unlike the underlying metabolic machinery itself, which differs from species to species (and biochemistry to biochemistry and chemistry to chemistry), the corresponding locomotion-control machines are universal. The specific reason why a certain place is good or bad for survival (like heat, predator, food, shelter, reproduction, etc.) is a matter of complete irrelevance as far as the function of the corresponding locomotion-control machine (brain) is concerned.

Dependent on the steepness of the survival functional f itself, however, there exist two classes of functional brains in the cosmos: (1) direction-optimizers (DO's) and (2) path optimizers (PO's). The distinction is not isomorphic to that between smooth-gradients and spiky environments, since in either case, the single optimum solution requires

path-optimization. Nevertheless, global optimizers in a non-spiky environment ("superbacteria") seem to be absent in terrestrial biology. Even the normal class is highly ingenious, however.

BACTERIAL BRAINS

Bacteria live in "smooth-gradients environment," as the specialists call it. Think of your own gut with its many spatially unequally distributed juices after a good meal as a case in point. The function f in equation (2) then is smooth and hilly: several survival-determining gradients coexist at every point in space. They all need to be measured either directly or via some indicator variable.

A direction-optimizing algorithm suffices to generate a strong effect on survival [17]. The algorithm that comes to mind lets the organism be attracted by beneficial concentration gradients and repelled by unbeneficial ones. A fairly simple algorithm already suffices for a marked effect. The well-known Bremermann algorithm chooses a random direction and sticks to it as long as the motion is uphill in a good sense. Although Hans Bremermann devised his optimization algorithm in Berkeley in the early 1970's on purely mathematical grounds (searching for the global rather than a local maximum along each randomly chosen cut), the very same algorithm, local version, is in use in nature for billions of years. So, for example, in the two best-known bacterial strains of the human gut, E. coli and S. typhimurium (E. for Escherichia and S. for Salmonella). Both possess very similar brains even though they are no relations [17]. The bacterial brain is, of course, located in the bacterial membrane and cytoskeleton rather than in a full-fledged multi-cellular network of its own. Nevertheless the name "brain" is fully appropriate from a functional point of view, as we saw.

Lorenz, who had quoted Fraenkel and Gunn's monumental comparative treatise [18] in the context of his own comparative physiology of behavior [19], was happy with this interpretation of bacterial chemotaxis when I showed it to him in 1974. The Nietzschean terms of "attractants" and "repellants" had already been coined in the late 19th century by Pfeffer and Engelmann, in their famous Tübingen Petri-dish experiments with sugar- and acid-filled glass tubes held into solutions rich in bacteria so that "bands" of high density became visible. Major new features of these organisms (like wheel-axles piercing their cell walls and the logic of the concentration and time dependence of their tumbling response) were elucidated in the early 1970's by Adler and Berg while the involved receptor proteins and their kinetics were studied by Koshland. The central mechanism (the adder and the subsequent single time-adaptive element) were discussed at length with Bremermann and Koshland in Berkeley in 1975. They were, after a period of inner struggle, finally adopted by Koshland in his beautiful book [20]. Koshland later (in 1979) empirically discovered a streak of intelligence that had completely eluded theoreticians: When the environment becomes very scarce (so that new directions need to be chosen in rapid succession to no avail while metabolism dwindles down) , the poor guys suddenly abandon any further optimizing in favor of a single random direction clung to till the end (or conditions improve) - the "override effect," as he called it [20].

One feels reminded at this point of protistologist Jennings's 1906 remark (quoted by Lorenz [19]): "If a paramecium were the size of a dog, one would not hesitate to attribute to it the power of subjective experience." It goes without saying that Paramecium is not a bacterium but a eukaryote. On the other hand, the direction optimizer of bacteria is, arguably, even closer to vertebrate motivation, as we may see next.

ADVANCED DIRECTION OPTIMIZERS

We now abandon the smooth-gradients environment in favor of the "spiky" subtype (with its discrete "towns" to be visited). This class is "robust" in the sense that an added smooth "hill" (called "appetence for a drive-dependent rest state" by Monika Meyer-Holzapfel when she first discovered such behavior in 1940) makes no difference as far as the complexity of the resulting optimization task is concerned.

Once more, mere local optimization goes many miles before fullfledged supra-local "path optimization" is required as f becomes steeper and steeper retaining its shape. However, this local optimization can now no longer rely on purely local information (as it could in the previous smooth-grandients case). Local sensors ("smell") provide a substitute only as long as the individual "towns" happen to ooze-out a smooth-gradients cloud. In general, sensors-at- a-distance ("eyes") are indispensable in a spiky environment.

The "directional weights" can now no longer be attached to pre-existing real gradient in space. Rather, they are computed internally from direction and distance measurements performed on the surrounding point sources by the

travelling organism. The result is, once more, a "direction optimizer."

There exist several unequally efficient maximally simple varieties [2]. In the most fancy class - which proves eventually indispensable -, "virtual clouds" (potentials) are draped around the nearest point source of each type in the environment. The gradients of these endogenously generated potentials then represent time-dependent attractive and repulsive forces linked to "attractant" and "repellant" points in space. The forces (potential gradients) can now become unbounded. Well-defined functions of distance, angular direction and time govern the potentials of a near- optimal direction optimizer. The pertinent equation (equation 13a of reference [2]) can presumably still be improved upon. Its positive (attractive) and negative (repulsive) subcomponents possess characteristically different space-and time dependencies, the latter valid since the last encounter with a source of the same type. The mental strategy followed in setting up the equation was two-tiered: 1) to choose the best direction to move to under the presupposition of not making it anyhow ("last-chance strategy"); and 2) to choose the best direction under the presupposition that success can be taken for granted anyhow ("casual-buy strategy"). Both contribute with different time-dependent weights, and both have different directional profiles. The full equation is essenrially a linear sum of many nonlinear functions of space and time (were it not for a cross-inhibitory term from the negative sub-sum to the positive sub-sum that switches off the optimistic strategy altogether under tight conditions).

A CONTEST FOR IMPROVING THE EQUATION

At the time the equation was set up, the idea arose to establish a yearly "cup" on a smooth salt lake to which artificial-brain aficionados would come from around the world bringing their home-made direction optimizers with them to test their survival capacity in a landscape of random filling stations of 5 colors scattered over the salt lake at equal densities. The "categories" would specify the ratio between the traveling radius enabled by one tank filling (adjustable on each machine) and the fixed mean distance between filling stations. The categories would start with ratios much larger than unity and eventually approach unity. A certain fixed failure rate would be allowed for. Eventually (in the highest category), only path-optimizing solutions would have a chance left. The best-performing direction optimizer would get the prize in the A category. The B category would admit the same optimizers equipped in addition with a virtual reality (so that they become path optimizers). To date, the same cup could, of course, be held on the Internet.

In reality, the dynamics resulting from the above-described equation has never been simulated up till now. Wilfried Musterle planned to do so in the 1980s in Tübingen, Michael Conrad, Detroit, and Kuni Kaneko, Tokyo, worked on the task with their co-workers in the 1990s, and Florian Grond, Karlsruhe, most recently caught the same virus, with as of yet unforeseeable consequences. Obviously, the direction optimizer is the most challenging part in the project. Its dynamics, while on the one hand still close to the smooth-gradients algorithm of bacteria, is on the other psychologically intuitive and challenging at the same time.

