DRAFT BOOKLET

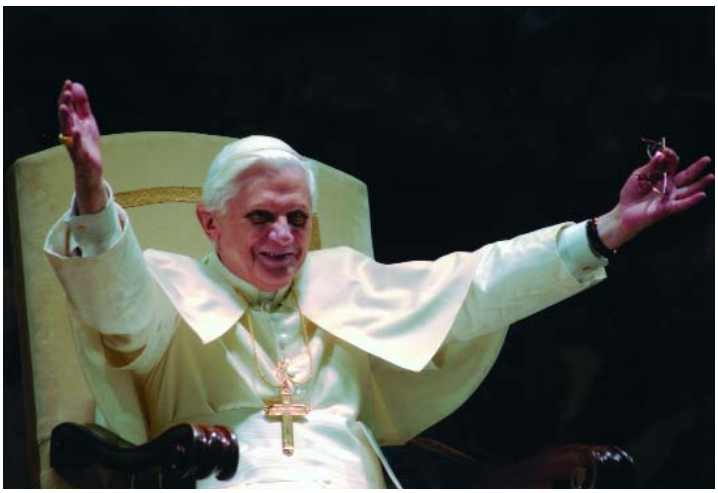
THE PONTIFICAL ACADEMY OF SCIENCES

Plenary Session on

SCIENTIFIC INSIGHTS INTO THE EVOLUTION OF THE UNIVERSE AND OF LIFE

31 October-4 November 2008

VATICAN CITY 2008



But the big problem is that were God not to exist and were he not also the Creator of my life, life would actually be a mere cog in evolution, nothing more; it would have no meaning in itself. Instead, I must seek to give meaning to this component of being. Currently, I see in Germany, but also in the United States, a somewhat fierce debate raging between so-called "creationism" and evolutionism, presented as though they were mutually exclusive alternatives: those who believe in the Creator would not be able to conceive of evolution, and those who instead support evolution would have to exclude God. This antithesis is absurd because, on the one hand, there are so many scientific proofs in favour of evolution which appears to be a reality we can see and which enriches our knowledge of life and being as such. But on the other, the doctrine of evolution does not answer every query, especially the great philosophical question: where does everything come from? And how did everything start which ultimately led to man? I believe this is of the utmost importance. This is what I wanted to say in my lecture at Regensburg: that reason should be more open, that it should indeed perceive these facts but also realize that they are not enough to explain all of reality. They are insufficient. Our reason is broader and can also see that our reason is not basically something irrational, a product of irrationality, but that reason, creative reason, precedes everything and we are truly the reflection of creative reason. We were thought of and desired; thus, there is an idea that preceded me, a feeling that preceded me, that I must discover, that I must follow, because it will at last give meaning to my life. This seems to me to be the first point: to discover that my being is truly reasonable, it was thought of, it has meaning. And my important mission is to discover this meaning, to live it and thereby contribute a new element to the great cosmic harmony conceived of by the Creator.

(Meeting of the Holy Father Benedict XVI with the Clergy of the Dioceses of Belluno-Feltre and Treviso, Church of St Justin Martyr, Auronzo di Cadore, Tuesday, 24 July 2007).

INTRODUCTION

Scientific Insights into the Evolution of the Universe and of Life

WERNER ARBER & NICOLA CABIBBO

Research into the origins and evolution of the universe, of matter and of life belongs to the focal topics of the natural sciences. The Pontifical Academy of Sciences has repeatedly paid attention to these questions both in plenary sessions and in specialised meetings. In recent years relevant basic scientific knowledge has been considerably enriched, in particular by the introduction of novel and powerful research strategies. Cosmic investigations can reach ever greater distances, while particle physics and the nanosciences allow scientists to explore structures of ever smaller dimensions. The results of these largely interdisciplinary studies considerably enrich our knowledge about natural reality and they also raise new questions. These concern, for example, a postulated multiverse or dark matter and, more generally, cosmic evolution. In the life sciences more precise structural knowledge on genetic information and on gene products provides insights not only into functional characteristics but also into molecular mechanisms that contribute to the occasional generation of genetic variants – the drivers of biological evolution.

By definition, evolution implies a changing reality. This is what the sciences have postulated as holding both for the inanimate cosmos and for the living world. Ever more powerful research strategies continue to strengthen the validity of these postulates.

The Council of the Pontifical Academy invites the Academicians to present in the forthcoming Plenary Session any scientific contributions that may validate or falsify evolutionary theories and can provide a deeper insight into the evolutionary processes of the living and of the non-living world. This might allow our Academy to update its own knowledge basis and to transmit this knowledge to human society for an actualisation of its science-based worldview. Scientific knowledge forms – in addition to traditional wisdom, religious beliefs and educational values – an essential part of the orientating knowledge that serves us for taking individual and socio-political decisions.

In these scientific debates the Council of the Academy proposes to focus more on the evolutionary process as such than on the postulated origins of things which, however, shall also be discussed. It is our intention to strengthen our knowledge on the dynamics of evolution in its historical dimensions and also to provide prospective views on upcoming developments into the far future. Contributions on the specific impact that human activities may have on evolutionary processes will also be welcome. The Council also expects to be able to draw from the Plenary Session conclusions that are of relevance to the subject of the creation of something out of nothing and the various forms – of an evolutionary kind as well – in which this participation in being, caused by the Being in essence, is realised. Indeed, for Thomas Aquinas, expressing a philosophical perspective, everything that is by participation is (or is caused) by the Being in essence. Thus not even the evolutionary processes of the universe and life can be excluded from emanation from the universal principle of being.

Wissenschaftliche Einsichten in die Evolution des Universums und des Lebens

EINFÜHRUNG

WERNER ARBER & NICOLA CABIBBO

Die Forschung nach dem Ursprung und der Evolution des Universums, der Materie und des Lebens gehören zu den Hauptthemen der Naturwissenschaften. Die Päpstliche Akademie der Wissenschaften hat des öfteren, bei Plenarsitzungen und bei spezifischen Tagungen diesen Themen Aufmerksamkeit gewidmet. In den letzten Jahren ist es zu einer Erweiterung des entsprechenden grundlegenden wissenschaftlichen Wissens gekommen, vor allem durch die Einführung von neuen und effizienten Untersuchungsstrategien. Die Weltenforschung ist imstande, immer größere Entfernungen zu überwinden, während die Teilchenphysik und die Nanowissenschaften es den Wissenschaftlern ermöglichen, Strukturen von immer kleineren Dimensionen zu erforschen. Durch die Ergebnisse dieser vornehmlich interdisziplinären Studien nimmt unsere Erkenntnis über die natürliche Realität beträchtlich zu, und dabei tauchen auch neue Fragen auf. Diese betreffen zum Beispiel ein postuliertes Multiversum oder dunkle Materie und allgemein die Evolution des Kosmos. In den Lebenswissenschaften gibt eine genauere Kenntnis über die Struktur der genetischen Information und der Genprodukte Einblick nicht nur in funktionelle Charakteristiken, sondern auch in molekulare Mechanismen, die zur gelegentlichen Bildung von genetischen Varianten – der Triebkraft der biologischen Evolution – beitragen.

