

Kinds of Pluralism: Stephen J. Gould and the Future of Evolutionary Theory

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Abstract Stephen J. Gould’s living legacy is a scientific and epistemological one, much beyond his talent as science writer and communicator in evolutionary topics. In the XX century Gould has been one of the most important evolutionary biologists proposing a new logical and theoretical “structure” for the whole theory of evolution, not just a description of disjointed innovative emerging fields. He named this structure “Darwinian pluralism” or extended Darwinism. Ten years after his death and after a lot of impressing new discoveries in many evolutionary fields, we discuss the efficacy and limits of his pluralism, also in comparison with other kinds of pluralistic approaches to the units, the levels and the factors of evolutionary change. Adopting the methodology of “scientific research programmes”, we present Gould’s legacy as a peculiar expression of reformist Neo-Darwinism: polemic targets are referred to the so called “hardenings” of the Modern Synthesis, whereas the assumptions of compatibility are referred to the core of the original Darwinian theory.

1 Introduction

Evolutionary biology is a rapidly evolving subject. At an accelerated pace, we are confronting uproarious advances in several fields like genomics (see for example “Encode” programme about the non-coding sequences of DNA, or recent discoveries about RNA machinery), lateral gene transfer, symbiosis, epigenetics, evolutionary developmental biology, new comparative studies, macroevolutionary patterns such as mass-extinctions, and so on. These wide and diversified domains of research have both experimental and theoretical impacts: they both enlarge

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additively the empirical basis of the theory of evolution in unpredictable ways and redefine concepts and terms. Ranging from ecology to molecular biology, they change evolutionary biology at different levels of analysis, from global ecosystems to the biochemistry of life. It is unlikely that all these progresses will not have an impact on the structure of evolutionary theory itself, which is not the same as decades ago.

The revision and extension of evolutionary theory was one of the main interests of Stephen J. Gould (hereafter: SJG), and for many reasons the core of his intellectual legacy. As first thesis of this paper, in terms of theoretical biology, we will point out that SJG did not have an additive and purely descriptive conception of these advances. In order to build a somehow “Extended Evolutionary Synthesis”, he thought that it was not enough to enucleate the more innovative emerging fields (like the conjunction of phylogeny and embryogenesis foretold by him very early in 1977 with *Ontogeny and Phylogeny* 1977a) and sum up the updating lines as a list of disconnected topics. In the XX century SJG was one of the most important evolutionary biologists proposing a new logical and theoretical “structure” for the whole theory of evolution. He named this structure “Darwinian pluralism” or extended Darwinism. Up to now, there are few other attempts with a similar ambitious scope. Thus, ten years after his death and after a lot of further impressing discoveries, it could be interesting to discuss the efficacy and limits of his pluralism.

A collateral question is steadily emerging, not so crucial in a scientific sense but very overexposed in mass media: is this new structure still Darwinian or “Neo-Darwinian”? (in an extended meaning of the latter term, as redefinition in modern scientific language of the core of Modern Synthesis). The answer to this question (our second thesis here: SJG as a peculiar expression of reformist Neo-Darwinism) leads to a contentious theme for the future. Are these extensions so huge and radical that there is no more a “theory of evolution”, but just a collection of mechanisms and data searching for coherence? Or is a new structured theory emerging? In order to reach a consensus about that, maybe the narrow term “theory” should be replaced by the more articulated epistemological tool proposed by Imre Lakatos for other disciplines: evolutionary biology today has something more than a theory, it has a “research programme” (Lakatos 1978; Pievani 2012a).

Is this research programme progressive (outwards empirically successful and inwards theoretically consistent) or regressive (accumulating anomalies)? Has SJG well interpreted the extensions and revisions needed? Focusing on his idea of “hierarchy” of selection units, we could surprisingly discover that SJG was for some aspects conservative, and that other kinds of pluralism could be even more far reaching. SJG’s pluralism should be intended as an agenda for future extensions and revisions of the evolutionary research programme: in many cases his predictions have been confirmed (an outstanding example: in paleo-anthropology) whereas in other cases they failed. Anyway, it should be acknowledged that SJG’s living legacy is a scientific and epistemological one, much beyond his talent as science writer and communicator in evolutionary topics.