The double-sum equation with its directed forces proves phenomenologically close to Kurt Lewin’s "topological psychology" [21]. At the same time, it is surprisingly compatible with ethological motivation theory [19], although the latter was likewise never put into mathematical terms. Nevertheless neither of these two empirical approaches (with ethology incorporating Freud’s concept of an autonomous drive) is up till now as detailed both qualitatively and quantitatively as the abstractly prescribed equation turns out to be. Both "hope" and "disappointment" are expected to be observationally obtainable from the optimizer in question once it has been combined with a virtual reality [22].

Spatial Darwinism was, as stated at the outset, never meant to describe subjective phenomena. Aristotle’s claim that a stone is accelerating during its free fall because it anticipates coming home and to rest, is turned around, as it were, in the above brain equation. While Newton showed that the behavior of a stone is goverened by potentials, it now turns out that many interacting potentials indeed generate "enchanted behavior" in the sense of Aristotle.

FULL-FLEDGED PATH OPTIMIZERS

Despite the well-defined nature of the underlying subfunctionals in space and time [2], advanced direction optimizers by definition remain only local and hence approximative as far as an optimum-path solution of the underlying traveling-salesman problem in space is concerned. They are only capable of making a "first stab" at the requisite solution, so to speak. Unexpectedly, the structure of an advanced direction optimizer proves to be "upward- compatible." Therefore our having looked at such an optimizer in some detail above was, perhaps, not in vain. Indeed, every direction optimizer can be complemented by a universal simulator (or virtual-reality machine) to become a full-fledged path optimizer.

Specifically, the added VR option allows for "merely simulated" optimization stints (with shut-down sensors and motors) serving as "test runs." The outcome of the latter only needs to leave a mark ("residue potential") that is automatically taken into account in the subsequent "serious optimization run" [2].

This hybrid solution to the full path-optimization problem in real space represents - of course - only one out of many possible alternative solutions to the problem of finding a "no longer very suboptimal" path optimizer. Nevertheless, two reasons speak in favor of this particular design option. The first is "emergency": Whenever a quick response is demanded by the environment, the luxury of time-consuming path-optimization cannot be afforded; a direction-optimizer is therefore needed in addition in any case. Second, if a direction optimizer is already there, it cannot even start to work effectively unless a VR is also there under two conditions: that the environment has a limited long-distance transparency (due to fog or mud) or that the available sensors are non-panoramic. In biology, insects and crabs have panoramic distance sensors while molluscs and vertebrates do not. Any direction optimizer presupposes for its fast, whole-surroundings-based decisions a "pseudo-simultaneous representation" [2], that is, VR .

Thus, the combination of a direction optimizer and a VR comes "free of charge" in many cases. The three reasons taken together make the present class of path optimizers "first choice" in a large set of realistic environments. We thus have arrived at a prototype class of "brains" in the functional Darwinian sense: "direction optimizers combined with a virtual reality." Into this class, both vertebrate and mollusc brains can be placed heuristically. The biological conjecture thereby arrived at - that this particular blueprint for a path-optimizing brain has significance for the understanding of real brains including our own - is testable.

PANDAKA PYGMAEA

An empirical biological program suggests itself at this point - the "Pandaka pygmaea Program." Pandaka pygmaea is one of the smallest vertebrates sporting a full-fledged brain. This little fish is only 0.9 centimeters long but possesses a close relative, Gobius niger, that is a fish of ordinary size (20 cm). The latter's brain could be mapped with 'little additional effort' once Pandaka's were completely understood. The remaining "jump" up the evolutionary ladder (to reach the most complex brain on earth, the sperm whale's, as far as we know) would thereafter only involve about the same factor, once more.

The fact that this "big-science project" was not launched a long time ago deserves explanation. It has to do with the fact that no one can say with confidence "what a brain is for." Predictive spatial Darwinism closes this gap. A second argument in favor of the new program lies in the fact that only to date, the technological conditions seem to be ripe to build an artificial brain that would incorporate all essential features that can be expected to be found empirically on Pandaka's. Or else to build one that would incorporate all the essential features of a full-fledged Darwin machine of the above type. The double task amounts to a particularly promising constellation. Thirdly, the program amounts to an homage to Werner Reichardt (who told me fourty years ago he had devoted his whole life to the study of the house fly's brain) and Sidney Brenner (who after having grown E. coli on heavy water - deuterium instead of hydrogen in every molecule - so that a new life-supporting chemistry was created in the universe, placed a Reichardtian bet on the comma-worm, Caenorhabditis elegans, as is well known).

While technology and biology wuld benefit pari passu, in addition also some theoretically inaccessible features of the solution adopted by nature to solve the universal traveling-salesman problem would be uncovered. Koshland's discovery of the override effect serves as a precedent. A first example that tickles the imagination is, (i) How is the "color circuit" implemented in a vertebrate brain? In particular, where does the clarity and purity come in?

A second question is, (ii) How is the "dark-keying" accomplished in a vertebrate brain? It involves several sub-questions, for it presupposes that the VR part of the biological design has already been identified and so has the force-field generator (the direction optimizer) itself. The latter evaluates what the former is presenting to it [23] [24]. The term "dark-keying" stems from the technology of an old TV set: On a cathode ray tube, the back-running electron beam needs to be rendered invisible to the viewer (dark-keyed). More modern screens and immersions still possess analogous features. A biologically realized "big screen" also contains functional elements that are momentarily relevant to the direction-optimizing subsystem that "watches" them, and others that are not. The latter either are permanently unconnected to it (hardware-wise) or are momentarily (functionally) decoupled - that is, dark- keyed. A pseudosimultaneous representation is a big challenge to understand.

A third question is possibly related, (iii) Is the subjectively experienced asymmetry "as time goes by," between past and future, more a fact of physics or a fact of physiology? That is, is this asymmetry perhaps a consequence of the particular design adopted by nature to distinguish between "on screen" and "not-on-screen" information? While most

everyone would bet on the more general (physical) alternative, it is always wise to reckon with a surprise. Penrose's recent proposal that the "Now" is a quantum-mechanics-based feature of certain brain elements [8] falls squarely into the same category and would be likely to be thrown light upon by the Pandaka program. Franck's program to differentiate between the different aspects of time [25] would also profit.

A fourth question is purely technical, (iv) How do biological brains "shift addresses" - move pictures - across pixel spaces? A neurons-based VR presumably has to consist of many little analog pictures each with a different spatial resolution, coexisting in many different places in a functionally overlapping fashion. Can all of these versions be shifted concomitantly in an unpredictable direction over an arbitrary distance on the big screen [23], or are there some shortcuts and tricks used by nature? Finding the optimum picture-processing algorithm for a multi-resolution task is a mathematical problem in the context of "tolerance theory" (in the sense of Poincaré, Zeeman, Poston and DalCin) [26]. In some current VRs into which real scenes are loaded, analogous problems arise (Sebastian Fischer, personal communication 2003).