Die Evolution impliziert per definitionem eine sich verändernde Wirklichkeit. Das haben die Wissenschaften sowohl für den unbelebten Kosmos als auch für die lebendige Welt postuliert. Immer effizientere Forschungsstrategien bestätigen die Gültigkeit dieser Postulate.

Der Vorstand der Päpstlichen Akademie der Wissenschaften ladet die Akademiker dazu ein, in der bevorstehenden Plenarsitzung wissenschaftliche Beiträge vorzustellen, durch die Evolutionstheorien verifiziert oder falsifiziert werden können und die einen tieferen Einblick in den Evolutionsprozess der lebendigen und der leblosen Welt vermitteln können. Dies ermöglicht unserer Akademie, ihr eigenes grundlegendes Wissen zu ergänzen und dieses Wissen der menschlichen Gesellschaft zu vermitteln für eine Aktualisierung ihrer auf Wissenschaft beruhenden Weltanschauung. Wissenschaftliche Kenntnisse bilden – zusammen mit traditioneller Weisheit, religiösem Glauben und erzieherischen Werten – einen grundlegenden Teil des Orientierungswissens, das uns bei individuellen und sozialpolitischen Entscheidungen dient.

Der Vorstand der Akademie schlägt vor, dass sich die wissenschaftlichen Debatten mehr auf den Evolutionsprozess als solchen konzentrieren sollten als auf den postulierten Ursprung der Dinge, der aber ebenfalls diskutiert werden soll. Wir beabsichtigen, unser Wissen über die Dynamik der Evolution in ihren geschichtlichen Dimensionen zu erweitern und auch vorausblickende Ansichten über kommende Entwicklungen in die ferne Zukunft beizusteuern. Willkommen sind auch Beiträge, die einen spezifischen Einfluss von menschlichen Aktivitäten auf den Evolutionsprozess behandeln. Der Vorstand erwartet ferner, mittels der Plenarsitzung zu Schlüssen zu gelangen, die bedeutend sind für das Thema der Schöpfung von etwas aus dem Nichts und der unterschiedlichen Formen – auch evolutionärer Art – in denen die Teilhabe am Sein, gründend auf dem Sein in seiner Essenz, verwirklicht ist. In einer philosophischen Sichtweise ausgedrückt, ist für Thomas von Aquin tatsächlich all das, was am Sein teilhat, in seiner Essenz beim Sein (oder davon verursacht). Daher können nicht einmal die Evolutionsprozesse des Universums und des Lebens von der Emanation des universellen Prinzips des Seins ausgeschlossen werden.

INTRODUZIONE

WERNER ARBER & NICOLA CABIBBO

La ricerca sulle origini e sull'evoluzione dell'universo, della materia e della vita è uno degli argomenti chiave delle scienze naturali. La Pontificia Accademia delle Scienze ha spesso rivolto la sua attenzione a tali questioni, sia nelle sue sessioni plenarie che durante gli incontri specializzati. Negli ultimi anni le principali conoscenze scientifiche a riguardo si sono notevolmente arricchite, in particolare con l'avvento di strategie di ricerca innovative e potenti. La ricerca cosmica raggiunge distanze sempre maggiori, mentre la fisica delle particelle e le nanoscienze permettono agli scienziati di esplorare strutture di dimensioni sempre più piccole. I risultati di questi studi, generalmente interdisciplinari, arricchiscono notevolmente il nostro sapere nel campo della realtà naturale e sollevano nuovi interrogativi riguardanti, per esempio, un presunto multiverso, la materia oscura e, più in generale, l'evoluzione cosmica. Nelle scienze naturali, una conoscenza strutturale più precisa delle informazioni genetiche e dei prodotti genici ci fornisce nuovi elementi non solo riguardanti le caratteristiche funzionali ma anche i meccanismi molecolari che contribuiscono alla generazione occasionale di varianti genetiche – il motore dell'evoluzione biologica.

Per definizione, l'evoluzione implica una realtà che cambia. Questo è ciò che le scienze suppongono sia per il cosmo inanimato, sia per il mondo animato. Strategie di ricerca sempre migliori continuano a rafforzare la validità di queste supposizioni.

Il Consiglio della Pontificia Accademia invita gli Accademici a presentare, durante la prossima Sessione Plenaria, un contributo scientifico che possa confermare o, al contrario, confutare le teorie sull'evoluzione e che offra uno sguardo più approfondito sui processi evolutivi del mondo animato e inanimato. In questo modo sarà possibile per la nostra Accademia aggiornare le proprie conoscenze di base e trasmetterle alla società umana, per un aggiornamento di quella visione del mondo che abbia basi scientifiche. Il sapere scientifico costituisce – insieme alla saggezza tradizionale, alla fede religiosa ed ai valori dell'educazione – una parte essenziale delle conoscenze orientative che ci servono a prendere decisioni individuali e sociopolitiche.

In questi dibattiti scientifici il Consiglio dell'Accademia suggerisce di concentrarsi più sul processo evolutivo come tale che sulle origini postulate delle cose che, tuttavia, saranno anche oggetto di discussione. Lo scopo è quello di consolidare le nostre conoscenze sulla dinamica dell'evoluzione nelle sue dimensioni storiche e, inoltre, di fornire possibili opinioni sugli sviluppi sia prossimi che in un lontano futuro. Sono ben accetti anche contributi sull'impatto specifico che le attività umane potrebbero avere sui processi evolutivi. Il Consiglio si auspica, altresì, di poter trarre, dalla Sessione Plenaria, conclusioni che siano rilevanti per quanto riguarda il tema della creazione di qualcosa dal nulla e le varie forme – comprese quelle evolutive – nelle quali questa partecipazione dell'essere, causata dall'Essere per essenza, viene realizzata. Infatti, per San Tommaso d'Aquino, dal punto di vista filosofico, tutto ciò che è per partecipazione è (o è causato) dall'Essere per essenza, perciò non si possono ritenere esclusi dal derivare dal principio universale dell'essere neanche i processi evolutivi dell'universo e della vita.