2 Stephen J. Gould's Pluralism

The heritage of such a polymorphic and productive scientist needs to be studied with careful methodological principles, in order to correctly analyze his vast production. SJG is known for his political and sociological thought (Prindle 2009), his style of communication and writing (Selzer 1993), his famous public controversies and intellectual provocations (Sterelny 2001), his role as a historian and philosopher of science, his ability to write remarkable works on the history of science based on primary sources. Thus, his influence was in many cases indirect. Let us take the case of human evolution (discussed in: Pievani 2012b). As an invertebrate paleontologist and evolutionary theorist, SJG did not publish any direct experimental results in palaeo-anthropology (with the exception of Pilbeam and Gould 1974), but was able to prepare the stage for many debates within the discipline, frequently concerning some implicit, powerful but misleading concepts applied to human evolution.

As for strictly technical contributions in formal palaeo-anthropological literature, Michael Shermer quantified 13 publications in the huge amount of SJG's technical papers (479) (Shermer 2002). The role of SJG's ideas in paleo-anthropology is an example of indirect, successful theoretical influence between a general scientific "research programme"—that is evolutionary thought at large—and one of its strikingly changing sub-fields, the study of human evolution (see also Tattersall 2013). Though indirectly, SJG was able to anticipate some meaningful scientific predictions, i.e. the branching richness of the "bushy tree" of hominin phylogeny or the role of neoteny in *Homo sapiens* evolution (Gould 1980, 1989). A similar case could be sketched out about the mass-extinctions debate and SJG's contribution to the revival of scientific "Neo-catastrophism" (Gould 1985; Benton 2003).

The scientific and epistemological production of this eminent Harvard evolutionist was very heterogeneous as well. The proposal of an extended and revised Darwinism was outlined mainly in the last twenty years of his life (1982–2002) and depicted in his monumental work, *The Structure of Evolutionary Theory* (2002a). In order to detail the structure of his extended theory of evolution we need to consider the two collective books dedicated to him after his death: Vrba and Eldredge (2005) and Allmon et al. (2009). The latter presents the first apparently complete bibliography of Gould's work, compiled by Warren D. Allmon: 814 titles. Furthermore, we have to consider his famous series of three hundred popular essays in *Natural History* magazine, carefully gathered in ten volumes (for an essential compendium: McGarr and Rose 2006).

One of SJG's preferred methods was the extraction of "general themes" of evolutionary thinking from idiosyncratic stories, seemingly insignificant details and marginal actors of the history of science (Gould 2002b). Surveying his writings, we could use the same criterion for an evaluation of the whole structure of his lifelong work, which includes 22 books (with the two most technical at the very beginning, *Ontogeny and Phylogeny*, 1977a and at the end, *The Structure of*

Evolutionary Theory 2002a), 479 scientific papers, 300 essays in the *Natural History* magazine, and dozens of other articles and reviews.

Organizing the huge material by conceptual themes, we propose to divide SJG's pluralism in three main fields, each one with a main topic, sub-fields, and more general philosophical consequences (see Table 1). Each domain has also its specific polemic targets, because SJG always followed one of his preferred Darwin's epistemological quotations. In a letter to Henry Fawcett two years after the publication of the *Origin*, the great naturalist, counterbalancing his typical inductivism as a methodological background, wrote: "All observation must be for or against some view if it is to be of any service" (Darwin to H. Fawcett, 18 September 1861; see www.darwinproject.ac.uk). In Imre Lakatos' modern terminology, any scientific research programme must be evaluated in comparison with at least one other rival programme (Lakatos and Musgrave 1974). SJG loved what Gerald Holton defined antagonistic themata or "thematic pairs" in science: gradualism/punctuatedism; holism/reductionism; time's arrow/time's cycle; adaptationism/non-adaptationism; contingency/necessity; theory/data (Sulloway 1987).

But each domain has also assumptions of compatibility, because SJG's overall proposal is a kind of inclusive pluralism with respect to the Neo-Darwinian tradition of research. As we shall see, polemic targets and thematic pairs are referred to the so called "hardenings" of the Modern Synthesis, whereas the assumptions of compatibility are referred to the core of the Darwinian theory. In those thematic pairs, as SJG's favourite conclusion claims, not everything can be explained by just one horn of the dilemma.