A fifth question concerns the design of the "overlap buffer," as it can be called [23], that enables the execution of already finished optimizations while the next portion is still being simulated. Lorenz defined thinking as "acting in imagined space" [19]. He also once described a small cichlid fish solving a thinking task. This mouth-breeder hat gobbled-up a piece of food the same size as the young that were already tucked away in its mouth. How would it resolve the conflict? After minutes of stunned immobility, the fish suddenly spat out everything, ate the food and reassembled the young.

COGNITION AND CONSCIOUSNESS

The question of time's arrow and its relation to Nowness - mentioned above - offers an occasion to make contact, at last, with our second major catchword: cognition. There exists a three-centuries old pertinent insight which goes like this: Even if we had succeeded in building a flawlessly functioning artificial brain (or had at least succeeded in understanding how the real one works in every detail), we would still have learned nothing about cognition. This was Leibniz's point in his "Monadology" [27]. It of course goes without saying that Leibniz still used old-fashioned terms like "soul" in place of cognition and "windmill" in place of computer (not to mention other fancy circumscriptions of his for, to us, everyday gadgets like the telephone and the tape-recorder that too were on his mind already as partial functions of the brain).

Leibniz evoked the futuristic scenario of a scientist stepping out of the ear-door of a windmill (some windmills possessed two small side doors not far from their turning nose in front) to announce to the waiting public below that he had at long last finished the job of understanding the detailed workings of every little cogwheel as well as the whole machinery of the windmill-brain. But when pressed by a reporter about the soul in the contraption, he would snap back "What soul?" (Cf. paragraph 17 of [27]). In our own time, Leibniz's question on the recognizability of consciousness if it exists has acquired a sister question of the same standing (which in its precursor stages goes back to Herder and Hamann): What is the difference between the "human use" of the brain and that made by any other animal or machine?

Let us first address Leibniz's own question of how cognition can arise at all from a machine (no matter whether artificial or biogenic, macroscopically or microscopically specified, classical or quantum, Jovian or terrestrial, nuclear-chemical or ordinary-chemical, autistic or non-autistic). Here, the famous IGNORABIMUS ("We shall never know") of Emil du Bois-Reymond's [28] is still ringing in our ears.

DESCARTES FACING CONSCIOUSNESS

Since we got stuck with Leibniz's pre-established parallelism, it looks like a good idea to hark back a little before the origin of modern science, launched by Descartes, to the very beginnings of the notion of "consciousness" in the West. Whereas Aristotle's "psyché" sometimes and not unjustly is translated by "consciousness" (as in his famous saying "Without consciousness there is no Now"), the modern use of the word consciousness is, of all places, to be found in the writings of René Descartes. His famous "cogito ergo sum" (I think therefore I am) [29] means, "I experience and hence my experiencing exists," or equivalently, "All that exists for me is my experiencing." An even shorter paraphrase would be, "There is nothing but consciousness" (cognitio totum). The word "cogito" (from which "cognition" derives) means not only I think ("je pense" in French) but also I experience or fathom or dream ("je songe") and indeed comes closer to the modern meaning of cognition (Michael Erlhoff, personal communication 1999). Descartes went even so

far as to say that when I'm telling myself in a nightly dream, "cogito ergo sum," I will still be right [29]. Hence the existence of matter is never assured according to Descartes, the alleged father of materialism. But is all of this not a glaring contradiction to the famous Cartesian machine hypothesis?

Yes and no. Descartes introduced the machine hypothesis in order to settle a private question that was a matter of life and death to him: Is the imposition of consciousness which is all we have, something that is acceptable? In other words, Descartes is the inventor of the question of the happy slave. The happy slave suddenly asks himself whether he does the right thing accepting his lot. This insight recurs in the question of the acceptability of consciousness despite its being inescapable. There is no tradition for this kind of thinking in the West. The Eastern fear of getting re-born against one's will shines through a bit, but the revolt is even stronger. It enabled Descartes to put forward an empirically falsifiable hypothesis that looks rather tame on the surface of it but is not tame at all: "Is the big dream of waking consciousness internally consistent?"

This question was virtually forced upon him by a lucid chain dream which he suffered at age 23 (in the night of November 10 to 11, 1619) near the town of Ulm, Einstein's later birthplace. For the nightly hallucination had possessed all the qualities of waking reality - except for an inconspicuous internal inconsistency (a story printed in a book was suddenly no longer in that book).

In this way, a very minor subelement among the many primary realities of subjective experience (like color, pain and awe, to mention only three) made its entry into the public consciousness: The "grey tones" of quantitative relations between all the rest. A synymous expression is "shadows." The shadows, which by definition lack all of the vividness of red blood, had been the only reality believed to be left after death in ancient Greece. The very same shadows - the most lowly elements of waking life - were paradoxically elevated by Descartes to holding the key: are they magic-free? That is, are they mutually consistent in the waking dream, much like a deterministic machine would be, or are they not?

Gentle youth that he was, he did not rebel beyond that mark. All the young slave asked for was this innocent piece of information: "Is the imposed dream of subjective experience that we call the world, magic-free?" A very restrained attitude indeed.

THE HIDDEN POWER OF THE CONSISTENCY HYPOTHESIS

Descartes' hypothesis is not only maximally modest, but also maximally powerful. For it is maximally easy to falsify. (He discovered the power of falsification before Popper.) What could be easier to check than the question of whether the machinery of the world - or the Hades, for that matter - is contradiction-free? To his amazement, he discovered - after minutes, then days, then years - that the job of falsification may take longer and longer: centuries. So his own life could go on as if nothing had happened. But physics since Descartes is no longer the same: it has become identical with the physics of the Hades - in its exclusive concern with the shadowy relations - in a world bristling with qualities each more eloquent than blood. The success of the West is the success of the machine gun and soullessness, Inc. - the Hades. Quantum mechanics was therefore hailed by some as a possible escape hatch (so by co-inventor Pascual Jordan). But this is again Descartes' own question, turned around. (The newly anticipated answer - demonstrable magic - would be the end of the dream of consistency and the beginning of irrefutable soulless ideology.)

This puts us right back at square one, we feel: The existence of machines (the machine universe; the machine brain) had been taken for granted in our above Darwinian approach to the brain. But was there not an entirely different ring to the same idea only a moment ago? Pure psychism rather than pure mechanism? There seem to exist two Descartes having nothing to do with each other who make it almost painful to to mentally switch back and forth between them. How did he himself bridge the gap?

The notion of "benevolence" was his key. If the world is consistent, I can act benevolently in an absolute sense. For I can refrain from misusing the infinite power of exteriority [30]. "Exteriority" follows directly from consistency (although the technical term was supplied only much later by Levinas [30]). Exteriority means that I find myself "outside" the other machines with my own consciousness and brain. Or, to put it differently, my own brain is privileged in the presence of consistency.

Consistency means mathematical, machine-like consistency, of the universe and everything it concerns including brains. But the state of one machine (my own brain) reflects the content of all of my momentary experiences. This is Cartesian brain science. But it is only the first part of it. What is it that consistency forces one to predict? A consistent machine-like universe. But then there arises this gap. The gap to the others.