Thursday, 30 October 2008

13:30	Council Meeting
19:30	Dinner at the Casina Pio IV

Friday, 31 October 2008

WELCOME, COMMEMORATIONS, SELF-PRESENTATIONS AND INTRODUCTION Chair: Prof. Nicola Cabibbo	
9:00	*Welcome* **Prof. Nicola Cabibbo**, President of the Pontifical Academy of Sciences
9:05	*Commemorations* • **Giampietro Puppi** (N. Cabibbo) • **Te-Tzu Chang** (P.H. Raven) • **Kai Siegbahn** (M.G.K. Menon) • **Carlo Enrico di Rovasenda** (G. Cottier) • **Joshua Lederberg** (D. Baltimore)
9:25	*Self-Presentation of New Members* • **Aaron J. Ciechanover** • **José G. Funes** • **Takashi Gojobori** • **Krishnaswamy Kasturirangan** • **Klaus von Klitzing** • **Yuan-Tseh Lee** • **Cesare Pasini** • **Ignacio Rodríguez-Iturbe** • **Govind Swarup** • **Edward Witten**
11:00	Coffee Break
11:30	*The Subject of the Meeting* **Prof. Werner Arber**, Coordinator of the Meeting and PAS Academician
11:45	**H.Em. Cardinal Christoph Schönborn** *The Reflections of Joseph Ratzinger Pope Benedict XVI on Evolution* (provisional title)
12:45	Lunch at the Casina Pio IV
***Session I* INSIGHTS INTO THE EVOLUTION OF THE UNIVERSE Chair: Prof. M. Govind K. Menon**	
15:00	**Prof. Martin J. Rees** (invited) *Universe and Multiverse* (provisional title) Discussion
15:40	**Prof. Govind Swarup** *Scientific Quest into Evolution of Life in the Universe* Discussion
16:20	**Prof. Stephen W. Hawking** *The Origin and Destiny of the Universe* (provisional title) Discussion
17:30	**Prof. Vera Rubin** *What We Know, and What We Do Not Know, About Our Universe* Discussion
17:30	Coffee Break
18:00	**Prof. Antonino Zichichi** *Rigorous Logic in the Theory of Evolution* Discussion
18:40	**Fr. Prof. Michael Heller** *The Early Evolution of the Universe: Problems and Concepts* Discussion

19:10	**Prof. José G. Funes** *Galaxy Evolution* Discussion
19:40	**Prof. Rudolf Muradian** *Understanding the Great Numbers of the Universe* Discussion
20:10	General Discussion
20:30	Dinner at the Casina Pio IV

Saturday, 1 November 2008

	Session II **INSIGHTS INTO THE EVOLUTION OF LIFE** **Chair: Prof. Nicole M. Le Douarin**
9:00	**Prof. Albert Eschenmoser** *The Search for the Chemistry of Life's Origin* Discussion
9:40	**Prof. John Abelson** *The Birth of Oxygen* Discussion
10:20	**Prof. Marshall W. Nirenberg** *The Genetic Code* Discussion
11:00	Coffee Break
11:30	**Prof. David Baltimore** *RNA and Evolution* Discussion
12:10	**Prof. Giorgio Bernardi** *Natural Selection in Evolution* Discussion
12:50	**Prof. Rafael Vicuña** *Bacterial Evolution: Random or Selective?* Discussion
13:20	Lunch at the Casina Pio IV
	Chair: Prof. Wolf J. Singer
15:00	**Prof. Fotis C. Kafatos** *Evolution: What the Insect World Tells Us* (provisional title) Discussion
15:40	**Prof. Werner Arber** *From Microbial Genetics to Molecular Darwinism and Beyond* Discussion
16:20	Coffee Break
	Session III **INSIGHTS INTO HUMAN EVOLUTION**
16:50	**Prof. Luigi L. Cavalli-Sforza** *Human Evolution as a Historical Process, and the Forces that Drive it* Discussion
17:30	**Prof. Takashi Gojobori** *The Evolutionary Origin and Process of the Central Nervous System: Comparative Genomics Approach*

18:10	**Prof. Christian de Duve** *The Facts of Human Life* (provisional title) Discussion
18:50	**Prof. Wolf J. Singer** *The Epigenetic Shaping of Brain Architectures, a Necessary Prerequisite for Cultural Evolution* Discussion
19:30	**Prof. Francis S. Collins** *The Language of God: a Scientist-Believer Looks at the Human Genome* Discussion
20:10	Dinner at the Casina Pio IV

Sunday, 2 November 2008

8:30	Departure from Domus Sanctae Marthae to visit the Papal Villa at Castel Gandolfo
10:00	Holy Mass at Castel Gandolfo
11:00	Presentation of the Pius XI Medal
13:00	Lunch at the Papal Villa
15:00	Departure from Castel Gandolfo and return to the Domus Sanctae Marthae
18:30	Dinner at the Casina Pio IV

Monday, 3 November 2008

Chair: Prof. Werner Arber	
9:00	**Prof. Yves Coppens** *The Bunch of Prehumans and the Emergence of the Genus* Homo Discussion
9:40	**Prof. Fiorenzo Facchini** *Culture in the Hominization and its Implications in an Evolutionary View* Discussion
10:10	Coffee Break
11:30	**Audience with His Holiness Benedict XVI**
13:00	Lunch at the Casina Pio IV
15:00	**Dr. Robert J. White** *Origin of the Human Species (Mind) Requires Divine Intervention* Discussion
15:30	**Prof. Stanislas Dehaene** *Cognition, Consciousness, and Culture: Understanding Human Specificity and Its Grounding in a Primate Brain* Discussion
Session IV **THEOLOGICAL, PHILOSOPHICAL AND SOCIETAL ASPECTS** **Chair: Prof. Nicola Cabibbo**	
16:10	**H.Em. Cardinal Carlo M. Martini** *Evolution: a Biblical Reading* (provisional title) Discussion
16:50	**Fr. Prof. Jean-Michel Maldamé** *Création par évolution* Discussion
17:30	Coffee Break

18:00	**Prof. Ulrich Lüke** *The Human Being – God's Plan or Just a Strange Coincidence?* Discussion
18:40	**Prof. Gereon Wolters** *The Catholic Church and Evolutionary Theory* Discussion
19:20	**H.Em. Cardinal Georges Cottier** *Evolution: a Philosophical Approach* (provisional title) Discussion
20:00	Dinner at the Casina Pio IV

Tuesday, 4 November 2008

9:00	**Prof. Jürgen Mittelstrass** *Naturalness and Directing Evolution. Some Philosophical Remarks* Discussion
9:30	General Discussion
10:00	Coffee Break
	Session V **IMPACT OF HUMAN ACTIVITIES: EVOLUTION, ARTIFICIAL INTELLIGENCE, COGNITIVE SCIENCE AND PUBLIC PERCEPTION** **Chair: Prof. Jürgen Mittelstrass**
10:15	**Prof. Ingo Potrykus** *Plant Breeding as an Example of Directed Evolution* Discussion
10:45	**Prof. Antonio M. Battro** *Digital Intelligence* Discussion
11:15	**Fr. Prof. Stanley L. Jaki** *Evolution as Science and Ideology* Discussion
11:40	**Prof. Pierre J. Léna** *Teaching Evolution* Discussion
12:10	**Prof. Maxine F. Singer** *The Latest Challenge to Evolution: Intelligent Design* Discussion
12:50	Final General Discussion
13:30	Lunch at the Casina Pio IV
15:30	Closed Session for Academicians
18:30	Dinner at the Casina Pio IV

From Microbial Genetics to Molecular Darwinism and Beyond

In a scientific historical synopsis of genetics and evolutionary biology, the role played by microbial genetics in the development of molecular Darwinism will be outlined. The knowledge acquired in experimental investigations allows us to define three natural strategies to generate genetic variants: local changes in the DNA sequences, intragenomic DNA rearrangements and DNA acquisition by horizontal gene transfer. The resulting genetic variants drive biological evolution, while natural selection, together with the, at any time available, genetic variants, directs the evolutionary progress. The theory of molecular Darwinism postulates that products of evolution genes promote in synergy with a number of non-genetic elements the occasional generation of genetic variants. Philosophical, world view aspects of the postulated duality of the genome will be discussed, as well as consistencies between the acquired scientific knowledge and traditional wisdom such as that reflected in the Old Testament.