The structure of SJG's pluralism is seen here in a synoptic way (see Table 1). He wrote 136 peer-reviewed papers about evolutionary theory, 64 about natural history (zoology, biology and environment) and 115 about paleontology and paleobiology (including Punctuated Equilibria, paleo-anthropology and geology). An analogous blending of themes emerges from statistics applied to his 300 essays in *Natural History* (the first one, in January 1974, was about "Size and Shape") (Shermer 2002). The same impression of integration arises from a diachronic sketch of the whole scientific production of the Harvard paleontologist (see scheme 1 in Pievani 2012b, pp. 2–3): with the early technical studies about allometry, shape and size in West Indian land snails (since Gould 1966), the strongly debated Punctuated Equilibria initial paper (Eldredge and Gould 1972), and the first essays against genetic extrapolationism and biological determinism (Gould 1977b). This scheme aims at putting SJG's work in a larger and consistent context, which stresses the global integration of his theoretical heritage. His writings are neither a collection of separated topics, nor a list of weird evolutionary stories. They have a visible frame, a pluralistic research programme. The same property has been highlighted by Michael Shermer in the interconnections of subjects throughout the broader SJG's interests in history of science, science studies, philosophy of science and evolutionary researches (Shermer 2002).

Table 1 Sketch of SIG's pluralistic and extended Darwinism (for the numbers of publications by categories: Shermer 2002)

| SIG's Pluralism (A + B + C) | Main topics | Sub-fields | Greater philosophical consequences | Polemical targets | Assumptions of compatibility |
|---|--|--|---|---|--|
| A—Plurality of rhythms of speciation and rates of evolution | <p>Punctuated Equilibria (three patterns: stasis, allopatric and geographic speciation, evolutionary trend; see Eldredge, 2013)</p> <p>15 papers on the subject (+5 popular essays)</p> | <p>(1) Biological definition of "species" as an ontological discrete entity</p> <p>(2) "Punctational" phylogenetic trees</p> <p>(3) Differential mutational rates</p> <p>(4) Mass-extinctions as independent macro-evolutionary pattern</p> <p>(5) Experimentation—standardization model (Burgess Shale case)</p> <p>(6) Role of the ecological opportunities</p> | <p>Evolution as an irreversible process of exploration of possibilities</p> <p>The role of chance in evolution</p> <p>"Punctational" extended thinking (in SIG, not the same in Eldredge)</p> | <p>Phyletic gradualism (44 essays)</p> <p>Uniformitarianism</p> <p>Progressionism</p> | <p>Slow processes of speciation not excluded (debate about their relative frequency in natural history)</p> <p>Gradualistic patterns (and trends) in natural history not excluded (but explained at a higher level of biological organization as differential survival of species)</p> |
| | | | | | |
| B—Plurality of units of selection | <p>(1) Species as units of evolutionary change</p> <p>(2) Hierarchy of levels between micro-evolution and macroevolution: each level with emerging properties due to the organization of the parts</p> <p>(3) Between hierarchical levels, interactions bottom-up (standard) and top-down (inaccurately defined in SIG)</p> <p>(4) Slippery concepts of biological "individuality" (community in nature) (see Minelli 2013)</p> <p>(5) Genome itself as a hierarchical system</p> <p>(6) Possibility of selective processes at the gene level</p> <p>(7) Group selection;</p> <p>(8) Species selection and "species sorting"</p> | <p>(1) Species as units of evolutionary change</p> <p>(2) Hierarchy of levels between micro-evolution and macroevolution: each level with emerging properties due to the organization of the parts</p> <p>(3) Between hierarchical levels, interactions bottom-up (standard) and top-down (inaccurately defined in SIG)</p> <p>(4) Slippery concepts of biological "individuality" (community in nature) (see Minelli 2013)</p> <p>(5) Genome itself as a hierarchical system</p> <p>(6) Possibility of selective processes at the gene level</p> <p>(7) Group selection;</p> <p>(8) Species selection and "species sorting"</p> | <p>Macroevolution cannot be linearly extrapolated by microevolution as an accumulation of effects at lower levels</p> <p>Emerging patterns at higher levels</p> | <p>Extrapolationism</p> <p>Genetic determinism</p> | <p>Standard natural selection acting on organisms still crucial.</p> <p>Selective processes, at any level, not excluded</p> |

(continued)

