I. Notion of Natural Finalism

1. Problems of Definition and Terminology. In this article the neologism “finalism” is preferred over the term “finality,” because of its many different meanings in modern English: decisiveness, fate, final stable state, purpose, goal, propensity, inclination, etc. The Free Online Dictionary defines finality as “the belief in final causes.” Aristotle criticized the mechanistic reductionism [2] (atomism, materialism [3]) with his doctrine of the four causes. He defines “cause” broadly, as an “explanatory or responsible factor” of some event or feature. He is also the first to claim, from a rational as well as heuristic view-point, that there exist final causes in [4]. This claim is grounded on the intuition that organized changes or events resulting from some action, are directed — intentionally or not — to achieving some goal or end.

Natural finalism answers metaphysical questions, such as: why do the natural forms appear as they do? Are there any natural goal-seeking processes? Finalism has been linked to determinism [5] as natural laws often relate causality to the prediction of final states. Modern science added much indeterminism: quantum physics, chaos, random mutations, etc. Aristotle did not just oppose chance to causality, but rather described “chance and spontaneity” as “incidental causes” or “infinite number of possible causes” (cf. Physics, II, 5-6: 197 a32 – 198 a13). The universe [6] may well be due to spontaneity, although this...
response seems short-sighted to him, since incidental causes cannot be the ultimate causes of reality: some natural or intelligent agent must exist beyond them as cause.

A final cause intrinsically possesses some guidance even if it is unpredictable. Aristotle fails to mention the notion in some places (cf. Meteorology, 390b; On Generation and Corruption, 335a, 28-31), because unlike the other causes (material, formal, efficient), a final cause is merely present as an active tendency in their cooperative work. But this virtual presence is prior to the beginning of the action. This generalizes the scholastic “Principle of Natural Inclinations,” according to which the final cause is first in intention, last in execution (see Thomas Aquinas, Summa theologiae, I-II, q 1, a 2, c). A final cause may be an advice, a proposal, a desire or a virtue: it need not be be substantial or energetic. It reveals the actual presence in other causal actions — especially involving efficient cause — of an intrinsic tendency towards some telos, that “for the sake of which” the process is brought about (cf. Physics, II, 3, 194b 15 ff.).

For Marjorie Grene (1972, pp. 397-398), the “kinds of ‘ends’ that usually interest Aristotle are the determinate end-points of particular processes within the natural world.” But Marie George objects that the Aristotelian telos is not a mere endpoint, because it must be naturally helpful for the being (cf. Metaphysics, 988 b 6-16): death [7] is not a telos, although it is an endpoint.

Even convinced reductionists admit the idea of finalism or design “for a purpose” (cf. Dawkins 1986, pp. 1, 5; Crick 1988, p. 138), particularly in biology. Striking examples abound: genes, DNA proteins and ribosomes work together to produce proteins; chaperons assist in the folding of proteins to get a functional form, or their unfolding to cross a membrane channel, helping them to fold back correctly afterwards; kinesin and dynein molecules “walk” on microtubules to tow their cargo organelle to remote cellular regions; by the coded message of her 8-shaped waggle dance, a scout bee communicates to other bees the distance and direction of interesting flowers (cf. von Frisch 1973); lung growth in the fetus makes future breathing possible; animals exhibit amazing predation or defense skills: chameleons “glue” flies; eagles catch fish out of water mid-flight; rifle fish shoot down insects with spurts of water; sea otters hammer hard shells with stones to open them; bombardier beetles fire explosive burning acid sprays against threatening enemies; group strategies for hunting, food hiding or storing, enable better chances of survival; etc.

Finalism is a strongly analogical notion, i.e. one having various similar meanings. This generates ambiguous terminology and confusions. Artigas (2000, pp. 126-127; 2002, p. 652) recognizes several different types of finalism in the concept of “natural teleology” (term, goal, value, objective, project), which are also all compatible with chance (see below, IV, 3). He analyzes the role of direction, cooperation and function, and distinguishes between subjective and objective ends. Ayala (2007; 1998, pp. 101-106) introduces the concept of unlimited natural teleology: teleology may be external (artificial) or internal (natural). The latter can be limited when linked to one final state despite environmental variations, or unspecified, unlimited, when related to an open “not predetermined” final state. The adaptation of organisms is of the unspecified type, with evolutionary use of chance and open-ended exploration, and is essential to the plasticity and self-determination of living systems. Ernst Mayr (2004, p. 61) distinguishes five definitions of teleological processes; a) teleomatic (law-like without a search for a precise goal); b) teleonomic (programmed or prepared goals, with internal finalism); c) directed behaviors or planned tendencies (towards some intentional goal); d) adapted systems (survival without any actual “goal”); e) cosmic teleology (global direction of a whole system towards ends, external or meta-material purposes). Mayr concludes that the first four meanings refer to a purely apparent teleology, rejecting the last one. But he rehabilitates Aristotelian finalism, even in a materialistic framework (cf. pp. 110-112).
Following those reflections, I distinguish here six different meanings of finalism (highlighting their essential terms), beginning with the generic notion of “outcome”:

a) outcome: a result of some process that is fortuitous, contingent or necessary, such as an accidental killing by a falling stone. A specific final cause is generally not present since the result is from an incidental cause (chance); some functions qua conditions are outcomes (niches, climate, catastrophe).

b) end or term: an outcome generally linked to stable law-like final states, often necessarily realized, such as a teleomatic tendency to increase entropy, to rest at the bottom, to damp out vibrations, to die, etc.

c) goal: a beneficial or useful outcome for some being(s) able to influence its achievement, such as biological functions including aptitudes, DNA coding and building of proteins, survival of the species, bird migrations; it is often contingently achieved, roughly equivalent to an aim, target or endeavor, and is often hardwired in the nature of beings. It is similar to telos, although telos may simply be a useful end.

d) project or objective: a proposed or anticipated goal, generally instinctive or unconscious, such as killing prey to feed offspring, a vulture smashing bones to eat the marrow, a bee dancing to communicate the place of interesting flowers, biomolecular machines matching proteins together to build up and fix a powered flagellum into the cell’s membrane.

e) purpose: a conscious project (design, plan) or intentional design, e.g. a man writing an article.

f) cosmic teleology: a global universal project or tendency toward some final state for individuals, the Earth or even the whole Universe; it may be conscious or unconscious, determined, undetermined or a combination of both, such as Intelligent Design, élan vital, some versions of Gaia, Strong Anthropic Principle, free Creation[8], divine emanation, predestination, ordinary or extraordinary Providence, etc.

2. Anti-finalism. Since Darwin’s Origin of Species (1859), words like teleology and finality often trigger hostile reactions, as those concepts are easily connected to supernatural explanations, which rightly should have no place in science. As Wattles, Ayala, Mayr, Grene, Cameron and others have argued, Aristotle is often wrongly accused of invoking an anti-scientific teleology, which is actually a neologism invented in 1728 by Christian von Wolff.

In an article entitled Darwin was a Teleologist, James Lennox (1993; 1994) reacts against Michael Ghiselin. According to Ghiselin (2004) and Ospovat, any teleological interpretation of Darwin must be rejected because he never accepted the existence of true final causes. But others such as Lennox, Young, Beatty, Kohn and Muñoz-Rubio, disagree. For Muñoz-Rubio (2003, pp. 303, 308-310), Darwin’s archived writings reveal his hesitation regarding the evidence of design, final cause and progress in nature: following Darwin’s gradualism such evidence appears undetectable or non-existent on human scales. But without sufficient empirical confirmation, Darwin is divided between possible interpretations of his theory. After Origin of Species, he thus does not see any intelligent design in each evolutionary step, but feels inclined to admit it in the laws of nature[9] or even macroevolution; he rejects the idea of a continually progressive natural selection, but finds a long-term progress plausible. He therefore appears to avoid the conflict by admitting these concepts on a global level. And he supports at least some finalism in a Malthusian predictability of population dynamics between “the means of subsistence” and “birth and death rates” (in Malthusian terms), which constitutes the basis for computer simulations of Darwinism.

3. Finalism, Indeterminism and Contingent Causation. In the Random House Unabridged Dictionary, finalism is defined as “the doctrine or belief that all events are determined by their purposes or goals.”
This definition seems too radical to me, because it rests upon a universal finalistic determinism that automatically rules out any contingency, a notion that is easy to disprove. I raise two objections: a) I dispute the completeness of determinism, because it is illogical that every possible event in a deterministic world must be uniquely determined; b) natural finalism need not be universal and/or deterministic to exist in nature.