Werner Arber

Human Evolution as a Historical Process, and the Forces that Drive It

My origin as an experimenter in bacterial genetics led me to appreciate the strength of the scientific method for understanding the world around us, thanks to the experimental approach. Doubt about the validity of experiments and their interpretation is frequent, hence the need for the independent repetition of experiments, and the generation of new ones in order to improve their capacity to confirm and expand an explanation based on a specific hypothesis, model or theory. The experimental approach forms the core of the scientific process, thanks to which we reach, in due time, a practically universal consensus on the explanations of the world around us, through a rich, often animated and occasionally protracted discussion of the different hypotheses, models and theories that are continuously presented and modified. By contrast, the historical sciences and the other more abstract fields of research, including philosophy, cannot make and repeat controlled observations, and rarely if ever seem to achieve agreement on theories. Genetics explains evolution with a theory that uses four basic factors or forces to explain the change in successive generations of the composition of populations of organisms belonging to the same species: a) *mutation,* causing rare, discrete, mostly spontaneous changes of DNA generating novelties of inherited characteristics; b) *natural selection,* the ensemble of changes in the composition of populations taking place at every generation because of differences in the probability to survive to reproduction ages and in fertility in the environment in which individuals live, determined by the inherited characters they carry; e) *random genetic drift,* statistical variation in the number of progeny per individual, a chance mechanism the effects of which are predictable by fundamental probability laws; d) *migration,* displacements in space of individuals and populations that generate genetic exchanges between populations of the same species occupying different areas, and allow the expansion of successful species like ours to the whole world. Clearly the last three factors demand demographic information, and the first mostly biological studies. The understanding of the continuous and automatic adaptation to the environment in which we live, made possible and inevitable by natural selection, demands knowledge of our physical and biological environment, i.e. ecology. Knowledge of the past is made possible by archaeology and palaeontology. The structure of human groups is the cause and effect of social interactions studied by anthropology and sociology. Communication among individuals has major importance for regulating social and individual behaviour, and humans have maximized it through the development of language. The study of evolution for organisms as slowly evolving as humans suffers from the same problems of historical research: it cannot use a controlled repetition of observations, modifying at will the conditions so as to test their possible causal roles. But the disciplines listed above can contribute greatly to the study of human genetic evolution, as each of them allows us to analyze the same historical process from different points of view. Therefore a multidisciplinary approach can be of great help for

all the disciplines, allowing a sort of "repetition" of the historical process by viewing it from different points of view, that can help clarify causal relations and even complicated interactions between various causal factors. Science has undergone an enormous specialization of disciplines, and the collaboration between specialists of the appropriate disciplines is becoming absolutely necessary, even if the specialized jargons and concepts generated by every discipline make it at times difficult. It has already given some important fruit, and one conclusion I would like to emphasize is that drift, i.e. the effect of chance, is more important than previously believed, especially for selectively neutral changes, which is true of the majority of mutations. Many seem to be scared by the consideration that chance has powerful effects on evolution, but the randomness of mutation and drift has advantages. Moreover all variation of living organisms is under the control of natural selection, that filters automatically inherited changes advantageous to the maintenance of all living species, and does it equitably, within the constraints created by the great variety of living organisms. The last phenomenon mentioned above, the development of human language, is the major difference between humans and the other Primates. It is only one of degree but it has given enormous power to another type of evolution, parallel and interactive with the genetic one: the evolution of culture, intended very generally as shared knowledge — including custom, that usually but not always favours social interactions, and also prejudice (that most often does not, almost by definition). Culture has supplemented biological mutation in producing novelties in the form of inventions, i.e. solutions targeted to perceived needs, while mutations are spontaneous and random. Also inventions are relatively rare, but they can spread fast within, and slightly more slowly between populations thanks to cultural transmission, which is only in part *vertical* (from parent to offspring) but is becoming more and more *horizontal* (from anybody to anybody), and makes cultural change faster and faster, as we are witnessing every day. But every species has a chance of becoming extinct. Cultural evolution is becoming so fast, and its negative consequences are often so difficult to predict or prevent, that the chance of extinction of our species has probably been increased by it. We should do everything to make sure that common sense may prevail.

LUIGI LUCA CAVALLI-SFORZA

The Search for the Chemistry of Life's Origin

The supreme property of chemical matter is its potency to have given rise to the emergence of life. Yet life's origin continues to be one of the big unanswered questions of natural science. This notwithstanding, the idea of the emergence of life to have taken place on Earth (or elsewhere) through a transition of chemical matter from *dead* into *living* as a consequence of the workings of the second law of thermodynamics is a central *postulate* of contemporary natural science. The induction of this process by the second law is considered to have been contingent by one group of scientists, imperative according to the belief of others; to both groups the origin of life is conceived as a natural process as much as Darwinian evolution is seen as such, the reality of the latter demanding the reality the former. Such a statement may collide with views of religious nature about evolution and, therefore, life's origin. In this context, and from the rigorous standpoint of experimental science, it may seem in order to remind us of the fact that, in referring to an event supposed to have occurred more than three billion years ago, the scientific view on the origin of life is bound to have, by obvious reasons, the status of a hypothesis; not a hypothesis in the strict *Popper*'ian sense, but nevertheless one that is amenable to experimental scrutiny at least as far such is possible in the attempt of reconstructing a pre-historic process that left us no 'fossils', except life itself. Life as we know it is a chemical life; thus, within science, it is chemistry that is supposed to play the central role in the interdisciplinary effort to pursue the challenge of scrutinizing the scientific view of life's origin experimentally. Challenged, in fact, is in particular synthetic organic chemistry, not only because the molecular work horses of life are organic molecules, but also – and perhaps most importantly – because an eventual understanding of life's origin will have to rely on experimental demonstrations of the potential of chemical systems to undergo the transition from non-living to living in the laboratory. The eventual aim of such research will be to explore what it means for chemical matter to be alive at a lowest level of complexity, a state of matter intended to be meant by a currently used definition of *minimal* chemical life: a chemical system is alive when, in a given environment, it is self-sustaining and capable of undergoing Darwinian evolution. In the reality of the laboratory, contempo-