Table 1 (continued)

| SI/G's Pluralism (A + B + C) | Main topics | Sub-fields | Greater philosophical consequences | Polemical targets | Assumptions of compatibility |
|--|--|--|--|---|--|
| C—Plurality of factors and processes able to produce fitness | <p>Exaptation (functional cooption from previous adaptation)</p> <p>and spandrels (non adaptive traits and functional cooption from non-adaptations)</p> <p>(the two concepts are different)</p> | <p>(1) Biased variation</p> <p>(2) Constraints and limits of natural selection</p> <p>(3) Interplays between functions and structures, internal factors and external factors</p> <p>(4) Structural changes, allometric constraints and forms in evolution</p> <p>(5) Organisms as integrated units</p> <p>(6) Positive causal role of constraints (developmental, physical)</p> <p>(7) Multiple sources of variation and innovation (genetic, epigenetic, developmental)</p> <p>(8) Adaptation as a constrained, sub-optimal solution for a selective pressure</p> <p>(9) Phylogenetic ancestry does not mean primitive adaptations</p> <p>(10) The role of plasticity (at different levels) in biological evolution</p> | <p>Join together the structuralist and the functionalist traditions in biological thought (76 essays)</p> <p>Disaggregate historical origin and current utility</p> <p>Time's arrow and time's cycle (80 essays and a book, from 1965 to 1987)</p> | <p>Biological atomism</p> <p>Pan-selectionism</p> <p>Strong adaptationism</p> <p>Strict functionalism</p> | <p>Standard adaptations by natural selection still included: exaptations, spandrels)</p> |

3 His Way to Be a Darwinian

Summing up the three great domains of his pluralism, we understand SJG's apical view of the "nature of history" (Sulloway 1987). Evolution is an irreversible process, with its specific historical patterns. As SJG repeated, history matters (Gould 1987) and after Darwin natural history has acquired a scientific status for the first time. Here we appreciate the everlasting dialectic that SJG engaged with the founding father of the theory of evolution by natural selection. It was a scientific, historical and epistemological man-to-man fight, with strong attractions and repulsions. Darwin has been for SJG at the same time a crutch and a straw-man: a crutch because very skillfully he stressed the contradictions, the ambiguities and the theoretical flexibilities of the English naturalist in order to set them against the hardenings of the later Modern Synthesis (playing the game of who is more Darwinian than Darwin); a straw-man because he underlined, sometimes compulsorily, the supposed mistakes of Darwin as a gradualist and progressionist, in opposition to the radical reformation he had in mind after the Punctuated Equilibria paper.

As a matter of fact, despite Darwin's wedge of progress and liberalist economy of nature (two preferred polemic and "political" targets of SJG), they were two authentic pluralists. The main debt of SJG to Darwin is the idea of natural history as a domain of "laws" (lawlike patterns, regularities) interlaced with the domain of chance (irreversibility): uniqueness of history and repeatability of nature's patterns. Here is the grandeur of Darwin's view of life, and the key to understanding the central concept of contingency in SJG (Gould 1989, 1991, 1993; Pievani 2009). It does not mean that evolution occurred merely "by chance", but through an entanglement of functional factors (produced by selective pressures), structural constraints, and historical contingent events: an interplay between random events and regularities (Gould 2002a). The massive contingency of history means that particular events, or apparently meaningless details, were able to shape irreversibly the course of natural phenomena. We could define contingency (36 popular dedicated essays, but a theme quite everywhere present both in books and in the 136 peer-reviewed papers devoted to evolutionary theory) as the more general philosophical consequence of SJG's pluralism (A + B + C).

In this ambitious proposal of SJG as a philosopher of history, in a dialectic position with the founder, we recognize that each domain of his pluralism shows points of continuity and points of rupture with the Darwinian tradition:

- points of continuity are: in A, the role of geographic isolation, the Neo-Darwinian forces acting during speciation, the different levels of analysis with micro-evolutionary gradualism compatible with punctuations at the paleontological scale; in B, standard natural selection acting on organisms as a central mechanism being part of a hierarchical multilevel process, selection between tribes and families tolerated by Darwin in special cases; in C, both standard adaptations and functional shifts already discussed by Darwin;

- breaking points are: in A, no all-powerful phyletic gradualism, no progressionism, biological concept of species, neo-catastrophism; in B, no extrapolationism from lower levels (theory of microevolution), top-down interactions, species selection; in C, no prevailing functionalism as in Darwin, spandrels.