As natural finalism is associated with determinism [5], the notion is often overly contrasted with chance, chaos and indeterminism. Chance refers to the unpredictability of events, which appear indeterminate. Chaos refers to apparent dynamic disorder, which seems indeterminate or incoherent, often resulting from highly divergent processes, i.e. sensitive to tiny variations of conditions. But causality is not necessarily mechanical, deterministic or unique, and may be compatible with various kinds of indeterminism: multiple effect possibilities, deterministic chaos and casual changeability under generic control, as well as quantum mechanics [10]. The Principle of Causality simply states that a cause is a principle on which some thing depends in its being or acting. This dependence is not always necessary or determinate: on the contrary, it may be contingent, incidental or indeterminate. Introducing Max Born’s meaning of quantum causality, Sanguineti and Artigas (1989, pp. 246-247) observe: “Only a total indeterminism would be incompatible with causality and the existence of natural laws. The confusion of causality with hard determinism is an error related to rationalism [...]. On the contrary, for Max Born: ‘The statement, frequently made, that modern physics has given up causality is entirely unfounded. Modern physics, it is true, has given up or modified many traditional ideas; but it would cease to be a science if it had given up the search for the causes of phenomena.’ And elsewhere: ‘not causality, properly understood, is eliminated, but only a traditional interpretation of it, consisting in its identification with determinism.’ This interpretation is derived from Kant. For Aristotle, however, many causes can be contingent and accordingly, subject to fortuitous factors.”

4. Finalism, Predictability and Deterministically Caused Spontaneity. There has been much recent debate over the possibility of pure spontaneity or pointless indeterminism in a world — following Newton, Laplace or Einstein — governed by full deterministic laws. Hoefer (2008) asserts that such a world “is rife with possibilities for determinism to break down,” because it allows inherent singularities where physical laws break down or degenerate with infinitely or evenly different possible outcomes: e.g. in general relativity, “Cauchy horizons” in some black hole models; in Newtonian worlds, the theoretical infinite velocity generators, the supertasks systems or Norton’s Dome. Such examples seem to eradicate the possibility of completeness in pure naturalistic determinisms: the possibility of “free” causation or spontaneous movement seems inescapable.

Although one may defend the case for freedom or contingency, however, confusing steps often arise between causal reality and pure deterministic representations or models, between finalism and predictability, causality and determinism, or a-causality and indeterminism. Besides their usual abstractness, these models consider odd cases of local singularities, which hinder a mathematical determination of the future. It seems to be a modern scientific version of Zeno’s brand of sophistry.

For example, Norton (2003) supports some causal skepticism reducing causality to an epiphenomenon, even if he admits practical causality and finalism for “folk science.” He stresses quite strongly that in a deterministic Newtonian system, an infinitesimal ball at the apex of his Dome may either stay there indefinitely or move spontaneously in any horizontal direction in a finite time “without any cause.” On my view, the “spontaneous” movement or rest of the ball, even if it remains unpredictable, is caused (in the Bornian sense) by the earth’s gravity, the shape and the interaction of the dome with the ball. It sounds like Aristotle’s infinite number of incidental causes. Norton certainly admits and uses causal laws: otherwise, he could not make his case. For as a causal application, he mathematically predicts...
Finalism
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deterministic and non-deterministic (or degenerate) processes. But predictability is not required of final causes. Norton seems to conflate causality and determinism, wrongly suggesting that there is no initiating cause. Causes co-produce — i.e., they are causing — the movement, without unequivocally predetermining it at the apex: the determination comes out spontaneously from the causes at the unpredictable moment of action.

Therefore, spontaneity may emerge in an ideal deterministic world, but it must be caused. The causes initiate and precede their unpredictable effects, but this is asserted only \textit{a posteriori}, once the effects are manifest. In addition, the presence of a final cause associated with this system still holds: it degenerates in a well-defined class of equally possible final states. This purely academic case interestingly illustrates two things: a) the prudent distinction we should make between close concepts like finalism and predictability, causality and determinism, modeling capacity and reality; and b) the possibility of \textit{contingent causation} even in deterministic world models.

II. Historical Natural Finalistic Systems supporting Theism

Thomas Aquinas understood \textit{telos} as a paradigm of developing his fifth rational \textit{way} to God as the Ruler and Governor of all beings, often inaccurately cited as \textit{Aquinas’s Argument from Design}. One of the greatest difficulties for the argument from (cosmic) Design is not scientific but philosophical in nature: it is known as the “problem of natural imperfections” (which extends the problem of pain or evil). The very existence in nature of suboptimal adaptations, monsters, errors, needless organs, junk DNA, cruelty, parasitism, etc. seems to confirm the shoddiness or lack of design, as well as a lack of (evidence for) a designer, at least of a perfectly good, omniscient and omnipotent God. Almost every agnostic or atheist considers this a key argument against God’s Existence or Providence. I will not directly address this complex problem here, but instead will study connections of \textit{natural finalism} to some \textit{religious cosmic finalism} not simply equated to a Designer, in three main philosophical systems: Thomism, Kantianism and Process Thought.

1. Intelligent Governor of Natural Finalism in Aquinas’ Fifth Way. Aquinas begins from the evidence of natural finalisms to conclude the truth of divine cosmic teleology (cf. \textit{Summa theologiae}, I, q. 2, a. 3): it is not a proof of \textit{God} \cite{11} from detectable designs or goals (God as Designer or Ultimate Final Cause), but from the “governance of natural things” (\textit{quinta via sumitur ex gubernatione rerum}) through natural finalisms. \textit{Governance} and \textit{Providence} are more general, holistic, a-temporal and systemic than \textit{design}. Applied to God, they somehow control past, present and future chance, suboptimal designs or other’s governances or stewardships, aiming for more future systemic or holistic perfection than that of temporal partial \textit{designs}. Governance extends dynamically from past to future through the present.

Modern notion of design must be applied with great care to Thomism. The term \textit{design} was coined from the Italian \textit{disegno} since 1444, long after Aquinas, to identify graphics representations or items machined according to a plan or blueprint, as opposed to primitive handworks. It mostly indicates a static, pre-designed system, often complex and inventive, similar to the Aristotelian example of a house plan. After the triumph of Keplerian and Cartesian \textit{mechanics} \cite{12}, industry as well as Protestant or even “cosmic” theologies (Calvin, Paley, Heindel, etc.), adopted this notion with the subsequent reductionist view, confined to efficient (or secondary) causality, of God as “Great Architect” or “Watchmaker.” In an interview, Catholic thinker John Haught criticizes this biased theological use of “perfect \textit{design}” as too rigidly predestined, “closing off the possibility of a future,” of progress, \textit{evolution} \cite{13} and autonomy (see \textit{Counterbalance interview} \cite{14}).
Aquinas’ natural finalism links irrational beings, who lack thought (qui cognitione carent), to non-casual, intended ends always or frequently achieved, fit for their own or others’ sake. These intelligible interactive finalisms in nature manifest some external finalism or intention, because, he adds, non a casu, sed ex intentione perveniunt ad finem, that is, they achieve their ends non-casually but as intended, like the (irrational) arrow shot towards its mark by the intention of the archer (cf. Summa theologiae, I, q. 103, a. 8 c). The English translation, “not fortuitously, but designedly, do they achieve their end,” conflates the concepts of “governance or providence” and “design.” Thomistic Providence foreordains things towards an end, the eternal “Reason of order” in God. As to Providence, God governs all things immediately; whereas in its executing Governance, He governs some things by means of others(cf. Summa theologiae I, q. 103, a. 6 c.). Providence may be: a) general (world governance through natural laws [9] and chance); b) special (free men and angels’ governances); or c) very special (divine supernatural actions or interventions: miracles, prophecies, grace, sacraments, Church, Incarnation, etc.) (cf. Summa theologiae, I, q. 113; De Veritate q. 5, a. 5).

Natural finalism falls under General or Ordinary Providence which, contrary to the Extraordinary Providence, does not force or exceed nature: not only does it make things happen, but it does so either by necessity or contingency, according to the nature of their proximate causes (cf. Summa theologiae, I, q. 22, a. 4). Aquinas’ God behaves by essentially following His ordinary Providence: He does not normally act in contrary ways, correcting with supernatural interventions what he supposedly did not permit by ordinary or hidden governance. Thus, Aquinas agrees with Dionysius (cf. In de divinis nominibus, IV, 23) that “to corrupt nature is not the work of Providence,” Providence does not destroy chance, contingency, nor secondary causes, but rather provides effects so that the order of secondary causes, with their limits, also falls under Providence (cf. Summa theologiae, I, q. 23, a. 8 c).

Aquinas concludes that all natural beings are ordered towards their ends by a supreme Intelligent Governor, adding later that He may often communicate some co-causality to creatures, allowing them to become co-adjutors able to produce life by either spontaneous or proper generation (cf. Summa theologiae, I, q. 22, a. 3; q. 23, a. 8, ad 2um; q. 71, a. 1 ad 1um; q. 118, a. 1). For Aquinas, the almost unfailing order we observe in things is a sign of their being governed (cf. Summa theologiae, I, q. 103, a. 1 c.). He reasons that “any natural order and any collection of beings is only preserved in harmony owing to some providential governance” (De Veritate, q. 5, a. 2 s.c. 2-3.). Aquinas admits that there may be partially suboptimal design, or even none at all (casualia et mala, lawless, accidental, evil, corruptible things), although this lack of design must providentially return to a higher order, mostly unknowable to us (cf. Summa theologiae, I, q. 19, a. 6 c; a. 7 ad 2um; q. 18, a. 3 c; q. 22, aa. 1-2; q. 103, a. 7 ad 2um; In II Sententiarum, d. 1 ad 3um). The First Cause knows, creates and rules everything, necessary or contingent. Reinhardt (1944) considers that the internal finalism as discussed by Aquinas is so coherently and universally ordered, that, even with apparent incongruities and disorders, it leads to an external finalism of cosmic degree.