rary experimental science is 'light years' of research away from achieving such a 'total synthesis' of artificial chemical life by the bottom-up approach starting from organic molecules. The difficulties of this task sharply contrast with the media-effective promises of (at least some) scientists working in what they call 'synthetic biology', an emerging field that pursues a top-down approach towards the goal of a 'partial-synthesis' of living cells. A central part of the empirical foundation of the scientific view on life's origin is the experimentally broadly documented generational elementarity of the basic molecular building blocks of life: carbohydrates, alpha-aminoacids, nucleobases, (certain) cofactors, and (certain) lipids. In the wake of the famous Miller-Urey experiment in 1953 which initiated the research field of 'prebiotic chemistry', it has been convincingly shown that most of these building blocks are elementary molecules in the sense that their formation from (essentially) the elements and excess energy can be spontaneous and proceed under an extraordinarily broad variety of potentially geochemical conditions. Amazing and chemically highly significant coincidences were observed between the constitutional spectrum of products formed under such experimental conditions and the spectrum of organic compounds found in carbonaceous meteorites, coincidences that strongly support the notion of the operation of an intrinsic chemical determinism in the generation of life's molecular building blocks. Such findings led to the concept of a *heterotrophic* origin of life, in which accumulated organic material on the primordial Earth (essentially free of molecular oxygen) is supposed to have gradually organized itself and eventually have led to the formation of informational oligomers systems, such as oligonucleotides and/or tagged oligopeptides, that may have been capable to self-replicate, mutate, thereby create specific catalytic properties and, therefore, evolve in a natural chemical environment. Extensive experimental research during the last five decades aiming at a demonstration of the feasibility of such a scenario of 'chemical evolution' has met with results that can be considered to be a partial success on the chemical level; but at the same time – and this perhaps more importantly – these results must be interpreted to have uncovered the intrinsic weaknesses of, and enormous difficulties connected with, such a scenario for life's origin. Major difficulties refer to problems of concentration, accumulation and selection of reactants, combinatorial reactivity of organic molecules, activation of monomers for the formation of oligomers, turnover of template catalysis in oligomer replication, chemical nature of a primordial metabolism, scarcity of potentially prebiotic catalysts, compartmentalization of reaction sites, and last but not least cellularization.

Some but not all of these problems are eased – at least conceptually - in an alternative view of biogenesis, one that is referred to as the *autotrophic* origin of life. In such models, all the organic material of geochemical and/or extraterrestrial descent generated under excessive energy conditions may have been largely if not completely irrelevant to the actual self-organization process that was leading to life. The basic requisites of such models are a common source of energy (thermal, radiative, or chemical), a common source of carbon (cyanide, carbon monoxide, carbon dioxide), an environment containing the hydrides of oxygen, nitrogen and sulfur besides minerals, and a common (compartementalized) reaction site for a chemistry that is supposed to have been capable of giving rise to the emergence of autocatalytic reaction cycles. It is through such cycles that a primordial chemistry is envisaged to have channeled itself towards a degree of directionality and order by imposing reaction and product selectivity on what otherwise (in the absence of specific reaction-catalysts) would have been a highly multidirectional or even chaotic geochemistry.

Irrespective of whether researchers adhere to the concept of a heterotrophic or autotrophic biogenesis, they agree on the point that whatever the geochemical, physical, locational circumstances and the workings of primordial chemistry may have been, what eventually must have arisen are chemical systems that had the capability to replicate autocatalytically. Replication cycles could have been either self-templating replication processes of informational oligomers, or any kind of molecular reaction cycles that autocatalytically replicate their constituents. In loose analogy to contemporary biology, the two types of cycles are referred to as primordial versions of "genetic" and "metabolic" cycles, respectively. A primordial emergence of replicating informational oligomer systems with the potential to evolve is considered to have been *the* essential event in life's origin according to the "geneticists' school of thought". The "metabolists" maintain what the "geneticists" deny, namely, that autocatalytic "metabolic" cycles also may have had an evolutionary potential and, therefore, that it may have been their emergence that marks the origin of life. Implicit in this

view is that such cycles were a prerequisite for a subsequent emergence of genetic systems.
There is a third group of researchers ("compartmentalists") who, irrespective of the dichotomies just mentioned, put on top of everything the fact that all life known on Earth is cellular; they determinedly deny that one can refer to a chemical system as being alive as long as such a system does not operate in a cellular compartment. While the fundamental role of compartmentalization for the capability of a system to efficiently evolve is not an issue, the nature of the compartments and the compartmentalization in the self-organization process remain a matter of debate and a topic for experimental studies.
Experimentally, the problem of the origin of life is being pursued worldwide by 'geneticists', metabolists, and 'compartmentalists' along directions that are determined by the preconceptions the members of the three camps are adhering to. There is no harm in this, on the contrary, in a science that aims at retrodicting the past, prejudices can be powerful motors for important experiments done by the prejudiced. Ultimately, a spectrum of such prejudice-driven research may – and that is one of the strengths of science – produce a platform of *facts,* upon the interpretation of which the community of researchers can eventually agree.

Albert Eschenmoser

Culture in the Hominization and its Implications in an Evolutionary View

The process of hominization reveals changes in the behavior of the Hominid which marks the appearance of man. This can be recognized when the Hominid realizes strategies of subsistence revealing intelligence and capacity for reflection. The products of instrumental and housing technology, when reveal planning and innovation and take on a symbolic value in the life context, suggest the presence of man. Symbolism, as attribution of a specific significance to something, not only belongs to art or religion (that go over the biological sphere: spiritual symbolism) or to linguistic communication (social symbolism), but it should be recognized even at what man produces intentionally by the technique, if it takes a meaning in the life context (functional symbolism). Ability to project and symbolism make the culture, which characterizes the human behaviour. This attitude is typically human since the origins of man, whatever its manifestations may be (pebble culture or leptolithic culture; hunt organization or artistic and aesthetic manifestations). Innovation and intentional transmission for learning are fundamental in this respect. We discusse on the age when a Hominid can be considered a human being, but if we assume culture as a criterion of presence of man (that is in presence of signs of reflected psychisme, capacity of thought and self-awareness, including the technological expressions), than the hominid can be considered human, whatever its physical evolution level may be. The culture represents a discontinuity in the evolutionary process, because it is not a biological property and does not follow biological laws. Dobzhansky spoke of transcendence for the human threshold, because the rules of human societies are different from those of animal world. The implications of culture in an evolutionary view relate to different levels. On the *palaeontological* level: the higher cognitive functions appear related to the development of cerebralization that characterizes the evolutionary direction of Primates. On the *evolutionary* level: culture enters in the mechanisms of evolution of species, as is a factor capable of facing and contrast intentionally natural selection On the *ecological* level: culture assumes a role of mediation in adaptation to the environment and can be considered "ecological niche" of the human species. On the *phenomenological* level: culture, as expression of higher cognitive capacities, represents a discontinuity to the properties and biological laws, and gives man a conscious subjectivity and freedom (matter starks thinking). On a *philosophical* level: the nature of discontinuity calls into question the spiritual dimension and thus leads to a transcendent sphere (ontological gap); On the *cosmological* level: by thought and conscience the entire universe is thought and becomes conscious. On the *moral or ethical-social* level: in hominization culture activates a process of "humanization" of the physical and social environment, but the future is exposed to the advantages and the risks of human freedom. All that gives man an uniqueness in living world, with the ability to ask questions about itself, its history and its future, and to seek answers.