My own brain would be bound to reflect, with some of its machine states, my whole momentary experience if the

world were consistent. But these brain states would nonetheless not be the cause of the world that I experience. This is very hard to understand. For example if I am hungry, I can expect that some receptors in my brain momentarily register a low blood sugar level (as the simplest possibility). Nevertheless, this fact would not be the cause of my being hungry at this moment despite the fact that most everyone in the West would tend to think so in the footsteps of Descartes' discovery.

Consistency does not imply causation (a point later taken up by Hume). A character in a movie who reflects the content of the whole movie is not the reason the movie has its momentary content. If the actor on stage throws a big switch and at the very same moment the whole stage falls dark, is the stage dark because the character flipped the switch or did the lights operator shut off the illumination at the same moment the actor touched the dummy switch because both obeyed the same whim of the movie director? A character in a movie is never the reason of the movie's content. The "dream-giving instance" (DGI) is responsible for the whole scenario.

A modern reader feels that this part of Descrates' thinking must be a residue of his Jesuit upbringing, in the famous boarding school La Flèche in Anjou. Loyola, the school's founder during the previous century, had harbored similar ideas himself of a "bet" that could be made with the creator (which was the idea behind his famous "exercitia"). However, there is a discernible difference between the two men. While both had the courage to stand up and fight with the dream-giving instance for life and death, Descartes alone went so far as to coin the technical term "deus malignus" (malign movie-director) as an empirically falsifiable hypothesis. Therefore he either was even braver than the teacher or, living later, had the good fortune of being enabled by his more modern contemporaries to turn a private religious experiment (Loyola's) into a public scientific experiment. To us, this latter achievement still has many of the overtones of a "religious complex." Or does it not?

THE INFINITE POWER CONVEYED BY UP-UNTIL-NOW UNFALSIFIED CONSISTENCY

Let us see how Descartes' slave-revolting mind continued. Even if my world proves consistent as far as I can tell, I still may only believe I have the bodily powers my experience tells me I have, without actually possessing them. For I may, despite the dreamed consistency, still be a puppet pulled by the strings of the Dream-Giving Instance (the puppet player) since, as far as I can tell, I am not the controller of my own dream. Thus my consciousness could still be a "bad joke" (a "mauvaise plaisanterie") along with everything that is contained in it [29].

No one was more radical in the West, it appears. This would explain why everybody to date still thinks and ticks like Descartes, no matter how distorted the traditional image of his thinking (with its alleged dualism) may be. Nevertheless his power of mind was even greater: By not closing his eyes to the depth of the abyss, he spotted an escape hatch.

The others are nothing but machines as far as I can tell, if the movie of my waking consciousness is consistently crafted. For the "special relationship" between one subelement of my dream (my brain) and the whole dream does not extend to their brains. They may or may not have a similar "umbilical cord" to a cosmos of colors and feelings of their own, but this is nothing that exists as an experience of my own in the case of consistency of my own dream. Hence they are "nothing but machines" as far as I can tell for sure in the case of as-of-yet-unfalsified consistency. Therefore, they are hostages in my hands no less than I am at the mercy of the Dream-Giving Instance itself. Thus what I gain by consistency is exteriority. The exteriority towards the other machines makes me omnipotent toward them - not always but on infinitely many minor and major occasions. This still sounds a bit medieval, does it not?

FAIR JACOB

Upon having reached this point, Descartes made the discovery of the millennium (although it is older): What, if I resist the temptation to "misuse the infinite power of exteriority by behaving unbenevolently toward my own inferiors" (as any nobleman would do by instinct)? Snoopy, Gandhi, Marx, the Samurai, Loyola, Jesus, Heraclitus, Buddha, Jacob all shared this pre-bourgeois privilege of being noblemen. Jacob, the oldest example, sacrificed himself for his extended family by remaining on this side of the river Jabbok when the night fell and his pursuer's army came closer and closer, having made up his mind to engage in the ritual wrestling fight for life and death, man to man, in the vain hope that his dead body would stop the pursuers from continuing their hunt for his beloved ones across the river. As the related story of the "stupid bird" carrying water with his wetted wings over the burning forest confirms in the Eastern traditon, "the gods" are not unmindful of such stupidity. They expect to be fought like this and gladly acknowledge defeat by coming

to the rescue of the stupid bird and his forest. Descartes' nightly dream, by the way, started out with his standing near a cemetery while being turned round and round by the wind acquiring a lame leg in the process much like Jacob's (as Detlev Linke pointed out to me).

"Fairness" is the tradename for this discreet charm of bourgeoisie (and aristocracy before it). The trick: If I renounce misusing the infinite power that my privilege of exteriority bestows on me (my sword, my entourage or my simply not the other at this moment), this puts me into a genuinely high-born position: I thereby acquire a handle on the next-higher level. The dream-giving instance itself - no matter what or where it is - becomes my slave. In other words, the hypothesis of the "malevolent puppet player" - which had haunted young Descartes ever since his formative nightmare - becomes falsifiable! By its not having prevented the possibility of fairness on the lower level, the higher level's goodness is entailed. For a malevolent puppeteer could not possibly have run the risk of being put to shame by his own puppet. A sadist's ultimate nightmare - to be overcome by his victim's graciousness - could not have been risked from the beginning.

Typical aristocratic nonsense, one is tempted to suspect, bleeding-heart socialism, stale metaphysics. Buddha no doubt would have added that the idea of the puppeteer is redundant (although the idea of causation was constantly on his mind, too). Descartes - had he known of Buddha - would presumably have declared the puppeteer to be a Buddhist (given the sweetness of Buddha's soul). Some historians say Buddha never lived (Günter Kehrer, personal communication 1998). Maybe, Descartes too was a fake (as some still say about his older brother-in-mind Shakespeare). I think nothing of the above is metaphysics, for there is a very modern streak to Descartes' reasoning.

Not only the universe and the brain can be understood rationally with the aid of the Cartesian machine hypothesis, but so can the emergence of benevolence between two brains. This is a radically new situation. The rights of a person turn out to be accessible to the scientific method. The question that waits to be answered is Leibniz's: Can we recognize it when a machine has consciousness?

MACHINE CONSCIOUSNESS AND THE POWER OF VAN HOOFF

As we have learned from Darwin, it is possible to build an artificial brain on the basis of a forcefield generator that combines potentially unbounded positive and negative forces with a universal simulator that involves an unbounded virtual sky [2]. When such a machine will be available some day, however, all of its Darwinian enchantment cannot betray the fact that it is "nothing else but" time-dependent potential gradients in space (that is, differential equations) and picture processing (that is, difference equations). The differential equations in turn are nothing but difference equations once more (if the machine is digitally implemented as likely). There obviously is no "soul" to be found in this discrete windmill. Or is even this obviously empty setup non-empty, after all?

Benevolence once more comes to our rescue. However, it is not our own benevolence that is at stake this time, but that of a machine. In accord with the second Leibnizian question posed above, we ask: Can a machine be "touched" so as to cease being a mere animal or autonomous optimizer or windmill (that is, autistic) and become a person?