Failure to make these distinctions leads one to confuse the way God [15] normally acts in Nature, as in certain interpretations of the Intelligent Design (ID) Movement, which sometimes portray God as a master artisan or laboratory worker, i.e., as secondary super-cause acting on bio-physico-chemical events: thus, several ID advocates maintain that their Designer is not necessarily God, the first Cause. But for Aquinas, proper divine action is absolutely necessary in all creatures and primary in their nature, properties and fundamental laws: Aquinas’ Governor must be the First absolute metaphysical Cause, the Cause of causes. Secondary causes act relatively, following those laws and dynamic contingencies or limits enacted by their Creator.

In this regard, the International Theological Commission (2004) commented on key Thomistic ideas,
stating that the appeal to divine interventions to fill in explanatory gaps in science is incorrect, except for ontological causation (ex nihilo creation of being or of each person): “The current scientific debate [...] between neodarwinians and their critics[,] sometimes implies a misunderstanding of the nature of divine causality. [...] A growing body of scientific critics of neo-Darwinism point to evidence of design (e.g., biological structures that exhibit specified complexity) [...] This cannot be settled by theology. But it is important to note that [...] even the outcome of a truly contingent natural process can nonetheless fall within God’s providential plan [...] Divine causality can be active in a process that is both contingent and guided. [...] The appeal to divine causality to account for genuinely causal as distinct from merely explanatory gaps does not insert divine agency to fill in the gaps in human scientific understanding [...]. The structures of the world can be seen as open to non-disruptive divine action in directly causing events in the world. [...] Acting indirectly through causal chains operating from the beginning of cosmic history, God prepared the way for what Pope John Paul II has called ‘an ontological leap... the moment of transition to the spiritual.’ While science can study these causal chains, it falls to theology to locate this account of the special creation of the human soul within the overarching plan of the triune God.” (Communion and Stewardship, Human Persons created in the Image of God [16], [2004], nn. 68-70).

Aquinas’ God is therefore Governor of necessity, chance and evil events, able to seamlessly take advantage of innumerable tiny natural events converging gradually, to our surprise, towards some long divinely foreseen results. Without precluding the possibility of special interventions (which is outside the realm of science), this view shows more grandeur in the divine control and creative unfolding than simple designs, together allowing natural autonomy in secondary causes. Remarkably, even if Darwin feels unable to reconcile the cruel parasitism of the ichneumon wasp larvae with God’s Providence, in concluding The Origin of Species [17], from the 2nd edition (1860) onward, he hints at some compatibility with faith in God: “There is grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.”

2. Kant: Nature as “System of Ends” and Man as “Final End”. Kant dedicated his Critique of Judgment (1790) to the study of aesthetical and teleological judgments. However, his ambiguity in several key notions (nature, purposefulness, end, mechanics, teleology) provoked diverse interpretations. Kant sees Nature [4] as a “System of Ends” whose internal mechanical explanation is phenomenologically incomplete, logically requiring teleological processes, and whose practical reason for existence — its final end — is external. An object is an end if it is purposeful. He applies “purposefulness” to organisms, artifacts, beautiful objects, the whole System of Nature, especially the harmonious and hierarchical relations in Nature. The fact that Nature is purposeful for our cognitive faculties or judgment is an a priori principle of reflecting judgment. The Kantian “end” appears somewhat subjective, a human paradigm used to explain Nature’s works, i.e. a regulating idea which helps us to capture nature’s aesthetics (subjective purposefulness) and their phenomenological lawfulness and utility, especially for organisms and functions (objective purposefulness).

“Organized beings” or organisms are regarded as “natural ends” whose parts stand in relation to the whole. We can conceive of their possibility only by assuming that they were produced by design, possibly self-design, being both “cause and effect of itself” with inner purposefulness: self-replication, self-development, self-feeding, self-repair (today’s homeostasis and autopoiesis).

Kant was interested in the pre-evolutionistic ideas of Maupertuis, Buffon, Foster and Herder, especially in their notion of life’s natural potential for diversification, gradual scale, and progress. In his earlier years, he tried to reconcile the antinomy between teleology and the mechanistic account of Nature. Later after
his “critical” period, he may have supported *transformism* in some way, i.e. the evolving transmutation of species as a natural “mechanical” or law-governed process. But Kant always excluded pure mechanical transformism from non-living matter to living beings (as in spontaneous generation). For him, teleology rules in a non-living world, because the production of organisms cannot be reduced exclusively to mechanical explanations; it must be accounted for in teleological terms (see §§ 78-81 of the *Critique of Judgment*, and Kant’s 1788 essay *On the Use of Teleological Principles in Philosophy*). Altogether, insofar as human intellect cannot understand it differently, the mechanics of transformism is seen as subordinated to the basic teleological processes of Nature, which is perceived as a *System of Ends* with external purposefulness, beyond the province of science or efficient causality.

Accordingly, he distinguishes between the “ultimate end” of Nature (the inner teleology to maintain the whole of Nature) and its “final end” (outer teleology, the *reason why* for the existence of Nature as a whole) which he considers to be the free moral man. Each human being is conceived as a *noumenon* from Nature’s System. As Hannah Ginsborg (2005) explains, Kant’s idea of man as final end of Nature is consonant with his practical idea of God as Creator and Governor. It relates more directly to moral and practical — not natural — teleology.

3. *Compatibility between Chance and Finalism in time-dominated Thought.* Bergson considers that although mechanism and finalism are everywhere in biology, their classic definitions are inadequate, especially with regard to internal finalism. On his view, the only viable finalism is *external*, in an ecosystemic sense of finalistic interactions between organs and organisms.

Bergsonian finalism is somewhat cosmic and globally networked, but also intrinsically loaded with the unforeseeable, the accidental, the discontinuous and the spontaneous. It is neither an immanent *entelechial plan* nor a divine preconceived *Design*, a big Leibnizian Plan; otherwise it would, for Bergson, “manifest a greater harmony the further it advances.” Bergson sees life’s evolution as an orthogenetic burst of the *Élan vital* (Vital Impetus), which erratically explores the various possibilities offered by its spontaneity, splitting and spreading life, adapting creatively without aiming at ends (see Bergson, 2003, pp. 107-108, 120-121, 142).

Close to Bergson, authors inspired by Process Thought developed a constructive immanent spontaneity that Charles Sanders Peirce calls *tychism* (from Greek *tyche*, that is, chance), as a casual generator of order, but with no reference to a pre-established plan. Process theologians like Arthur Peacocke suppose that natural evolution is divine creation through chance and laws, made open-ended with creative emergence, not pre-designed but teleologically directed toward man through explorative chance, selection and self-organization.

With regard to finalism, key ideas for those presuming a Process Thought or a Bergsonian perspective include the *self-surpassing capacity of nature*, its creative novelty, its spontaneity or lack of concrete preconceived design. Nicholas Rescher (2008) divides them with respect to their view of nature's processuality: a) the *naturalistic wing* (generally secularist) sees “an inner push […] to something new […] in terms of chance-driven randomness that leads away from the settled formulations of an established past”; b) the *teleological wing* (often theological) sees “directedness towards a positive destination […] in terms of a goal-directed purposiveness pre-established by some value-gearied directive force.”

Many proponents of Process Thought seem to endorse a non-classical image of *God* [11]. Their God does not know with certainty the future, and some fortuitous events may escape his prediction and providence, even if He can always reorder them *a posteriori*. Such a God is not Omniscient, Omnipotent, Absolute and Perfect, pure Act and Necessity: He becomes relative to his creatures, full of potentialities, necessary
in being but not in becoming and knowledge, complex, self building, mind changing, eventually immanent to the world, etc. The problem of evil and sub-optimality are less acute on this view, but God’s powers and relations to the world appear more problematic.

III. Science looks back to Finalism in Natural Processes

1. Attractor and Evolution in Epigenetic Landscapes. Conrad Hal Waddington represents the morphogenetic tendency of a system in a fictitious epigenetic landscape, similar to a hydrological topography subjected to gravity. The dynamic state corresponds to a ball moving on this landscape, dodging hills, following valleys split at some bifurcation points, or captured by pits or basins of attraction. An attractor—i.e. a dynamic state zone towards which the system tends to be trapped— is a finalistic concept which inspired erudite scientists like Michael Polanyi (see [18]Life’s irreducible Structure [19], in Science, New Series, 160 [1968], p. 1310) and René Thom (1988). Thom proposes a landscape model of the morphogenesis (living or not) in his Catastrophe Theory, not restricted to the ordinary 3D or 4D geometries, but also to the space of states associated to morphogenetic parameters. He first focused his study on simple potential systems, and found that for elementary attractors there are only 7 possible complementary types of elementary catastrophes. Simple mathematical models of attractors are linked to potential wells and gradients, tendencies to equilibrium or stable states, least minimum action, etc., which present some physical finalism.

But real attractors are often far too complex for a comprehensive analysis. For example, a mere bipendulum (pendulum suspended to another one coplanar in a gravitational field) already behaves as a chaotic attractor with fractal topology and long-term unpredictability: it magnifies the effects of microscopic variations to macroscopic levels. The emblematic case is the Lorenz attractor, better known as the Butterfly Effect. The complexity of living beings increases even more tremendously with competition between strange attractors.