The global sense of SJG's peculiar operation on the Darwinian tradition has been the construction of a "third-generation" Darwinism, which (1) contains the nucleus of Darwin's theory (common descent, tree thinking, variation, inheritance, selective processes), (2) enlarges it in a plurality of rhythms, levels and factors, (3) cleans it from unnecessary hardenings of the late "dogmatic" Modern Synthesis (phyletic gradualism, extrapolationism, adaptationism). Considering in addition the growing historical awareness of the original Darwin's pluralism (about the three lines above: rhythms, levels and factors), even underestimated by SJG, we can agree with the very clear and somehow surprising statement of Niles Eldredge 2013

And, I must also say, in an evolutionary context, Steve was as much of an adaptationist as the next person. I know it sounds strange to say so, given his reputation as a critic of hyperadaptationism—and his search for alternative explanations for morphological change in evolution (as witness his enthusiasm for Elisabeth Vrba's concept of "exaptation"—published as Gould and Vrba 1982—though the initial idea had been developed by Vrba). All that is true—but at heart he was a neo-Darwinian always. As am I—and so are we all.

4 Hierarchies and Levels of Selection

But Niles Eldredge stresses also another synthetic point: "Steve, at heart, was first and always a morphologist and developmentalist" (Eldredge 2013). In other words, strongly focused on internal constraints, developmental processes, complex forms: an internalist view of evolution (the third domain of his pluralism, C in Table 1, maybe the most relevant). We have seen above that points of rupture and points of continuity (with respect to the Darwinian theory) are consistent with each other because of the different scaling of evolutionary causality, a crucial issue for SJG. Nevertheless, as Niles Eldredge points out in his contribution in this volume (2013), the novelty of Punctuated Equilibria was not only related to the rates of speciation (the axis of time in representing evolution), a matter given undue weight in debates, with confusion between Punctuated Equilibria and versions of "saltationism" (Dennett 1995). The novelty was mainly related to the ecological, biogeographical and macroevolutionary conditions surrounding speciation processes (the axis of space in representing evolution: Vrba and Eldredge 1984; Eldredge 1989), like climate instability, geophysical disruptions, ecological barriers, fragmentation of habitats, and their consequences (turnover pulses, habitat tracking, mass or regional extinctions). Then, not only the "tempo" but also and mostly the "mode" of evolution.

It is interesting that about the “mode” of evolution (ecology, geography, and so on) a difference of sensitivity emerged in early times between SJG and Eldredge. As an extension of Punctuated Equilibria, in SJG, genomes, organisms and groups (even species for some characters like the degree of internal genetic variability) are different, inherently hierarchical levels of evolving “Darwinian units”: autonomous and integrated levels of the organization of life. In Lloyd and Gould (1993), species selection on “variability” (intended as a good species-level trait associated with genuine species-level fitness) was depicted as a major force of macroevolution (see also Gould and Lloyd 1999).

The fact that SJG intended hierarchical levels merely as sets of Darwinian units is relevant. Defining the levels of selection as units of interaction, rather than units of inheritance (see also Minelli 2013), SJG showed his mainly antagonistic way to interpret the “multilevel selection” debate (which is related but theoretically non coincident with the problem of the evolution of the hierarchical structure of the living world). He had steadily in mind the intellectual fight against Richard Dawkins and his gene-centered reductionism, so he thought to simply broaden the concept of replication. The result is a hierarchy with standard organism-like units (groups, species, super-organisms), intended as interactors, with the risks related to a strongly discontinuous concept of macroevolution as independent theoretical domain. Differently, in Eldredge the “hierarchy approach” is a more externalist extension of the mode of speciation inherent in Punctuated Equilibria, with a double genealogical (time) and ecological (space) logic (Eldredge 1999). The two parallel hierarchies in Eldredge are not a prosecution of Dawkins’ replicator/interactor scheme, because they are two causally inter-dependent levels of evolutionary change. On the contrary, in Dawkins interactors are mere vehicles for replicators and the replicative logic is the fundamental one.