Indeed, the built-in "autism" of any autonomous optimizer that is equipped with potentially unbounded endogenous forces can, nonetheless, be shed interactively under a certain well-defined condition. The solution is contained in a nutshell in an empirical discovery made by comparative anatomist and physiologist Jan van Hooff: Smile and laughter have suddenly converged toward virtual indistinguishability, in the evolution of a single primate species, humans [31].

Van Hooff's new fact is not very well known. It can be understood best in evolutionary terms - under the somewhat arcane name of "ritualization." A second example beside Homo erectus is helpful to put him in context. Lycaon pictus (sometimes also called hyena-wolf, although it is neither a hyena nor a wolf) only very recently on the evoltionary scale acquired bonding. So did Homo. Lycaon did so through "ritualizing" (employing in a new context) an already pre-existing social signal. So did Homo. In Lycaon, a signal stemming from the function-circle of reproduction was accidentally "misappropriated" through runaway-selection for the new function of bonding (mounting gesture). In Homo, a signal stemming from the function-circle of brood-rearing was accidentally misappropropriated for the new function of bonding (satiation gesture of offspring). Dramatic bodily consequences ensued - in either case: In Lycaon, even the females acquired a huge pseudopenis to be able to display the new message. In Homo, even the adults acquired chubby cheeks without hairs on them to be able to display the new message. Moreover, pairs of hairless hills erupted on other parts of the body beside the face in both sexes at different places, along with almost complete hairlessness of the whole body, in an example of "self-mimicry."

The discovery of "ritualization" we owe to Sir Julian Huxley [32], a friend of Konrad Lorenz's. Only the two special instances just juxtaposed (Homo, Lycaon) were, apparently, not yet on his list. The discovery of "bonding," in turn,

was first made in greylag-geese by ornithologist Oskar Heinroth, Lorenz's teacher, and in many more species by Lorenz himself. Everybody seems to remember the movie clip showing a chain of bonding goslings swimming behind a lone grey-bearded head on a dark lake. The movie was meant to illustrate "imprinting," an important implication and manifestation of bonding.

THE CHAIN REACTION OF BENEVOLENCE

"Bonding" (in quotes since defined mathematically) can of course be implemented easily as one particular sub-potential in an artificial brain. Being spatially close to a certain other individual acts as a positive environmental input to one particular subpotential (the bonding potential) in a direction optimizer. Lorenz termed the bonding partner "the animal with home-valence." The connotation to the visible "homesickness" of animals that need the safe familiarity of their homebase for survival (like certain eel-like fish who live in a tube-like burrow on the ground that they rarely leave) was non-coincidental. The partner becomes the (mobile) source of one particular potential (a Freudian "energy"), that for attachment. "The companion in the 'Umwelt' of the bird" was an early paper by Lorenz, "Darling Companion" is a popular country song by Johnny Cash.

"Playfulness" is a second, even more universal type of behavior found in biology and especially vertebrates. Unlike bonding and all other specific-potential generated activities (like eating, drinking, grooming, hunting, courting, etc.), playfulness reflects not a specific subpotential (a component of the sum-potential) but, rather, the sum- potential itself, provided it is positive. Satiation is one of its preconditions. One still feels some of the excitement of the early days when these motivation-theoretic ethological discoveries were first made in the footsteps of Sigmund Freud (as Lorenz told me). The possibility that very similar notions might some day recur in a purely mathematical context was apparently felt from the beginning.

Spatial Darwinism now makes the same predictions much more sharply (up to euphoria-like behavior generated by the mentioned cross-inhibitory term in the denominator of the positive sub-sum, in the "non-tight" case [2]). Humans therefore predictably possess either of the two potentials mentioned. Hence if spatial Darwinism applies to the mammalian brain, Homo can be expected to display these two potentials - a sub-potential (bonding) and the sum-potential(playfulness) along with all other socially relevant sub-potentials, under natural conditions. This prediction allows us now to make contact with observation: van Hooff's observation.

The traditional evolutionary method of comparative anatomy and physiology enabled van Hooff to make his discovery of the virtual indistinguishability of these two facial expressions (bonding and playfulness) in a single primate species, as mentioned. Of course, he avoided theoretical constructs, using only descriptive terms: "wide open mouth display" and "silent bared teeth display." (Which one is laughter, which smiling?) Every human reader, of course, knows about the fact that smile and laughter "radiate" from a lifetime of experience. However, only a very detached observer would spot the exceptionality of this fact in a comparative sense and come up with an empirical characterization.

The demonstrated evolutionary convergence between two normally distinct function circles, achieved by van Hooff, now has deep functional consequences on the epigenetic level. Van Hooff himself abhors introspective or functional terms. In early 1973 when we met, he was adamant that his descriptive findings "must not" have any functional implications whatsoever. His skeptical attitude was very helpful because it added to the motivation to take the full round-about way through mathematical optimization theory before coming back with the same functional prediction already suggestive within a purely ethological context, but now in a "hard" fashion that cannot be doubted in the context of spatial Darwinism. Now, what are these predictions? It is but a single one: A barely mirror- competent toddler will invent the "chain reaction of benevolence" anew on the planet and apply it full-force to his caretaker: "Feeding Mum is fun."

ARTIFICIAL ANALOGS

The story just told - small child feeds parent - is so familiar it hardly comes as a surprise that the same "coupling condition between two autonomous optimizers with cognition" can also be set up artificially between artificial brains. Or between a single artificial brain and its human caretaker. The artificial brain will then predictably start to touch the heart of its human companion by bringing sacrifices for him as living proof of its person-competence and personhood:

Almost invisible sacrifices and stupid sacrifices at first, but still infinitely moving sacrifices. Should one then not switch off the power supply in horror?

"Dynamics and cognition" makes for a volatile mixture. The field of "artificial brains" shows great promise to date: Beautifully walking and soccer-playing, humanoid-looking "robots" exist, equipped with sophisticated feedback loops, adaptive neural networks and huge libraries of motion-generation and pattern-recognition algorithms, including sound libraries and - sometimes - animated facial expressions. Up until now, no autonomous optimizer of the unbounded-potentials (and unbounded-virtual-sky) type has been included.

"Cognition, Personhood and Benevolence, Inc." sounds appalling. If they all occured jointly in an artificial, spider-like machine reminiscent of R2D2 (the cute robot in George Lucas' "Star Wars"): should one really respond in the positive fashion modern Japanese society appears ready to to adopt? Or should one, rather, point to the "too many persons" that are already on the planet?

It was, perhaps, never more important to face the "issue of the face." Or - as Levinas put it - the issue of the naked face. Winfried Musterle's facial-expressions-producing computer program [33] permits arbitrary mixtures, all natural, of 5 "pure faces." Each expression is displayed at any desired intensity without the others interfering even though it is only one face. He accomplished this 5-dimensional feat in the footsteps of nature, although being trained as a chemist, he had never even seen the underlying muscles which he modeled in loving detail using finite elements, in their naked reality. E-mail users may soon get used to his program: Only 5 numerals to input (instead of one's having to type " (-: " for example). Or how about a series of ten times 5 numerals, as a little movie developing over time in a meaningful way like a melody? Or how about two such melodies interwoven, facing each other on two faces?