Furthermore, Thom formalized several fuzzy concepts: morphogenetic field, organizing centre, entelechia and internal finalism. For him, the steering force of the natural selectivity and adaptation in evolution rests in the morphogenetic and semiotic laws originating at the boundaries of the forms. The variation of morphogenetic parameters (sometimes only one) between individuals of the same species may sometimes automatically produce mutually adapted forms and structures, i.e., without need of a gradual mutual adaptation process: for example, the sexual divergence of fetal hermaphrodism seems to develop automatically into complementary paired sexual organs.

2. Laws, Constants and Anthropic Principle. A teleomatic process expresses the simple Aristotelian movement of a potency finalized towards its corresponding act, mostly found in simple attractors: fall, radioactive decay, chemical reaction towards balance, self-organizing membranes, etc. It coincides with the constitutive finalism of matter [20]—being it animated or not— along with its fundamental fixed and universal laws (i.e., without evolution). Darwin seems ready to assign its deep source to God (see his letters in 1860-1861; The Correspondence of Charles Darwin, Cambridge University Press, Cambridge 1985, vol. 8, pp. 225, 258, 275, 496, etc.; Muñoz-Rubio 2003, pp. 306-313).

The observation of astonishing matching coincidences in most natural constants and fundamental laws constitutes the basis of the Anthropic Principle [21], and triggered controversies on the reintroduction of finalism and its heuristic use in the sciences (see L. Susskind, The Cosmic Landscape: String Theory and the Illusion of Intelligent Design, Little, Brown 2005, pp. 192-195, 360-362; and his debate with L. Smolin on Multiverse, on line at Edge - The Third Culture [22]). An everyday coincidence is found in the
multi-critical value of the electromagnetic fine structure constant \( \alpha = \frac{1}{137.036} \) (Barrow 2001; 2005), a pure number without dimension, which underpins all the structural activity of biology, ordinary physics and chemistry: macromolecules, chemical polarity, hydrophobia, H bonds, crystal patterns, solid/liquid/gas state and even isotopic stability. Such key physical values and laws place strong constraints on the way matter works, under law-like teleomatic finalism.

3. Thermodynamics, Entropy, Irreversibility. Max Planck strived to recover some finalism in science. He defended the teleological significance of the Least Action (or Hamilton) Principle, which inspired his discovery of the minimum or quantum “step of action” \( h \), the famous Planck’s constant: “The causa efficiens, which operates from the present into the future and makes future situations appear as determined by earlier ones, is joined by the causa finalis for which, inversely, the future —namely, a definite goal— serves as the premise from which there can be deduced the development of the processes which lead to this goal” (Planck 1938, p. 26). Modern quantum mechanics [10] offers a new explanation of the followed path using path integrals. When a particle’s path involves exchanges of action near the minimum \( h \), it appears fuzzy and the particle finds its way with “stochastic action jumps” in a bunch of probable, yet statistically predictable paths, like most microscopic quantum physical tendencies. This leads to contingent teleomatic finalism, avoiding either black and white classical logic, or “magic” forces, on some views. Recently, R.I. Kaila and A. Annila (cf. Natural Selection for Least Action, in Proc. R. Soc. A., 2008, 464, 3039-3054; see the on line article [23]), compared the Least Action Principle to the evolution by natural selection using entropy and energy landscape analogies.

In the last 30 years, some physicists, like Gatlin, Wicken, Ho, Saunders, Brooks, and Wiley, have developed a new vision of information [24], free energy and entropy in information-closed and energy-open systems, i.e. a network of structures far from equilibrium with activated memorized information.

*Thermodynamic entropy* macroscopically represents the unavailability of a system’s workable energy, while microscopically representing its internal structural “disorder.” Some scientists avoid using the notion of disorder, as it is somewhat subjective: it represents the absence of macroscopic pattern (smooth or chaotic look) for a given systemic property (such as molecular energy). Classical entropy expresses constraints on the directions many natural processes can take, following the equation: \( dS = dQ/T \), where \( dS \) is the differential change in entropy resulting from an infinitesimal flow of heat \( dQ \) in the system at the temperature \( T \). Any spontaneous energetic process in a non-equilibrium isolated system will tend to increase the thermodynamical entropy until equilibrium is reached. The differences in shared properties between interactive parts, tend statistically to flatten or smoothen at a global level. This is the case for any energy-like properties (energy, temperature, pressure, density, chemical potential, etc.), but is also valid for other interchangeable properties in a dynamic system. For example, shaking two piled layers of sugar and sand grains will chaotically mix them with apparent irreversibility. *Statistical entropy* or dynamical “disorder” emerges from the equivalence, or non-distinguishability, between the most probable apparently equivalent states (i.e. reaching a global “equilibrium state” among the most equivalently mixed-looking states), in turn due to the non-distinguishability of the grains with regard to the shaking process. The *irreversibility* is due to the extremely low probability for the mixing process to reproduce an “ordered state,” apparently equivalent to the initial state (ordered piled layers of sugar and sand). As the dynamically produced states appear mostly “disordered,” the thermodynamics which follows from analogue interacting parts of a closed system tends to increase entropy or “disorder” and irreversibility, i.e. *time asymmetry*. The greater the number of analogue interacting parts, the stronger this tendency: because entropy is statistical, few systemic parts may sometimes “violate” the entropic increase (2nd law of thermodynamics), spontaneously rebuilding “order.”
But if some discriminating properties between parts take effect, it is possible to reverse the system to an equivalent ordered state. Differences in the properties of sugar and sand (e.g. density or water solubility) enable their easy separation (by centrifugal refinement or dissolution) from any previously achieved “disordered” state. Therefore, if a process somehow discriminates between parts in a chaotic medium, some patterns will often appear, as seen in many processes exploiting chaos joined with discriminating force or field: star and earth dynamics, refinement, decantation, layer deposit, electrophoresis, chromatography, haematocryte centrifuge, osmosis, sift, etc.

Some processes are thus able to locally decrease entropy (at the expense of global increase), and take advantage of chaos to accelerate their work. Life is replete with such processes that place, maintain and control “order” against the “entropic fate”. E. Schrödinger thus coined the expression “negative entropy” in his famous Trinity College lectures on *What is Life?* (1943); Boltzmann compared life to a struggle against entropy.

4. **Self-organisation, Fractals, Information and Kolmogorov Complexity.** As Ilya Prigogine (1984) showed, some spontaneous macroscopic order may emerge from chaos, especially in some non-linear cases far from equilibrium of dissipative structures: e.g., the temperature dependant self-organisation of “Benard cells,” where billions of molecules move coherently and form bordering hexagonal convection cells.

This kind of process produces some configurational or spatio-temporal order, as often seen in nature’s numerous chaotic and fractal patterns. Yet, it cannot produce information-rich or semantic order: their visible order or harmony simply emerges from the most probable configurational state under definite constraints. The scarce information content is visible in the boring repetitive patterns produced, with high redundancy, free-scale self-analogy, coherence and self-repetition, resembling the order of tapestry-works or garlands, far below the complexity of a genome or a well-written prose text.

Therefore, the complexity of the most “stunning patterns” found in nature (curves, polygons, crystals, fractals, trees, flower patterns, lobelia leaves, nautilus shell, etc.) depends more on space-time than on information [24], and can be (re)produced by processes with low Kolmogorov Complexity (i.e. low information content). For example, the fractalization of surfaces is a cost-cutting method of optimizing gaseous, liquid or information exchanges. Life tends to select many fractal structures because of their low genetic information cost, for high quality exchange, iteration and multiplication rates.

5. **Teleology newly baptized as Teleonomy.** The notion of finalism was reintroduced in the 1950s in various scientific and technical disciplines concerning biological life: *Semiotics* by Jakob von Uexküll; *Object Oriented Programming* by Alan Kay; *Epigenetic Landscapes and Morphogenetic Fields* by Conrad Waddington; *Attractors and Catastrophes* by René Thom; *Feedback and Predictive Cybernetic Systems* by Piotr Anokhin and Norbert Wiener.

In this context, Colins Pittendrigh (1958, p. 394) reintroduced biological ends or goals, with the forged neologism *teleonomy*, replacing the word *teleology*, in order to eliminate any confusion about the concepts of purpose and project, which he hastily labeled as “Aristotelian” concepts. The controversy over finalism, which was thought to have calmed, was indeed revived. Pittendrigh gives an inaccurate interpretation of Aristotelian finalism in terms of efficient cause, hidden force, which refers to his notion of teleology. David Hull (1982) sees therein an unnecessary terminology, driven by the rejection or the fear of theism.

Nobel laureate Jacques Monod (1970) popularized the word *teleonomy* in biology. Connecting finalism...
and teleology to purpose, he sets up his Postulate of Objectivity as "the systematic denial that 'true' knowledge can be got at by interpreting phenomena in terms of final causes — that is to say, of 'purpose.' [...] It is obviously impossible to imagine an experiment which could prove the non-existence anywhere in nature of a purpose, of a pursued end. [...] Objectivity nevertheless obliges us to recognize the teleonomic character of living organisms [...]. In fact the central problem of biology lies with this very contradiction, which, if it is only apparent, must be resolved; or else proven to be utterly insoluble.” (pp. 37-38). As his postulate must be fundamental to any science, Monod states it universally: “Nature is objective, not projective.” (p. 17).