Fiorenzo Facchini

Galaxy Evolution

Galaxies are the building blocks of the universe, tracers of cosmic evolution over the last 13 billion years. They are also the crossroads of Astro-

physics, the true link between the present universe we observe and the properties of the early universe. I will review the two processes that rule galaxy evolution, hierarchical clustering process and the secular evolution. Hierarchical clustering is a violent and rapid mechanism that dominated the growth of galaxies at early times. On the other hand, secular evolution is slow but will be dominant in the future universe. I will discuss the observational evidence for both processes.

José G. Funes, S.J.

The Early Evolution of the Universe: Problems and Concepts

There are several problems plaguing all approaches (superstrings, M-theory, loop gravity, quantum groups, noncommutative geometry) to the very early evolution of the Universe: • The structural problem: How to find a mathematical structure rich enough to unify quantum physics and the theory of gravity? • The nonlocality and the background independence problem: After Bell's inequalities, when the EPR thought experiment can be performed in laboratory, we are facing the plethora of nonlocal effects based on entanglement, decoherence, delayed time experiments. How to reconcile them with the time honoured causality and reality postulates? There is a growing feeling that the future quantum gravity theory should be background-independent theory (be it space-time or some other stage-like field). How to achieve this? • The problem of time and dynamics: It seems that the final theory cannot avoid the problem of dynamics, and consequently the problem of time. Which time, if this theory is supposed to be background free? There are some hints (also from the side of noncommutative geometry) that the fundamental level of physics is a temporal. If so, what about dynamics? • The problem of probability: The laws of quantum mechanics, in their standard formulation, are intrinsically probabilistic. Is this a peculiarity of quantum mechanics that will disappear if we have the 'final theory'? Or is it a fundamental property of nature? Quantum probability exhibits some essential differences as compared with classical probability. Are they but variations of some more general probabilistic measure theory? • The generation of matter and space-time problem: Einstein's field equations suffer from a certain duality: their left hand side is purely geometric, whereas their right hand side contains a physical phenomenological entity, called energy-momentum tensor. There were two strategies to get rid of this duality. Einstein himself claimed that it is the matter term (the energy-momentum tensor) that should generate geometry of space-time (this philosophy led to various formulations of Mach's Principle), whereas Wheeler proposed that *vice versa* there are various configurations of space-time that should generate various species of elementary particles (Wheeler's geometrodynamics). Neither of these programs turned out to be successful. If the final theory should be background free, it should provide a mechanism of space-time generation. Should we go a step further and not only try to explain the generation of space-time, but also its material content? • The singularity problem: It is almost commonly believed that the final theory should be singularity free, but this will be not known until we have this theory. It seems that, as far as the existence of the initial singularity is concerned, one can expect either 'yes' or 'not' answers from the final theory. However, if the mathematical structure of the future theory is supposed to be truly more general than the mathematical structures of the present general relativity and quantum physics, is a 'third answer' possible? Could this third answer be related to the probabilistic character of the final theory? And how it would influence dynamical properties of the final theory? These and some other questions will be discussed at some length.

Michael Heller

Evolution as science and ideology

Evolution as science is the mechanism of evolution as specified by Darwin. Evolution as ideology ranges from sheer materialism to revelationary theism. These two meanings of evolution intermingled already in Darwin's publications and the immediate reaction to them. The second phase of that intermingling is found in the reaction to the discovery of Mendel's genetics. The third phase is constituted by the temporary eclipse of Darwinism in the early part of the twentieth century. The fourth is tied to the rise of the synthetic theory of evolution which culminated around the centenary of the *Origin of Species*. The latest or fifth phase is tied to the biochemical approaches to life's origin and to space exploration. The analysis of these phases supports the need for a radical separation of those two meanings of evolution if a sane cultural atmosphere is to prevail.

Stanley L. Jaki

Modern Life Sciences and Evolution

The process of biological evolution is the foundation stone of modern life sciences. This process was originally inferred with high confidence by comparative studies of similar species that occupy distinct ecological and behavioural niches. More recently, genomic analysis in numerous micro-organisms, plants and animals has revealed a panorama of very ancient, shared and yet diversified types of genes and putative regulatory DNA elements. Experimental biology has confirmed broad functional conservation and progressive diversification of such genes and regulatory elements, consistent with temporal series of the corresponding species, as inferred from the fossil record. A process of neutral evolutionary change has also been documented, deepening our understanding of continuous, even clock-like molecular changes in the DNA. These apparently represent a continuous generation of variants, which are then selected or lost, by positive or negative selection, or by stochastic as well as geologically driven processes of ecological isolation and speciation. In this context, the theory of biological evolution must be understood not according to the popular meaning of theory as an unproven concept, but as a scientifically established complex process whose description is subject to refinements as more knowledge accumulates. The "creationist science" that is promoted by some fundamentalist currents is simply not an alternative, and undermines the important goal of linking spirituality with logic.

Fotis C. Kafatos

The Human Being – God's Plan or Just a Strange Coincidence?

In the present debate between creationist theology and evolutionary biology a new front seems to be opening up on old battlegrounds long considered pacified. The main opponents in this battle are a bible-orientated creationism and a materialist and reductionist version of evolutionary biology. What the debate is mainly focusing upon is the concept of coincidence and the consequences which are supposed to ensue from it for humankind and the image that it forms of itself. Some evolutionary biologists claim that due to the randomness of mutation there is no sense in evolution. The only sense they are prepared to admit is an exclusively population-dynamic interpretation of religion. 'Religion survives, because it produces offspring, not because it is true' (von Hayek). Its sense is accordingly said to lie in a 'side effect' of religion, an optimized care for offspring, which is ultimately believed to be its main function. The first aim of this present paper is to clarify, also for the sake of sciences, the concept of coincidence which is often insufficiently specified in biology. What must be distinguished is: 1) objective coincidence, as it is seen to be observable and stochastically quantifiable, but not reconstructible in causal analysis, with phenomena of quantum physics and 2) subjective coincidence, as it occurs in biology for instance, which is in principle accessible to a causal analysis, though not in practice, for practical reasons. Secondly, the paper discusses the question of whether any philosophical conclusions touching on our image of mankind can be reasonably drawn from the concept of subjective coincidence. Does the concept of coincidence as it is seen in biology warrant the assumption that there is no aim, no plan, no sense in evolution (as Monod, Wilson an others have claimed)? Can we conclude from the biological fact that in the course of evolution innumerable species have died out or not developed to any recognizable degree that there is basically no tendency, no direction, no improvement and no increase in complexity (Wuketits etc.)? Both questions must clearly be denied, because without disclaiming the theory of evolution in any sense, it is perfectly possible to interpret the 'randomness' of mutation as an exploratory, innovative and distributive element in a larger plan. Man forms part of an evolutionary process which, not having any knowledge of the origin and the end, he only vaguely understands and cannot approach from an objective viewpoint. Scientifically speaking, he can only speculate about the entirety of this process in a philosophically interesting manner, without staying on the ground of science proper. The physical build of birds reflects the laws of aerodynamics, which they 'extract' from nature, which surrounds them, without any active consciousness. In this case, Man as an extrinsic and superior observer is able in retrospect to discover a plan in the birds' phylo- and ontogenesis, which as far as we know, they themselves cannot understand although they put it into practice. As long as evolutionary biology intends to remain on the ground of science, it must not make any universal claims that transcend what is quantifiable in an empirical manner. A theory of evolution that is philosophically loaded will change into metaphysics, without knowing it