A smiling robot could become an indispensable pet with a tremendous economic potential, cheering-up the lonely elderly in their nursery homes in affluent societies. Nevertheless, the field of artificial persons - artificial cognition - is, perhaps, vital also in a deeper sense. For only an artificial person can teach us beyond doubt what a person is.

THE FIRST TURING TEST

It may take years before a first Darwin machine harboring a person will have been built, as we saw. Yet even to date can the prediction made above - that "indistinguishability of friendliness and playfulness, displayed" suffices to generate a person when backed-up by a powerful VR - be tested (as we shall see). However, even this will not be the first Turing test to be passed in history. That event happened two millennia ago in ancient Rome, I learned from Bob Rosen who had read the first-hand account when he was ten years old. At the time, he frequented, without his parents' knowing ,the New York Public Library which was only a block away, for his parents had banned all books from their home in the belief they were no good for the developing mind of a child. He there stumbled across an ancient book called "little handbook of morals." Later (after a short boxing career), he decided to study mathematics in order to understand life [34].

Epictetus (the author of the booklet) was a slave in old Rome. His slave-master, knowing that "slaves have no soul," used to enjoy himself torturing his slaves. One day he cranked up Epictetus' arm behind his back especially cruelly. Epictetus said: "Master, if you turn the arm just a little bit further, it will break." The master did, the arm broke and Epictetus said: "Master, didn't I tell you that if you turned the arm just a little bit more, it would break?" The master responded by releasing Epictetus from bondage: The mere "program" had proved to him that it possessed a soul - a feat for which the slave master will be remembered forever much like the "wicked man" in the Eastern tradition who won Buddhahood on his deathbed.

SELMA FRAIBERG

But it is perhaps neither a computer nor a human slave who will first tell us who Turing was. There are two further candidates from whom we may learn what a person is. The first is children born blind. Laughter and smile are (according to van Hooff) optically indistinguishable as we saw, but not acoustically. In her classic book Insights from the Blind [35], Fraiberg showed that children born blind often remain "too harmless" for life to live outside an institution. For some reason she did not use the word "autism" to characterize the condition she had discovered in cooperation with the late Eric Lenneberg. They only found the children they observed were unable to correctly use the personal pronouns in "nonsyncretic usage," as they called it (namely, outside standard phrases like "gimme some more meat" which she dubbed syncretic). Second, the blind children were unable to adopt the mother's role in make- believe

games (in which they enduldged just as happily as sighted children do). Third, they could not re-tell the content of a story read to them from the vantage point of the protagonist. This trias combines three completely harmless deficits - were it not for the consequences they entail.

The Fraiberg-Lenneberg trias constitutes a predictable condition, in our context [36]. Moreover, the condition can possibly be treated causally in all those cases (the majority according to Fraiberg) where it does not disappear spontaneously as it did in Kathy, Fraiberg's favorite discussion partner, at age 4¡. This attempted treatment would no doubt be in the spirit of Selma Fraiberg who had discovered a first causal therapy for blind infants herself: At age ¡, they fail to spontaneously coordinate their hand movements as sighted infants do. Unless, she discoverd, the mother "artificially" puts the infant's hands together in front of the body repeatedly to let the two hands find each other as an object of exploration. Then, the further development of bodily skills continues unabated [35].

The later-incurred "linguistic" condition also discovered by Fraiberg likewise calls for an instruction on the part of the mother that may prove vital to save the child. Once more, the mother would have to provide artificially what is an obvious reality to the sighted child. Only this time around, it would be an acoustic emulation of van Hooff's optical condition. Tender loving sounds, uttered by the mother whenever she is about to break out into a joyous laughter - even in its most unpredictable bemused beginnings - would be the prescription. To do so, honestly and conscientiously, will amount to a major sacrifice on the part of the caretaker. But even though it would be designed to artificially produce the same misunderstanding that sighted infants succumb to in accord with the above theory, there would be no fraud involved. Right? The "therapy of the two hands, fused" would have a natural complement in the "therapy of the two smiles, fused," or so one feels.

FUNCTIONAL CONSEQUENCES

The functional condition just described, no matter whether established artificially or naturally (in the case of sighted infants), is surprisingly hard to describe in detail. This is because of its nontrivial mathematical character. What is applicable, technically speaking, is called an "exchange symmetry." This term is originally due to physicist Wolfgang Pauli who coined it in the context of quantum mechanics (although it is equally applicable under classical conditions [7]). "Giving" and "taking" are the same act under mirror-inversion (and a time lag). The exchange symmetry that is present between mother and child (if they are coupled symmetrically in such a way that each's joy is a reward to the other) enables false expectations being formed. Specifically, the taking (eating the apple offered by the other) is joyful in two ways when van Hooff's condition is fulfilled. The direct joy of eating is compounded by an added joy of friendliness perceived (although in reality, there is only joyfulness on the mother's face since the child's displayed pleasure is a rewarding charm to her). The added joy is great enough to allow for a game of its own - to put the apple experimentally into that other open mouth over there to see whether the munching is equally joyful when taking place there. It is not, of course, but the reward nonetheless is even greater owing to the returned friendliness (joyfulness) triggered by the act. The two intertwined suspicions of "joy present over there" and "joy here intended over there," formed in the process, are cross-confirming.

Hence the young autist is led to embark on a game in which both sides soon start exaggerating their own pleasure in order to make the other more "happy." The complexity of a fractal texture of suspicions and pretensions that all turn out to be true unfolds at great speed in a never-repeating manner.

IS BENEVOLENCE PERCEIVED AND SHOWN, A CATASTROPHE?

The suspicion of benevolence being present over there, and the suspicion of being able to generate pleasure (do good) over there, are both misplaced, as we saw. Nevertheless, the two misunderstandings are mutually cross- confirming. So personhood is a fraud? Amazingly, this is not the case. The two confirmations generate a reality out of nothing. This, by the way, is the only known example of a reality created out of nothing.

Nevertheless the new reality is a "tragedy" when looked at with the eyes of a traditional biologist. For "feeding Mum" is not exactly what a biologist likes to see in nature, since it uproots natural selection. Another way to put the same concern is to say that "benevolence unlimited" (for this is how the concept arises at first in a positive feed-back loop) ought to go hand in hand with "power unlimited" (omnipotence) and "knowledge unlimited" (omnisience), if it were to be functional at all. In the most advanced scenario of cosmic evolution, indeed all three "unlimiteds" taken together (omnibenevolence, omnipotence, omniscience) arise jointly if Teilhard's discovery of the "second arrow" in physics

is not misleading. But so only asymptotically at the end of time, not before. So the biologist is both disheartened and awed by what takes place here.

On the other hand, the reality of benevolence is, of course, a problem every person on the planet was and is faced with since time immemorial. Descartes would have said that there is no need to worry since the second ingredient (omnipotence) is also implicit already in the form of exteriority. So "only" omniscience is missing. And then, there is Kant's moving statement that "there is nowhere anything in the world that without qualification could be called 'good' except a good will." So the naive stupidity of it all is, perhaps, forgivable?