For Mayr, the terms teleomatic and teleonomy are advantageously more specific, and avoid any implicit reference to a conscious project. At the end of his life, Mayr thus avoided the word teleology, with an enforced politically correct cliché of scientism, expurgated and reduced to the logical naturalistic and mechanistic order. His reduction of the teleonomy to the “automatic software predetermination” is significant. This position results from the a priori adoption of the Postulate of Objectivity. Subsequently, evolutionists like Stephen Jay Gould and Michael Ruse (2004) appear more careful in their conclusions.

6. Unfalsifiable, Anti-finalist and Ideologically clothed Postulates. Darwinism is not directly interested in the apparent internal finalism but rather in its causal origin, often presented as a black or white dilemma: creation’s design or evolution’s selective random processes. Adjectives as random and natural are available for exclusive use, i.e. excluding a priori any other possible cause, especially any involvement of God. However, this is philosophy, not science. The use of methodological naturalism is compatible with the belief in God. According to naturalistic interpretations of Darwin’s postulates, the randomness of the inheritable variations reveals the lack of a (fixed) goal, project or plan; likewise, the naturalness of the selection should express the absence of intention, design and intelligent intervention (i.e. artificial or supernatural selection). The presence of errors, evil and monstrosities would confirm this absence of purposeful directivity in living processes. Neodarwinist antifinalism led to some “dogmas,” i.e. limits not to be crossed, which according to Muñoz-Rubio (2003, pp. 304-305) and Thom (1990, pp. 600-605), have restricted the productivity of evolution research.

As seen earlier, Monod maintains the impossibility of proving the nonexistence of purpose in nature. Likewise, “random look” of some sequences does not entail their past random generation. Besides, pure randomness does not appear in DNA (neither coding nor junk; cf. Caporale, 2003, pp. 42 ff.) or protein peptide sequences: they exhibit redundancies and coherences, partly because the selection itself wiped out unused random events, giving at least the impression of a design, as Francis Collins suggests in his book The Language of God (2006).

As the postulates of randomness and naturalness of original processes are not falsifiable in a rigorous way, John Maynard Smith (1989, pp. 5-6) asserts that Darwinism “fits badly into the mould of the Popperian criterion of scientificity.” In principle, Ockham’s razor could even apply to these almost superfluous atheist-friendly adjectives: in place of random and natural processes, incoherent mutations and automatic selection suffice for evolution dynamics to occur. Their biased use undermines the debate between Faith and Science, hinders believers’ acceptance of evolutionary mechanics , and keeps teleological conflicts alive.

Besides, why do many believers unhesitatingly accept the naturalness or randomness of physical processes while simultaneously remaining reluctant to accept biological naturalness? Is this caused by the rooted idea of the sacredness or irreducibility of life? Is it a vestige of Vitalism? Perhaps, but it certainly also depends on the biased anti-finalist and anti-religious presentation of Darwin’s postulates.
7. Cybernetics and System Theory: Behavior and Teleology. Among the scientific streams that rehabilitate some finalism, Cybernetics is particularly significant. By the 1930s, biologist Piotr Kuzmich Anokhin developed a new theory. A system of functions is finalized towards goals, desires or needs, according to a synthesis of estimates, feedbacks and anticipations (Anokhin, 1935: 1962): e.g., Pavlov’s dog salivates in response to the sound of a bell, because this predicts the immediate appearance of food, thanks to the association with memorized events. Mechanisms of feedback and feedforward organize behavior, based on the association between passed experience and a forecast of the immediate activity and possible reactions. More advantageous finalized processes may emerge in self training processes, where any error or success is memorized and handled to refine the acquired experience for future use.

In 1943, Bigelow, Rosenblueth and Wiener titled an article Behavior, Purpose and Teleology. They discovered in natural living teleologies the retroactivity of feedbacks. Wiener (1948) founded a new science and titled his bestseller book with a finalistic neologism coined from the Greek kyberno (that is, to pilot a ship; also used for “governance”): Cybernetics, which describes how to control and optimize a system’s response to a great range of stimuli, such as in feedbacks.

8. Feedbacks to track Targets, Growths or Cycles. A simple feedback system presents a closed loop which controls his response to a current stimulus by comparing it to some (fed back) information on earlier responses. It is characterized by two essential parameters: $X$, the feedback’s intensity (which may vary with frequency) and $\Delta t$, its delay. In fact, the fed back information is memorized in this loop delay $\Delta t$, which is never null in practice and determines the minimum reaction time of the controlled system. Three generic types of reaction arise:

a) convergence, stabilization or conservation: it corresponds to a simple dissipative attractor with damped down and fast negative feedback ($-1 < X < 0; \Delta t$ short); any deviation from the position of equilibrium is thwarted and tends to cancel, sometimes after damped oscillations related to the delay $\Delta t$ (e.g. chemical equilibrium, damped pendulum or vibration, ball reaching the bottom of a bowl);

b) divergence, growth or decrease, steady amplification: it corresponds to a cumulative or positive feedback ($X > 0$), with looped reinforcement of reaction. The system diverges all the more quickly as $X$ is large and $\Delta t$ short. Any deviation is accentuated and the system diverges (e.g. explosion, outbreak of fire, evaporation, collapse to a black hole, hypertrophy or atrophy, cooling, entropy increase, Norton’s ball motion);

c) oscillation, vibration, beat: it corresponds to a sustained undamped negative feedback ($X < -1$) where $\Delta t$ fixes the period of oscillation; any deviation is periodically reversed after a certain time. If $X$ has an important absolute value, the amplitude of the oscillations grows. This corresponds to a delayed negative strong feedback (e.g. Larsen effect, heart-beat, breathe cycle, Parkinson's disease).

Usually an unstable or divergent system can be stabilized by adding a negative feedback, whereas a positive feedback will steadily intensify some effect. In practice, physical growth or decrease cannot last indefinitely, and are limited by some negative feedback (saturation, exhaustion) or by damaging the system (death, rupture). Evolution, ontogenesis, epidemics, callus, synaptic reinforcement, cellular multiplication and life itself are roughly comparable to developing positive feedbacks. From the start, living systems develop and exhibit countless feedbacks to pursue useful responses.

9. Feedforwards: Hardwired Internal Finalisms. There are also anticipatory systems with feedforward controls, able somehow to guess possible future conditions and reactions, theoretically eliminating non optimal deviations, even canceling response time; it depends of course on the predictive and speed
capacity of the anticipatory system, which often supposes an internal modeling of the functions and reactivity of the uncontrolled system and environment.

To illustrate the difference, a feedback is like tracking a fugitive, correcting path deviations which appear, whereas the feedforward corresponds to waiting for the fugitive at a place where he must pass, or controlling his flight (varying his pathway, setting obstacles …) by directing him towards a trap. In biology these finalistic controls are found in pre-programming or fore-adaptations: provision, preparation, protection, migration, care, trap, bait, animal courtship, etc. Their “control” is somewhat calculated in advance. In general they instinctively direct the system towards concrete solutions to frequent and expected problems, are easy to fine tune and are thus more effective than pure feedbacks. But they can also be generic or partial, and apply to classes of problems (such as escape, self-cleaning; see also below IV, 3).

The best regulators combine the advantages of feedbacks and feedforwards whose predictor can itself be based on feedbacks which estimate and fine-tune the future evolution according to past experience. Feedforwards often extrapolate an external perturbation which is sometimes not yet active, but assumedly impending: a shock, a bend, a precipice, a hole, a rise of temperature, a combat, a predator, a prey, some food, the surface of water, etc. The living system can thus prepare its future reaction, also evaluating its own potentialities and optimizing its response, before experiencing the perturbation.

Feedforward is only understandable in terms of internal finalism. The concepts of feedback and especially feedforward partially invalidate the anti-teleologic argument for the impossibility of “backward causation” or “retro-cause” for which future events cannot “act on” or “be a cause of” present and past events. In fact this impossibility does apply to efficient causes, but not to final causes. The mechanisms directly studied in sciences deal with efficient causes. This predisposes to reductionism [2] and inhibits the understanding of finality. Final causation results from an association between present and foreseeable events or outcomes. It manifests a relation between the future effect and the necessary presence (past and actual) of a specific tendency towards the efficient cause. In short, the efficient cause is selected and preserved because of its previous effectiveness, for future similar effects, which constitute the final cause.

One might object that the for lies in the way, as “nature” acts as a Blind Watchmaker who does not know the future in advance: even if future problems will never come, the selection would nevertheless have taken place in fact; future utility adds little to it, and only the present one is selected. This reductive approach seems too simple to me, because even if nature must not be anthropomorphized and endowed with any conscious purpose, it actually optimizes the processes of selection themselves. Besides, even purposeful, conscious predictions or choices are often not made with certainty. The natural final cause is not simply recording past “cause to effect” relations, but is dynamically open to preserve those which were advantageous and useful, to fix similar future problems. It is the essence of adaptation that current utility was and is essentially future utility, as uselessness was and is selected out by natural selection (see infra: fore-adaptations and forms predictability, IV, 4.1 and 4.2). In addition, however, natural feedforwards take into account foreseeable future actions and control the system by anticipation. The concepts of gained experience, fine tuning, hardwired program and memorizing develop naturally.