or allowing others to know it. If the theory of evolution runs through this change, either in general or with respect to any of its elements (such as 'random' mutation or 'necessary' selection), it runs away from being a science.

ULRICH LÜKE

Understanding the Great Numbers of the Universe

Physicists describe the world using 'fundamental' or 'universal' constants. In some way the basic physical characteristics of the world depends on the numerical value of such constants. If they change, the world would change drastically. Some important constants are: the speed of light (c), the Planck constant ($\hbar$), the gravitational constant (G), the proton mass (m_p), etc. Although physicists know quite well the numerical values of this constants, there is no theory, which can predict this values from the first principles. John Barrow in his book *The Constants of Nature* tells: 'This is the Holy Grail of fundamental physics and it means the numerical calculation of one of the constants of Nature. This has never been done. So far, the only way we can know their values is by measuring them. This seems unsatisfactory. It allows the constants that appear in our theories to have a huge range of different possible values without overthrowing the theory'. Instead, for description of physical reality, more appropriate seems to use a pure dimensionless numbers. The important role of dimensionless combinations of fundamental constants in describing essential characteristics of physical world was noticed first by Hermann Weyl and further elaborated by Sir Arthur Eddington and Nobel laureates Dirac and Chandrasekhar. Some of this 'large' or 'great' numbers are proportional to 10^{40}, its square 10^{80}, cube 10^{120} and power 3/2 10^{60}. The aim of present report is to show that using Chew-Frautschi-Regge spin – mass paradigm it is possible to derive old and some new Great Numbers relations from simple unifying principle. In the first time in the history of physics and astronomy large number coincidences are derived from physical principle, without any 'numerology'. Cosmological implications of this relations are explored.

RUDOLF MURADIAN

Plant Breeding as an Example of 'Directed' Evolution

Crop and forage plants which cover most of our cultivated land and provide, directly or indirectly, most of our food, have not evolved naturally but through intervention of man. Breeders have used the principles of evolution – creation of genetic variation, hybridisation and subsequent selection of the best adapted to specific ecological niches – in several ways: They have increased the frequency of mutation, thus creating more genetic variation. They have encouraged novel genome combinations and recombinations by interspecific hybridisation and embryo rescue. And they have given evolution specific directions by selecting for traits (genes) in their interest, and against undesired traits (genes). And they have combined numerous desired traits (genes) in ever improved varieties to exploit the potential nature has provided them with. Virtually all plants used to date in agriculture and horticulture are not "natural" but "intensely genetically modified" in the interest of man. These plants have little chance for survival in any natural environment, but require continuous care in agricultural habitats. None of these biologically disadvantaged plant varieties would ever have evolved without the intervention of man and they would disappear within few generations without the continuous care provided by farmers in the artificial habitats of agriculture. Without these interventions into natural evolution, there would be no food for the great majority of mankind, and there would not have been the development of culture and civilization as we have experienced in history on the basis of agriculture. Thus far, up into the 80's of the 20th century, the approach to man-made evolution was based on 'trial and error' and 'learning from experience' and knowledge was limited to 'phenotypes'. Thousands of novel varieties for all our crop and forage plants where developed and were consumed without any special precaution. And there was virtually no harm to the consumer. Of course, there were dramatic effects on the environment. Monocultures of crop plants were replacing natural vegetation where ever agriculture was established. The effect was, however, not entirely negative. Numerous plant species could invade – as 'weeds' – the agricultural land, and relatively monotonous natural forests were replaced by a rich novel flora of pre-industrial agriculture. What is, however, most important: on the basis of these massive, 'uncontrolled and unpredictable alterations of the

genomes' mankind could increase from a few millions to over 6 billions. With the advent of molecular biology and plant cell culture a refinement and extension of the adoption of plants to the needs of mankind was possible which is now based on 'knowledge and understanding'. Complex phenotypic traits can be analysed on the level of genes, their regulatory signals, and their interactions with other genes in biochemical pathways and cellular networks. Genes for desired traits and appropriate regulatory sequences can be isolated, newly combined, and their function predicted and tested experimentally. They then can be introduced selectively into otherwise unaltered genomes, thus providing 'direction' for evolution even before selection. Undesired traits such as anti-nutrients or allergens can be inactivated and traits which are not available in a given species can be introduced from other species. These and other technological possibilities enable breeders to exert 'direction' and to 'predict' novel phenotypes by not only selecting gene combinations from increased variation, but by planning variation and gene combinations 'a priory' and making more efficient use of the potential nature is providing to us. This improved technological possibilities are urgently needed to secure food for an increasing world population, from agricultural production systems which are faced with increasing shortages in land, water, manpower, energy, and capital and which are requested to produce food for more and more people with less and less negative impact onto the environment. To save the last remaining refuges of natural environments is only possible if we can produce more food on the agricultural land already in use. There is no alternative to intensive and sustainable production systems. And this requires careful exploitation of science and technology. Paradoxically, as long as 'man-made evolution' was based on 'trial and error', without any other knowledge base than 'experience and phenotype' it was considered 'natural' and was accepted by our society. Now where the same is based on knowledge, science, prediction, and controlled experimentation, the same process is discredited as being un-natural, highly dangerous, and unethical, and of unacceptable risk to mankind and environment. This present attitude lacks any justification from science, experience, logic, and common sense – but it is a widespread psychological fact, and difficult to change with argumentation based on science and logic. This is extremely unfortunate, especially for those underprivileged poor in developing countries, for which food insecurity and malnutrition is an outstanding problem, which takes a daily toll of 24 000 lives per day. Many of these lives could be saved, if Western societies would change their hostile attitude towards this knowledge-based progress in plant breeding technology, which is nothing else but a more sophisticated continuation of the use of genetic modification to the benefit of mankind. Blocking the use of these modern genetic approaches to plant improvement is not justified and has the consequence of hundreds of millions of avoidable deaths.