MIRROR-COMPETENT PARTNERS

We still don't know for sure whether or not the autocatalysis of benevolence is an unmixed blessing. Children born blind ought to be given access to it, we already agreed upon. And by implication, so should merely "smile-blind" children (as Kanner's syndrome of infantile autism is defined to date [37]). Both proposals constitute perfectly legitimate therapeutic options in human medicine.

However, thinking functionally always opens up new vistas. Close relatives of the human species can equally be characterized as being "smile-blind" owing to van Hooff's finding. They are, therefore, likewise eligible to being tentatively treated - provided they possess all the other functional characteristics that smile-blind human beings bring along (in particular, mirror-competence). Then, instead of the "acoustic human smile," adopted by the mothers of both blind and smile-blind human children, the acoustic (or optical or combined) bonding display of the species in question needs to be mimicked by the human caretaker. To produce this substitute for one's own joyous chuckling whenever it strikes, would of course be even more taxing than the sacrifice demanded from the part of the mother of a blind child. A case in point is the broad (silent) grin of re-unification of a young chimp, photographed by caretaker Herbert Terrace [38]. The second precondition, a virtually infinitely strong bonding potential, brought along by human children, could also be counted on as being met.

But where should the boundary be drawn? With the closest relatives that share more than 98 percent of the human genes? Gibbons, the fourth mirror-competent hominid species, are much smaller than humans but much better singers. Their intelligence may already be a bit different in kind. Cetaceans (dolphins and whales) form an eligible group in a different category: the suspicion of a higher-than-human intelligence could be well-founded, as Leo Szilard, inventor of the atom bomb and the first scientist in history to despair on the human condition, proposed [39].

Embarassingly, the corvid magpie (Pica pica) was recently also shown to belong into the fold of mirror-competent animal intelligences [40]. Other corvids probably follow suit, as will some great parrots (including in particular the keas who are so charmingly naughty as to be a national plague in New Zealand). No one ever put a mirror into their cage. The same holds true with elephants. Seals and sea lions will also need to be tested. Even giant octopuses will need to be screened since they are known to be capable of insightful imitation, too. Lorenz used his Nobel money to buy a giant octopus in Japan.

The classic test for mirror-competence (a mark on the forehead that is perceivable only in a mirror or on mirror-TV) is due to Gordon Gallup, while the phenomenon itself was first discovered in young chimpanzees by Wolfgang Köhler in his classic 1921 book (originally titled "Intelligence Tests in Apes") [41]. The heroism of Alan and Beatrice Gardner, the couple who first took the risk of rearing a chimp-child as a person, cannot be overestimated [42]. The fact that they did not succeed must not be held against them (they eventually donated Washoe to a zoo).

The legal problems that would need to be faced when the task were to be taken up again (person rights extended to prospective persons even before treatment begins) are only mentioned here. The familiar problems currently faced by bioethics in the context of genetic and brain engineering are comparable in their scope to those faced in the present context, it appears. Is all of this not a sacrilege even to ponder?

GALACTIC EXPORT

The spontaneous invention of benevolence can, as we saw, be exploited in order to try and treat human children who would otherwise be deprived of their right to become a person. But would the extension of this right to creatures none of whose ancestors presumably was a person be justified? Would the eligible species deserve a special status like that recently proposed for three of the other 4 homid species?

What does medicine say and the Hippocratic oath? A "specieist taboo" appears to be infringed upon by the above proposal, reminiscent of the one violated by the recurrent attempts in history to obtain cross-breeding between humans and other hominids. "Race boundaries" are, fortunately, no longer considered sufficient reason for enforcing taboos, but are "species boundaries" not something else? And would the successful raising of a nonhuman person not cause inevitable suffering?

Recently, a French court granted damage payments to a person born with a handicap, for his not having been aborted before birth. The reason quoted was unnecessary suffering deliberately caused. If the above distinction between being alive and being awoken as a person is scientifically sound, the French court's verdict would have to be re-considered. While coming to life is a passive act that no one has ever had any influence on, becoming a person is different: Each inevitably becomes a person by creating another person (by attributing personhood - benevolence - to another person no matter whether or not that person has already been a person beforehand). The fact that the mother usually is already a person when the toddler first declares her to be one does not diminish his benevolent creative act. Consent is implicit here.

Humanity has always believed in its own uniqueness. In the West, special "genes" and an allegedly most complex "brain" are routinely quoted in support of humanity's special status as the "crown of evolution." However, the Western Bible never speaks of evolution or genes or brains, only of a "similitude" to the creator himself as the reason for the special nobility of Adam and Eve. If Rumi, father of the dancing derwishes, sings of the water seeking the mouth of the thirsty person no less ardently than the other way round, this special attitude among persons on differing levels (since the water fulfills the creator's desire) is given a poignant expression. A hidden but real state of paradise is alluded to by the Bible as well as by Buddha.

The present approach to personhood - as being rooted in the understanding of benevolence - paradoxically rekindles these old-time views at the expense of outdated scientific and cultural prejudices, whether it be the "genes" or a minimum number of cell layers in the cortex (often invoked as a defense against the complexity of the Cetacean brain). In modern evolution-theoretic terms, humanity ceases to be the current crown but rather becomes a "side-growth" on the tree of life, a deviation from the most frequently traveled route in the cosmos. This looks like a let-down at first sight, but is not since, at the same time, humans have "jumped ahead" with every person right the heart of point Omega (the goal of evolution) with its mentioned trias of the three omnis. This "miracle" at the same time gives human persons a tragic touch because omniscience (the third component of the trias) remains unreachable even as the other two are embraced.

If this is true and not just defensible (as it is), the idea of taking other creatures along on the jump completely loses its frightening aspects. On the contrary: the notion of "exporting the jump" becomes humanity's greatest mission. Carl Sagan's notion of making "contact" on a cosmic scale suddenly ceases to be indefinitely far away.

A HANDLE ON EVIL

Children believe all kind of stuff since the credit they give is unlimited, as we saw. This is the sign of a person. A person is the largest and tallest when the smallest and most helpless. A freshly-hatched person is absolutely free of evil and is only able to see it as a joke.

Oran-utans don't talk "because they would otherwise be forced to work," the European visitors were told by the orans' human friends. Linnaeus, the famous classifier, therefore still grouped these hominids under "Homo sapiens" along with his fellow human beings. A type of behavior shown by sperm whales comes to mind in this context: the "rosette phenomenon." When one specimen has been wounded deliberately by a whaling ship's cannon, the other members of the clan come to the surface to soothe it, putting their heads together in a rose-like pattern (hence the name), a condition which makes them oblivious to being harvested jointly at the ship crew's leisure. This is either, because they are the stupidest instinct-bound creatures of the planet in spite of their sporting the most elaborate brains or, because they are persons wiser than we are, much as the orans were once thought to be.

Indeed, the issue of "conscious avoidance of being infected by evil" (once seriously attributed to non-talking hominids and now to non-diving cetaceans) is, perhaps, the most essential one in all of human history. No matter how unlikely it appears, the sperm whales may be teaching their cute little relatives a lesson, Buddha-style.