IV. Finalism in Biology

1. Biological Finalism: Language and Nature. As we have seen, it is difficult to do without some “intrinsic teleology” or teleonomy in biology. But some estimate that the introduction of finalism is purely linguistic or anthropomorphic, lacking any useful objective reality, or that teleological
formulations of natural life processes can be expressed in non-teleological manners, with pure
descriptions of factual consequences. So the finalistic sentence “I have lungs in order to breathe” would
reduce to an efficient causal version, “I breathe thanks to my lungs, and thereby I survive in fact”. But
such a reduction is not as easily applied to a sentence like “the foetus develops lungs in order to be able
to breathe after its birth” (see infra IV.4, 2).

Ayala (1970, pp. 11-12) shows that no perfect equivalence exists in the efficient causal translation,
because the organized directivity of living beings is fundamentally different from that of a falling stone.
For Ernst Mayr (1974), the anti-finalist sentences neither take into account nor reflect the former actual
presence of internal programs directed towards precise useful effects.

2. 4-D Evolution. Marjorie Grene (1972, pp. 405-407) justly refutes the Lamarckian teleology of
“function creates the organ”: the giraffe did not acquire a longer neck by trying. Grene claims that the
Aristotelian telos is particularly present in ontogenesis but not in the phylogenesis. There is no general or
ergent telos (a fortiori, no purpose) in the biological mechanic: “Darwinian evolutionary theory
appears teleological because it is first and last a theory of adaptation.”

This conclusion, however, appears questionable. Evolution seems more complex than the
one-dimensional Darwinian selection process. Slow gradualism does not seem able to account for fossil
records of phylogenetic explosions. Some thinkers ask for more sophisticated regulating mechanisms than
the simple “Trial and Error” natural selection process (where trial is a genetic random variation test, and
error is the Selection’s elimination by infertility or death): its rough binary feedback — offspring and gene
survival or not — is known to be the simplest in system theory, the most aggressive, slowest, easily
divergent and unstable, especially in a changeable environment. Besides, contemporary evolutionary
reductionism often endorses the idea that “it’s all in the genes”, at least likening the gene to the main
actor of evolution.

Eva Jablonka and Marion Lamb (2005, pp. 233-238, 319-353) defend a much wider four-dimensional
evolution (with genetic, epigenetic, behavioral and symbolic variations), where a number of
“Neo-Lamarckian mechanisms” are likely to control, target and work out various basic evolution
variations (which are more generic than mutations). The current study of genetic control (DNA
methylation, parental imprinting, si-RNA and μ-RNA, viral genomic contributions), of chaperones,
chaperonines and protein folding, complicate our vision of the evolutionary dynamics. In the same way, it
seems that some advantageous epigenetic controls worked in the evolution without gene mutations and
were fixed genetically only later: e.g. the caryotypic sexuation seems to have been fixed after a stage of
thermal sexuation, still seen today in several reptiles, where sex difference is fixed by egg’s incubation
temperature.

Even if such processes are not fully Lamarckian (i.e., where the use changes the inheritable phenotype),
future utility appears in fact to order and stimulate the generation and fine-tuning of organic functions,
mainly as a result of complex internal control of the evolution itself at all systemic levels of life’s
organization. A concrete goal is not projected or known in advance; rather evolution leads to higher
probability of utility, holding mechanisms more elaborated than simple optimal Darwinian adaptations.
Selection processes are in turn selected, fine-tuned and adapted to several types of function utilities. For
example, several organisms are able to differentiate the rates of genetic change (Campbell 1985, 1986;
Caporale 2000, 2003) and thus, to somehow control their long-term evolution: untied or accelerated
mutability permits the exploration of future potentialities; restrained mutability helps to stabilize certain
important useful genes, organs or individuals. Nature uses techniques of genetic interdependence that can
help fixing (i.e., making non-evolutionary) or even repair essential utility functions or genes: bisexual
reproduction assists long phylogenetic stabilities; various archaic essential genes are extremely stable and seem secure against hazardous mutations, e.g. Hox or Homeobox genes complexes.

3. Finalistic Use of Chance. Countless natural processes often take advantage of chance or chaos to optimize adaptation processes. For instance, the presence of “noise” in a neural network may help it to spontaneously unlock when trapped or locked by a strong attractor; acceleration of random mutation rate helps explore new genetic possibilities.

Polymerization, synthesis of DNA or proteins, regulation of genes, osmosis or any chemical reaction in solution, etc. are all made possible by some chaotic nature of the medium, which accidentally brings into contact the reactants or connects random parts to a selector and manufacturer system. Enzymes, chaperones, gradients, warm-blooded animals, etc., use statistical diffusions and chaotic collisions of the thermal agitation to speed up their chemical reactions, just as laboratory assistants warm up or agitate test-tubes. These are examples of simple finalistic use of chaos and chance. Chemical thermodynamics studies such phenomena, universally found in nature.

Furthermore, when a concrete solution is difficult to fix in advance, especially with a changeable environment or predation, most life systems develop flexibility, plasticity or extended capacity in order to randomly or selectively explore new possibilities, to in situ adapt, to (re-)program, improve or respond to unpredictable events (cf. Jablonka 2005, pp. 311, 377-378). In this case, feedforwards and fore-adaptations emerge without direct concrete solutions, but generalize their response to an indistinct domain of problems, and generically control it by selective filtering, learning and memorizing of advantageous casual events. For example, several flower plants produce and somehow control systemic randomness or contingency, such as seed dispersal with explosions in some Euphorbia, or with parachutes in dandelions.

Fuzzy solutions are sometimes designed in computer simulations, inspired by evolution’s paradigm (e.g. genetic programs, Dawkins’ biomorphs, bootstraps and Monte Carlo tests: cf. B.F.J. Manly, Randomization, Bootstrap and Monte Carlo Methods in Biology, [London: Chapman and Hall, 2006]). The evolutionary nature of Darwinism corresponds to a type of statistical filtering process where the inept is eliminated and the suitable is selected. Selection grants a certain organization or intelligibility in random processes, which leads to the discovery of morphogenetic laws. But as chance is a player in the game of life, it is naturally used, even producing or causing the optimized achievement of certain “goals.”

4. Teleonomy and Directed Behaviors. Teleonomy extends the finalism of teleomatic processes, to provide more complex and diversified powers, features and capacities. In his closing passage of The Origin of Species, Darwin speaks of living powers, which are emergent (not vitalist) potencies. The examples of apparent design (see supra I, 1) show the existence of properly naturally directed behaviors. Teleonomy seems to be specific to living beings, which are not only equipped with the classical Aristotelian life-qualities (i.e., growth, self-motion, nutrition, reproduction), but also with other goal-directed resources such as memory, information [24], instinct, trainability, plasticity, genetic program, feedforward, predation skills, etc. I will focus my analysis on six types of natural finalism in biological systems.

1) Inherited adaptations as fore-adaptations. Finalism is apparently recorded in the adaptive process. Inherited adaptations are almost equivalent to feedforwards as fore-adaptations, since they are not in situ adaptations to actual conditions. An adapted system which has reacted to past events is expected to be useful and able to further adapt in the future. Why? Since the environment benefits from many lasting stable characteristics and similar conditions (sun, gravity, pressure, atmospheric and oceanic
compositions…), and since radical catastrophes are rare, then past experiences are potentially reproducible and improvable. So, they may accumulate and be fine-tuned in phylogenetic memory. Otherwise neither the selection nor the adaptation, nor the anticipations would have been booked as evolutionary mechanisms, and evolution would never have taken place. Evolution thus continues, as in the past, in a law-like progression, and even seems somewhat predictable.

2) Predictability of analogies: similar solutions to similar problems. Actually, some anti-finalists claim that adaptation does not entail general laws allowing concrete prediction of the future of life, nor necessarily actual future adaptations: a lack of laws entails lack of predictability as well as finalism. But this leads to a somewhat incoherent Humean skepticism: if correct, this lack of laws obliterates the very possibility of any evolution theory.

Evolution supposes “evolutivity,” which in turn presumes a certain ecosystemic or epigenetic stability. Adaptation looks like the training in a given art. To refine his skill for future performances, a pianist needs adequately stable conditions: a piano with a fixed keyboard to note match, fingers, muscles, memory, etc. Stable conditions grant life to inherit working adaptations, not only in fact, but also because adaptation is replicated and refined under similar conditions. The anti-finalist functional language tends to eliminate the future utility — or at least “very probable” — and its predictability by downgrading it, as Hume did in his analysis of causation, to a deficient factual description.

Some scientists like René Thom’s and Simon Conway Morris (2003) maintain that organic morphogenesis tends towards predictable forms regardless of most phylogenetical or historical contingencies. Most stable systems reach their attractor’s final state regardless of intermediate states (like a ball’s convergence towards the bottom of a bowl). Most living forms in different environments follow similar adaptations and exhibit evolutionary convergences (analogies between different cells, organs, organisms, etc.) without homology through a common ancestor.