The refusal of the double hierarchy of his friend and colleague is based, in SJG (2002a, p. 642), on two misleading arguments: useless complexity and overlapping (see also Minelli 2013). In Eldredge’s “sloshing bucket” model (2008), the nested evolutionary individualities are defined as kinds of biological organization, from the point of view of genetic transmission (genealogical or evolutionary hierarchy) and from the point of view of exchanges of matter and energy (ecological or economical hierarchy). Thus the groups of organisms inside a species, at the same population level above organisms, could be organized in two different ways. It is not essential that replication is a necessary and sufficient criterion for individuality, because the two hierarchies are not independent, but interdependent. In Eldredge’s model no faithful inheritance is required and the levels are wider units of evolutionary change (ecological and genealogical). In this case SJG’s criticism is linked to a rigid way to see hierarchy in an exclusively selective way (*contra* Dawkins), trying to define what exactly should be an “individual” (where species become “individuals” as well).

Hence all the problems related to “species selection” (and to strong versions of “group selection”) arose as well. “Interactors with adequate modes of plurification” (Gould 2002a, p. 642) is a quite vague definition, with serious difficulties at higher levels of the hierarchy. Moreover, “selection” is a very demanding causal

concept and it is not enough to have somehow a discrete individuality for representing a unit of selection: without species-traits, competition, differential survival and inheritance of some kind no natural selection occurs. In Eldredge's (2008) model, standard natural selection between organisms is the hinge of the scheme, the locus where ecological logic and genealogical logic melt and coincide at the organismal level. No other metaphysical and unsteady definitions of "emergent properties" are needed to see standard natural selection as causation everywhere compulsorily. Instead, considering a stronger continuity between levels, we could observe "multilevel selection" processes depending on the different interactions (ecological and genealogical) below or above organisms: for example, phenomena of species sorting; phenomena of group selection depending on social organization and population structure; changes of the units of evolutionary change; trade-offs between selective forces, random events and structural changes; interplays between biological and cultural evolution. This kind of pluralistic explanation fits very well with a lot of contemporary integrated field researches, in which molecular biology, paleontology, ecology, paleo-climatology, demography, population structures, and other points of views at different levels (ecological and genealogical) make evidences and patterns to converge in shaping an evolutionary scenario, for instance in palaeo-anthropology (Jacobs and Roberts 2009; Pievani 2012c).

In this case we have different confronting kinds of pluralism (selective hierarchy of interactors *vs* ecological-genealogical hierarchy), that could be surpassed by new evidence and even appear as oversimplifications in the future. More generally, not only about the units of selection debate, adopting a "parliamentary metaphor" we envisage three possible positions about the future of the Neo-Darwinian research programme:

- (a) *Conservatives*. Extensions are sufficient and they are already incorporated in the Modern Synthesis (like neutralism and near-neutralism), so the programme needs just superficial restyling case by case.
- (b) *Revolutionaries*. Extensions are insufficient and the programme is going to become regressive, because it accumulates more and more serious and fatal anomalies. A rival research programme, no longer Darwinian, will replace the present one.
- (c) *Reformists*. Extensions are insufficient, but they could be incorporated in a revised research programme, still Darwinian in its core but re-established both experimentally and theoretically, or in multiple theories with specific mechanisms and *explananda*.

As a matter of fact, it seems that the consensus of the many involved in theoretical issues of evolutionary biology is concentrated at present in the third position (see also Müller 2013). SJG proposed a "new synthesis", a new version of Darwinism, as an expression of the reformist claims. He envisaged neither an alternative "paradigm" (despite his attraction for Thomas Kuhn's "punctuational" way to see the history of science, SJG used this term for his opponents, for example labeling the "adaptationist paradigm"), nor a rival research programme.

He tried to trace the lines for updating the existing one (Pievani 2012a). Then it is inaccurate to say that SJG has been a “failed revolutionary” (Dennett 1995). As a reformist, he was radical in some points and quite moderate in others. Provident or not has he been in this enterprise, he understood that it is not enough to say that a research programme (the Modern Synthesis) is in the middle of a crisis (regressive), and that recent advances are deeply innovative. He proposed a frame for the future evolutionary research programme to be “progressive” (in Lakatos’ terminology), and any proponent of “extended” new syntheses should acknowledge it.