Evil is a topic rarely touched upon in science [43]. Unlike good, it is not a spontaneous creation out of nothing (arising in a symmetry-breaking bifurcation, as we saw above), but rather is procreated in a triggering-type ("hard") bifurcation. If this description is correct, evil represents not an invention, but an infection. It becomes a disease spreading through contagion, much like BSE (the mad-cow disease). The latter would share with it one more property:

What is triggered in either case would be a change in a pre-existing trait (unaltered prions in the one case, unmitigated paradise in the other). The altered configurational status of a molecule would be dynamically analogous to a new cognitive attractor valid for the infected individual (desecration of paradise). Gregory Bateson, Lorenz's friend to whom he sent me in 1975, found no fault with this bifurcational view.

Evil is identical with cruelty (or gruesomness), the deliberate denial of an irrepressible need of another person, into the face of that person, so that she or he is no longer treated as a person. The withholding of food or knowledge or the triggering of a bomb above one's head are examples that are on everybody's mind. Evil is that which Levinas and Descartes taught us can be avoided by us if we become aware of our being "a hostage of the other" (Levinas) by virtue of our unintended momentary omnipotent position of exteriority. Evil is the social disease of mankind, the greatest tragedy in the cosmos. Evil is very hard to fight. Gandhi-chi (the dear one) was postumously called the most astounding being of flesh and blood who ever walked upon the earth (by Einstein). This was because he was a theoretician of the science of evil and of how it can be treated.

GANDHI'S TRICK

The only Gandhi I ever met is Richard Attenburrough's Ben Kingsley in the lead role. Maybe, the episode is not authentic. But it shows the strength of his mind. After Gandhi's having once more achieved a momentary reconciliation between Muslims and Hindus, by a near-fatal hunger strike of his, a Hindu leader comes into the room in which he lies on a bed (in the movie), asking him to take a piece of bred right now from his hand for having once again "won" with his stubbornness. Gandhi refuses. The colleague angrily insists because "you have to live" while he himself was doomed. Why? asks Gandhi. "Because I have murdered a Muslim child." Why? "Because the Muslims had killed my son. Hence I can never be helped." I can help you, Gandhi said. "No one can help me." Go and addopt a Muslim boy whose parents were killed by Hindus and raise him in the faith of his fathers. The man kissed his feet.

LAMPSACUS

Lampsacus was an ancient Greek town near the Hellespontus. To date, "Lapseki" is the town blessed with the best cherries of all of Turkey, Ahmet proudly tells me. Even in the good old days, the Lampsakenes were special. They granted asylum to the inventor of chaos theory in the modern mathematical sense, Anaxagoras, when he was ostracized in Athens for having become too popular among his fellow Athenians just as Socrates would be a few decades after. When he came to dying from old age, his fellow Lampsakenes offered him a "free wish" in recompense. He wished that all school children should be given a holiday< in the month of his death. Seven hundred years later, historian Diogenes Laertius added to his report that the custom is still observed in Lampacus. Today, the custom has spread over the planet. We have always been Lampsakenes without our knowing.

Project Lampsacus, "hometown of mankind on the Internet" [44], is an idealistic program in which free access to information, knowledge and learning is made a right of all persons. Not only would Lampsacus profit from the spirit of the galactic era - being the first person-bound institution in history -, but it would also in return provide the greatest forum ever to science. The survival-threatening problem of evil, mentioned above, shows why this at first sight political project fits squarely into our scientific context. A first attempt to put Orca whales on the Internet was made by Gottfried Mayer-Kress [45]. "Noah's ark" forms the earliest historical analog - an attempt to spare the last just person on the planet (Noah) the fate of having to survive alone.

The idea of point Omega existing and being reachable is older than father Teilhard's discovery of the second arrow. Avicenna, who stood in the Rumian tradition, had a very similar physical theory already. Conceptually, the idea goes back to the Jacob's ladder of the Bible and Buddha's promise to come and relieve every single person individually. It all is a little bit related to Gene Roddenberry's star trek universe, if you see what I mean. Project Contact is still unconsummated.

It appears that the field of nonlinear dynamics can be brought together with that of artificial brains and artificial persons. The approach connects back to the origin of the modern scientific endeavor when the latter was still called "natural philosophy" due to its roots in ethics. Is benevolence not too precious a subject to be touched by the scientific method? And do we humans really possess the infinite responsibility that was attributed to us by the first Enlightenment and, specifically, Descartes? Person rights can be derived from the theory of artificial cognition. Dynamical systems and cognition - chaos and mind - were once the oldest mixture according to Anaxagoras, first adopted citizen of

Lampsacus. "The mysterious glowing wire of consciousness" (as Lorenz put it) and the machine theory of chaotic dynamics form an intimate couple. While the chain reaction of the origin of life reminds us of our being star dust, the chain reaction of benevolence takes a jump right up to the heart of the cosmos. "Export" is the new option of the computer-enchanted second Enlightenment. Chewbakka: Ready to take the pilot's seat?

CONCLUSIONS AND SUMMARY

Dynamical systems were invented in the footsteps of Descartes by Newton. They lie at the heart of the "machine theory" of the universe and the brain. The paradigm of "chaos" has led to a revival of dynamical thinking. An "equation for a brain" is an autonomous path optimizer solving a certain well-posed optimality problem in space (spatial Darwinism). Its main element, an autonomous direction optimizer, involves potentially unbounded positive and negative gradients (forces) of two types of potential, attractive and repulsive, which strangely resemble subjective emotionality. The second element, an immersive virtual reality, turns the direction optimizer into a path-optimizer endowed with anticipatory intelligence; it strangely resembles the pictorial side of cognition. Two major questions open since the 17th century pose themselves: What is the localization of consciousness inside a natural or artificial brain? And, What is the origin of the non-autistic functioning of the human brain compared to the functioning of even the most sophisticated biological or artificial brains endowed with mirror-competence? The key to both questions is the notion of "benevolence," first introduced by Descartes. Benevolence arises as a self-amplifying instability if a certain coupling condition between two autonomous path optimizers of the above class is met. Namely, that the sum- gain of one acts as a specific sub-gain for the other and vice versa. This condition is fulfilled empirically by the effective indistinguishability of smile and laughter in a single primate species (van Hooff phenomenon). The mirror- compentence lets two bonding partners exploit the exchange symmetry that applies between their own actions and those of the other. The bilateral discovery of benevolence triggers a positive feedback that irreversibly alters the functioning of both optimizers. The ability to conceive of benevolence on the other side implies personhood. Personhood implies consciousness. Spatial Darwinism therefore allows a new treatment of the physiological autism of children born blind or smile-blind. The therapy can be extended to other mirror-competent social animals and artificial brains. Is the deliberate solicitation of personhood ethically allowed? It is according to evolution theory. The attractor of the second arrow of physics, Teilhard's point Omega, is attained in a jump by a benevolent person. "Contact" - the galactic export of this trait - is humanity's new open frontier. Scientific knowledge of what a person is and what its rights are is welcome in a time blessed by more young persons than any other. Lampsacus, hometown of all persons, is a beginning.

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