If some evolving life efficient enough to explore ecosystemic niches appeared on an earth-like planet, its genetic system would be rather different, but the basic phenotypic forms would be quite similar: wings, fins, legs, whips, flagella, fractals, etc... Genetics acts neutrally in morphogenetic evolution, enabling without directing it. We find animals with fur in the artic circle, and thorny plants in deserts, regardless of the genetic constraints. Legs developed independently for spiders, mammals and insects. Teeth and horns have the same functional penetrating form. Hydrodynamic fins resemble aerodynamic wings. Bronchi, blood vessels or tree branches and roots are all similar ramified fractals.

The directionality towards classes of forms is the work of morphogenetic laws, which select the living forms as well as the genetics itself. Contrary to Dawkins’ claim, genes are not “selfish” but replaceable parts of the evolving morphogenesis, as manifested in convergent evolutions, fast occupation of niches and competition between phenotypically close but genetically different species. The enormous diversity of life comes more from ways of assembly or interactions than from the core diversity of bio-atoms, DNA, gene families, proteins or elementary forms, just as the diversity of houses does not come from the low brick diversity. Similarity and limited types of constraints steer convergence and parallelism to reduce the number of elementary morphologies and lead to lots of predictable living analogies at all levels. Australian Platypus (Ornithorhynchus) is a good example among patchwork analogies. So, contrary to the anti-finalist view, nature resorts repeatedly to the morphogenetic principle: “Similar solutions to similar problems.”

3) Embryo’s oriented dynamism to adulthood. Modern embryology revisits the Thomistic and Aristotelian ontogenesis of bisexual species, seen as the unfolding of active potencies (i.e. ready at hand
for use: see Fargès 1909, pp. 105-107; *Summa Contra Gentiles*, book II, chps. 88 and 89; Haldane 2004, pp. 534-535) of the male’s semen, which extrinsically activates the passive uterus or egg to build up the embryo in steps: vegetative and sensorial. The rational stage is only triggered by the appearance of the human soul. This scenario, known as delayed animation, prompts metaphysical problems (e.g., generations-corruptions, multiple coexisting forms).

Yet modern analysis shows that oriented dynamism belongs essentially to the embryo, not the semen or uterus, and is activated from its generation (by fecundation, scissiparity, gemmiparity, cloning, parthenogenesis) which fully supplies the necessary internal active potencies. This internal dynamism is a specific individual adulthood attractor which unfolds rather autonomously (cf. Dalleur 2006, pp. 330-332; Thom 1988, pp. 123-125, with his model of the *Physiological Blastula* as “adult targeted”). In most species (esp. parasites, oviparous), the embryo is not directly dependent on its parents. But even the placental embryo is primarily engaged in building its own life. It sets up and targets sophisticated self-defense, such as protection against maternal interferences or immunizing attacks, the growth of the placental barrier to filter exchanges without mixture of blood: as a tree’s roots are filtering extensions in the soil, similarly the fractalized placenta is the embryo’s extension in the uterus wall. So, the embryo builds itself up after generation, i.e., after reception of internal capacities of targeted development to adulthood (which is not true of gametes).

4) “Prey” and “Predator” as morphogenetic final causes. Darwinian expressions like “adaptation to the environment” appear unable to account for morphological diversity in the same milieu. In fact, the adaptation results from biological loops, such as the predation and the reproduction loops (see Thom 1972, pp. 294-299). The efficient cause of the predator’s morphology is its own development, but the final cause which guides its morphology is its prey: in short, predators adapt to their preys. The example of predatory morphogenesis aptly clarifies the difference between final and efficient cause.

The notions of prey and predator may be broadened to account for similar mechanisms: “prey” is any supply mostly useful for the survival of a living structure or “predator”. In this broad sense, air is the “prey” of wings: thus the prey is not necessarily destroyed. “Preys” apply a morphogenetic pressure on “predators”. Adaptation to some part of the environment is only performed when this part constitutes a “prey”: other parts are not directly involved in morphogenesis. Besides, prey morphogenesis often develops with reference to predators as final causes for new skills, and may trigger a mutual escalating race: preys often adapt back to predators; speedy gazelles escape lions, nipples fit the baby’s mouth.

Predation also triggers differences in cellular potency between plants and animals. Both in ontogenesis and in phylogensis, living beings begin roughly as spherical cells, but their semiotic surfaces evolve differently. Plants are autotrophic: they produce the needed substances from the environment; their “prey” is mostly inanimate, microscopic or fluid (molecules, minerals, water, gas and photons). For efficient nutrition, their exchange surface increases and ramifies, extending contact with their prey, similar to the four Greek elements: air and light upwards, moisture and soil downwards. Plants are anchored at the ground-air interface and explore these media in a fractal way. By such tendencies to explore, grow and fractalize, they preserve a self-similarity and a highly iterative generation: most of their cells are stem cells, easy to clone, transplant or redevelop structures.

In contrast, an animal’s prey is usually macroscopic and living. It requires ingestion, digestion and waste elimination. A swallowing processing shape, e.g., tubular, achieves those functions: embryonic archenteron outlines the future digestive tract as the basic animal exchange surface. The predation is further optimized by the appropriate growth along the tubular tract of specialized organs for wandering autonomy (fins, legs, wings), pre-processing capture by the compact bordering of the senses (eyes, nose,
ears, antennas, tongue) and brain near the mouth, organ of capture, to optimize speed and precision, to prepare digestion (mouth, teeth, chewing). The functional specializations of animals’ organs increase cellular differentiation and often carry a loss of potency. Hence animals are less easy to clone and transplant than plants.

These morphogenetic predictions buttress some finalistic logic, largely freed of concrete genetic background or history. From simple consideration of prey, one can predict corresponding predatorial features. Predatory morphogenesis begins during the embryo’s gastrulation with the formation of the **ectoderm**, which constitutes the primeval sensory skin, the original interface to the world of prey. The evolved ectoderm deploys effective openings towards the external world: the brain/nervous and sensory systems, and the lungs. Those ectodermic extensions are in fact predatory adaptations according to a targeted organic morphogenesis. Eyes have evolved from photosensitive skin cells, to achieve ectodermic solutions to vision. Most of those sophisticated organs are somewhat predictable, because their finalism is inherent in the evolutionary predation loop. Actually, morphogenesis expands to a universal semiotic order: leaves follow the sun; roots seek moisture; a macrophage identifies bacteria; a receptor’s binding site identifies its ligands; the HIV virus recognizes CD4 receptors.

5) **Progress of the “Life Tree”**. Most scientists deny life’s hierarchical Scala naturae and replace it with a Darwinian “Life Tree.” Anti-finalist skepticism led some of them to refute any evolutionary progress, which would simply reduce to a pure anthropomorphic projection or a simple unfolding of virtual capacities present in archaic (not necessarily lower) forms.

Darwin (1872, pp. 175, 200-204) noticed that continuous gradualism, the lack of finalistic directivity and the presence of old forms and retrogressions, pose a problem for progress, as still discussed today (cf. Kass 1978; Wandschneider 2005). In certain excerpts of *The Origin of Species*, he seems to reject a real evolutionary progress. But this concept also seems original to Darwinism. Thomas Henry Huxley explicitly formulated it. Darwinian theory intends to naturally explain the prodigious life diversity as a slowly gradual but globally progressive cumulative process of the living organization. Concepts like evolution, selection, fittest, favored races, advantage, phylogenetic tree or graduality, make at least indirect mention to progress or progression. The simple appearance in a poorly organized world of brand new species, phyla or domains, shows that some progress is inherent to evolution theories, naturalistic or not.

In the abnormality of atavism (individual regression to ancestral organic forms, like teeth in chickens or tail on humans), Darwin admits some progress in the evolution of normal forms. He also uses progressive terms and constantly refers to the efficiency of artificial selection: domestication, breeding, arboriculture, pigeon fancying, etc. Some anti-progressive excerpts of *The Origin*, expediently show this conceptual and terminological perplexity (cf. Darwin 1872, p. 98). But those passages often portend the notion of occupied niche (only coined in 1917) by a yet adapted form and do not directly oppose evolution progress itself. In realized niche width, progress halts when new advantages cannot be “selected”. The progress of species may also be “trapped” by temporary conditions: progress is not necessarily continuous or actual, as stated by Catastrophism, Saltationism and Punctuated Equilibrium.

Darwin (1872, p. 176) seems to dispel such doubts with the idea of global progress of the biosphere, in terms of efficiency, specialization and organization (not precisely of complexity or survival of species): “Although we have no good evidence of the existence in organic beings of an innate tendency towards progressive development, yet this necessarily follows, […] through the continued action of natural selection. For the best definition which has ever been given of a high standard of organization, is the degree to which the parts have been specialized or differentiated; and natural selection tends towards this
Evolution Progress can be observed in:

a) \textit{tree-like diversification}: The common ancestor is a concept related to a point of bifurcation, where “branches” of species diverged (cf. Darwin, 1872, pp. 104-105). Darwin and Darwinists often drew sketches of evolutionary trees (cf. Bossi, 2003, pp. 139-171) presuming that life started developing from some old cell, the LUCA (Last Universal Common Ancestor) of which all cells and organisms would be the internal growth: each individual death is an abrupt end to a multi-billion years continuous living path since LUCA. Some speculate whether the \textit{Life Tree} could be the only \textit{Individual} (biological monism).

b) \textit{interactivity and simplification for more efficiency}: For Gould, the growth of the Life Tree is not vertically progressive, but bushy, erratic, aimless, omni-directional. He simply admits that the randomness appears above a \textit{minimal complexity barrier}, below which life is impossible (cf. Gould 1989, 1996). His critique targets only \textit{complexity progress}, and has been challenged by J. Maynard Smith and Szathmry (1995). In any case, current studies show that there \textit{has been and is} an overall \textit{progress of complexity} (cf. Maron, 2004).