5 Discussion: How Much Extended the “Synthesis”?

As main focus of his heritage, SJG was not a science communicator, but an evolutionary biologist skillfully using history and philosophy of science for an ambitious proposal of revision and extension of the structure of evolutionary theory. He was not an anti-Darwinian (i.e. saltationist) or a post-Darwinian. He was historically aware in his scientific challenges, defending the autonomy of paleontology, the role of natural sciences and the morphologist and developmentalist traditions of research.

SJG’s pluralism (A + B + C) is an “adaptive radiation” of possible directions of change in contemporary evolutionary research programme. In other words, an agenda for future research. In these first ten years without SJG, his proposals and provocations suffered a differential survival. Probably SJG was partly wrong about the non-functional role of non-coding DNA, claiming for a vague role of “biological redundancy” and flexibility. His analysis of the Burgess Shale general dynamics has been questioned (Collins 2009). Species selection is very seldom considered in current literature. Even some historical interpretations in his anthropological essays have been criticized (Lewis et al. 2011; see also Tattersall 2013).

On the contrary, if we focus on the main topics of A + B + C, according to Pagel et al. (2006), Punctuated Equilibria are far from being “a tempest in a teapot”, as Richard Dawkins imprudently asserted. Their relative frequency, as one of the patterns of speciation, is substantial (for a reconstruction of the debate: Sepkoski 2012). Group selection, whatever its frequency or rarity in natural history, seems a real pattern, empirically testable (Goodnight and Stevens 1997; Nowak 2006; Wilson 2012). From a theoretical point of view, we have by now in the literature several proposals of multilevel or hierarchical selection theories, even if each author has a different version (Okasha 2006). About the present uses of three crucial SJG’s concepts—such as heterochrony, developmental constraints and constructional non adaptive byproducts—as powerful theoretical frameworks see Müller (2013). Exaptations received growing quotations as mechanisms of change, not only in strictly biological fields (Pievani 2003, 2011; Pievani and Serrelli 2011).

Discussions are open about the empirical importance and relative frequencies of these patterns, but around the basic issues of SJG's overall proposal a pluralistic consensus seems to be gaining ground (Lewontin 2008). The future will say if this extension of the theory is becoming too large and frayed, and requires a more fundamental reduction to few principles. A first account of these ten years of new researches after SJG's death gives apparently two preliminary results:

- (1) The amount of new discoveries with relevant evolutionary consequences (gene regulatory evolution, plasticity, epigenetics, niche construction, evolvability, and so on) went much beyond SJG's pluralistic expectations, making the "conservative" attitudes more and more anachronistic.
- (2) In front of "revolutionary" temptations (the dawn of a new theory of evolution is coming), the reformists split between those who think that we need a succession of extended "special theories" with delimited *explananda* and mechanisms (see Müller 2013) and those who think that we need a third-generation "general theory" of evolution still Neo-Darwinian (after the original Darwinian one and the Modern Synthesis, like the "pluralist Darwinism" outlined by SJG). The former has the problem to figure out the theoretical and methodological relationships between the extended "special theories" and the supposedly basic "general theory". The latter has the problem to explain how the tumultuous empirical updates could be incorporated in a still coherent and unitary structure able to cover all kinds of evolutionary phenomena.

According to the methodology of scientific research programmes (Lakatos 1978), the "general theory" could be represented as an extended core of the programme (still Neo-Darwinian and corroborated) and the "special theories" as provisional extensions of the protective belt, subject to falsification. What is inside the core and outside the core depends on the relative empirical frequencies of the explanatory patterns (for an example of a very high frequency pattern: genetic drift), according to the current scientific literature. The internal theoretical coherence (in the core) and the increase of explanatory effectiveness and predictive power (in the belt) are two criteria to judge the scientific programme as "progressive" or "regressive", also with respect to possible rival research programmes.

Despite his stressing on cultural biases in science, "empiricist myths" and theory-data complex relationships (143 essays), SJG was not a sociological relativist, and never abandoned his scientific rationalism and even objectivist realism (Gould 2002a, p. 969). Thus, about the future of the structure of evolutionary theory, we could imagine that he would suggest to search for further empirical evidence in order to receive new, often unpredictable, answers from nature. In a Gouldian view: let us give the final word to the history of science, through a passionate and hopefully fair contest between pluralists and non pluralists.

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