Besides, this minimal “barrier” is rather unclear, first because species control their evolutivity and interact with their environment and other species, so that the whole evolves. Even that minimal barrier varies, with its random distribution above, and furthermore is somewhat under control (mutation control, epigenesis, symbioses, gene protection, DNA repair, etc.).

Second, \textit{progress is not uniquely related to complexity but also to simplifications}: many species stay alive below the complexity they would have if isolated. Systemic evolution is organizational, web-like, and multidimensional with interdependent interactivity, as Jablonka, Lamb, Lovelock, Capra, Campbell and Wandschneider show. Almost all species survive thanks to the Web of Life. Their own complexity is too low to survive alone, because progress does not lead directly to more complexity, neither global nor local, but to more efficiency and autonomy.

Adaptation progress may paradoxically arise from \textit{regressive gradualism} and \textit{simplification}. Darwin (1872, pp. 98-100, 175, 201, 308, 390, 394, 417-418) mentioned the existence of “retrogression in […] the organization” of life. Darwinian gradualism is often wrongly thought to increase monotonously, as Michael Behe presumes in \textit{Irreducible Complexity}. In fact, the beneficial loss of evolutionarily acquired features may facilitate plasticity and open new phylogenetic exploration by increasing the degree of freedom and the global efficiency of remaining structures. Well before human factories, life selected and learned to optimize parsimony, energy spare, division of work, resource management, recycling, redundancy relief, release of constraints or efforts, modularity, production and growth rates (e.g., with ramified fractals, simply generated by reducing an attractor’s dimension), slack coupling (e.g., chameleons, as advanced ambush predators, helpfully lost the automatic stereoscopic eye coupling), simplification of processes for an equivalent or richer global functionality (e.g., bio-symbioses; animals resting on autotrophic plants). Mere reshuffling of interactive parameters or species, even without loss, may be sufficient for cost-cutting efficiency or exploration of new evolution pathways.

c) \textit{cumulative upgrade}: Artigas (2000, pp. 152-156) discussed the thoughts of several current thinkers on directed evolution (Ch. De Duve, G. Rattray Taylor, C. Bresch, J.M. Templeton, etc.). Likewise, Dieter Wandschneider (2005, pp. 196-215) recently defended a directional and self-transcendent progress. He highlights horizontal and vertical patterns in the Life Tree. Bushy horizontal evolution results from diversification by adaptively occupying vacant niches. This evolution then slows or stops like a
close-ended progress. Vertical evolution appears in cumulative steps of evolution as *self-upgrades*, which use former evolutionary steps as starting points for novelty. For example, the organic chemistry allows a first evolutionary step in the appearance of cells. The subsequent vegetative stage sees the emergence of plants, followed in turn by the herbivorous step, and then the carnivorous. The evolution of animals did not exclude that of plants; on the contrary, it opened ways back to additional possibilities, like bee pollination or carnivorous plants.

In fact true *progress* is weakly related to the intensity and variety of horizontal adaptation. Real progress is overall vertical, because it synergistically nests new adaptive structures on top of old ones, as modular upgrades that increase dependant autonomy and efficiency (see next point for details). Apparently, main vertical steps: 1) went along with great paleontologic decimating events (major asteroid collisions, glaciations, hothouses) which exerted high evolutionary pressure; 2) were mostly related to the acquisition by a generic common ancestor (or several) of new major living qualities (such as ATP use, endosymbiotic chloroplast or mitochondria, multicellular life); 3) were often followed by phylogenetic explosions (new horizontal diversification).

Besides, Darwinian evolution was followed by human cultural and technical evolution. Man represents a real threshold in life’s history, the universal predator able to survive even in space, to create new species while resuscitating the extinct, to project other planetary civilizations, or to destroy the entire biosphere. Human action in nature supersedes Darwinian features, i.e., the “naturalness” and “randomness” of evolutionary processes: man, domesticated species, and perhaps the whole biosphere, are no longer subject to pure *natural* selective pressure. Once it appears, *artificial evolution* even prevails strongly for many species and habitats. Seemingly over-equipped for his own survival and able to control the evolution of all species, man may regard his own purely natural origin as a fallacy. Pope John Paul II said in his *Message to the Pontifical Academy of Sciences in 1996* [25] that the human body may well be prepared by natural evolution, but that the whole of man cannot be its result, due to spiritual characteristics which are beyond the reach of natural selection.

6) “Dependant Autonomy” of higher levels.

a) *Progress patterns of the Life Tree*. The cultural/technological top stage requires the former steps in the Life Tree. Today, however, the Life Tree paradigm must be revisited or expanded with the notion of Web of Life. Like almost every natural relational network, the living webs co-evolve and organize quasi-spontaneously as optimizing sets of intertwined “Scale Free Networks” (SFN). The picture today is far more complex than that of a gentle phylogenetic tree, mainly at its archaic stems, and resembles more a dynamic web of diversified interactions, and even genetic jumps, between unattached species from one taxon/domain/phylum to another, as Doolitle (2000) observed. Today the chronological heredity tree appears more like a web of genetic interdependences. The levels co-exist, co-regulate, co-operate and co-evolve sometimes peacefully and symbiotically, differing from the gradual, sequential and competitive reductionist vision of strong Darwinism.

b) *Progress to more “dependant autonomy” and plasticity*. Total autonomy is impossible to realize. But autonomy is not equivalent to independence: any autonomous level must be based on some lower functional system. In reality, the progress hierarchy follows the chained dependence between levels: upper levels need the lower ones to survive and progress, but not *vice versa*, except for food chain cycle (as death is a huge recycling factory which levels down all levels). The subsistence of lower forms is stronger because they do not need the higher forms, and are generally more simple: higher structures are often more complex, dependent, and hence fragile.
Systemic sociologists Edgar Morin (1980, p. 148) and Robin Fortin showed that level autonomy increases with dependence: computers provide more opportunity and autonomy (formal level), although we become more dependent on technology (material level). In the same way, greater formal autonomy corresponds with more material reliance on lower structural levels (e.g. animals’ autonomy with material dependence on autotrophic plants). Almost all new levels emerge with a new type of autonomy, while being materially dependent on lower levels. This formal autonomy is directly related to the evolutionary flexibility to explore new vacant niches.

Besides, in order to grant autonomy to a higher level, life must ensure a formal neutrality of the lower levels with respect to it. An old proverb by Lao Tzu says “Give a man a fish and you feed him for a day. Teach him how to fish and you feed him for a lifetime.” Likewise, evolution tends to increase autonomy by tuning a lot of living structures in a state of self-decidability or free “determinability,” i.e., an open-ended “neutral state” endowed with resolving or explorative powers. When a field of possibilities is too vast and complex, or when environment or predation conditions are unpredictable, higher autonomy of exploration and reaction is often granted by life, with the ability to fix future accidental problems: e.g., motility is the ability to move in any direction; the transparency of the vitreous humor and the lens enables the eye to focus any color view; the boundlessly concatenable DNA’s ACGT bases are able to code any protein.

Action autonomy — or better, determinability to account for the ability to self and ab alio guiding processes such as training, empathy, imitation, learning — is an essential property of higher level life forms to explore spaces of new possibilities. This corresponds to an open-ended type of capacitating finalism. In addition, superior levels organize lower level structures to optimize skill autonomy. Examples of pre-wired determinable potencies are the initial tabula rasa, omnia fieri or equipotentiality of cognitive and operative potencies, plasticity, motility, adaptability, versatility.

V. Conclusions

Philosophy putatively answers the finalistic question of why, whereas science deals basically with the how, linked to material and efficient causes. Some thinkers may exaggerate this division between science and philosophy. The distinction must lead to a harmony rather than a rigid separation. In fact, many key philosophical concepts, such as final cause, or at least their methodological abstraction, are advantageous to science.

Although the main purpose of this article was to analyse active finalisms in nature, their link to external finalisms was examined in Thomism, Kantism and Process philosophy, as well as in Darwin’s doubts. The philosophy of nature wavers between finalism and chance, vitalism and mechanism, design and spontaneity. An analysis of finalism expresses the special status of biology at the center of the debate on the triple origin of material universe, life and man.

Evolutionary biology cannot be considered separately without seeking rational compatibility with other levels of knowledge. Darwinism offers only a partial explanation of the evolutionary movement. Natural selection tends to free species from its own constraints, towards self-transcendence and self-determinability. This finalistic tendency to self-control takes advantage of chance, environment, lower levels and passivity of substances to progressively optimize the autonomy and plasticity of living forms. Accordingly, natural selection seems to prepare a higher level, truly free and intelligent: the human threshold which makes room for the most proficient reign of cultural and technological control as well as for artificial selection.
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