Ingo Potrykus

What We Know, and What We Do Not Know, About Our Universe

Every civilization, from the time of the earliest humans to the present day, tells stories about the universe. What is known at each epoch is limited by the available technology. During the last century, we learned that we live in a galaxy of ~200 billion stars; at the center of our Galaxy is a Black Hole. Our sun, an average star, is located 30,000 light years from the galactic center. The light that reached us today from the center of our Galaxy began its journey when civilization on earth was just starting its migration across the ancient land bridge now covered by the Bering Sea. Our sun carries its planets with it as it orbits the center of the Galaxy at a speed of 500,000 miles/hour. Even with this high velocity, it takes ~200 million years for the sun to complete one orbit about the center of the Galaxy. We know that the universe is populated by billions of galaxies, and that galaxies are moving away from each other, thus expanding the universe. Equally important, we understand that everything evolves: stars are born, evolve, and die. New stars arise from their remains. Galaxies grow by acquiring neighborhood dust, gas, stars, and smaller galaxies. Luminous galaxies and clusters of galaxies populate the universe. However, in the second half of the 20th Century, observations of rapidly moving stars far from the centers of their galaxies led astronomers to conclude that the stars are moving in response to matter that we cannot see. This dark matter is not radiating at any wavelength, and constitutes most of the matter in the universe. Evidence of dark matter comes from its gravitational effects on the bright matter that we see. A few smart scientists are brave enough to consider

an alternative explanation. They suggest that Newton's laws of motion should be modified to describe the orbital motions of stars that are far from the centers of their galaxies. There is a precedent for modifying Newton's laws of gravity. Almost 100 years ago, Einstein used his new relativity theory to modify Newtonian gravitational theory in order to account for peculiarities in the orbit of Mercury, the planet closest to our Sun. As early as 1784, discussions of dark stars were in the literature, although attempts to evaluate the density of these non-luminous objects were rare before the early part of 20th Century. Even more mysterious is dark energy, a force that may be causing the expansion of the universe to accelerate. I believe that our knowledge of the universe is vastly incomplete. In the past century, fundamental features have been discovered every decade. It is unlikely that we have suddenly reached the end of discoveries. The science stories we tell today identify the state of our science at the present time. Future generations will learn more, and tell more complete stories about the universe.

VERA C. RUBIN

The Latest Challenge to Evolution: Intelligent Design

Science and technology have entered peoples' lives worldwide. People everywhere eagerly adopt new technologies that are themselves dependent on advances in science. And yet, after more than a century and a half and affirmation by countless scientific findings, evolution by common descent and natural selection is still rejected by millions of people. This rejection is stronger in the United States than in most other nations. Decades of polls demonstrate that more than 60 percent of the U.S. population is unconvinced. The most serious real consequence of these views is the continuing battle over the teaching of evolution in U.S. public schools. One reason for the repeated emergence of this debate is the structure of school governance in the U.S. Educational policies are set by the approximately 17,000 separate, local school boards. These boards make final decisions about curricula and textbooks. The members of the school boards are either elected by the local community or appointed by a mayor; in either case local politics is a powerful element in the making of educational policy. The central government has no authority or power to decide on school policy because the U.S. Constitution does not assign that authority to the federal government. The Constitution also provides an effective tool whereby citizens can challenge local decisions to undermine the teaching of evolution. The first amendment to the U.S. Constitution states that Congress shall make no law respecting an establishment of religion, or prohibiting the free exercise thereof. In view of this, 40 years of rulings made by the United States Supreme Court, the ultimate arbiter of legal issues in the nation, support the teaching of evolution. More than 40 years ago, the Court declared unconstitutional state laws outlawing the teaching of evolution. The Court declared the teaching of creationism, the Biblical creation story, in U.S. public school science classrooms unconstitutional and thus illegal. They also declared unconstitutional the teaching of so-called 'creation science' including 'balanced treatment', that is, the presentation of both scientific evolution and creationism. In each case, the Court concluded that creationism is a religious teaching. Nevertheless, individuals, local school boards, state legislatures, and national politicians continue to seek ways to circumvent the law. Recent attacks on the teaching of evolution are based on the old notion that there are aspects of LIVING things that cannot be explained by anything other than an intelligent design. Examples such as eyes and the immune system are described as being 'irreducibly complex' and thus, designed. To try to avoid conflict with the Constitution, the intelligent design proponents decline to say anything about the nature of the implied designer and thus any implication that intelligent design implies a supernatural deity. They present no scientific experiments or observations to support their ideas. Attempts to introduce intelligent design into school curricula were dealt a major blow when, in 2005, a Federal court in Pennsylvania ruled that intelligent design was repackaged creationism and unconstitutional. Most dangerous to science is the intelligent design community's claim that their concept is scientific and that the definition of science needs to be changed to allow other than natural explanations of natural phenomena. If they were to prevail, science as we know it would be destroyed. This conflict is not going away soon. Already there is evidence of new packaging by those who object to teaching scientific evolution in U.S. schools. And, the movement has begun to move outside the borders of the U.S. to other

countries. It is essential in coping with this situation that the scientific community underscore that the issue is what is taught in science classrooms in public schools, not what is taught in history or philosophy. Some students will retain their own religious views; that is their right and privilege in a democratic society. At the same time, however, their science educations must be about science; they can accept or reject the conclusions, but they should learn to understand what scientific research teaches about the natural world. This talk will describe the scientific knowledge about a few of the 'irreducibly complex' biological phenomena that are the focus of the intelligent design community. It will examine how modern biological investigations demonstrate that far from 'irreducibly complex' these very phenomena are already understood. Data will be drawn from studies on the various beak shapes and sizes in Darwin's Galapagos finches, from the development of eyes, and from growing knowledge of the role of development in evolutionary change.

MAXINE F. SINGER

Scientific quest into evolution of life in the Universe

After the earth cooled about 4 billion years ago, chemical evolution began and gave rise in due course to viruses, fungi, the cell, prokaryotes, eukaryotes, mammals, primates, homo-erectus and humans. There is considerable scientific evidence that Darwin's emphasis on evolution by natural selection has played an important role in the growth of millions of species. The agrarian development by humans over the last 10000 years gave rise to philosophy, culture and myths. Scientific experimentation, and theoretical developments over the last few hundred years have vastly expanded our understanding of the evolution of the Universe. Surely there are many unanswered questions, but our experimental tools are getting sharper and more powerful and will continue to answer many puzzles. Anthropology, fossil records, modern genetics, astronomy and astrophysics are now rapidly contributing to our scientific quest into the evolution of the Universe and of life on the earth. There are many exciting challenges, e.g. synthesis of living cells that scientists working in the field of synthetic biology hope to demonstrate at least partially, a daunting task but possibly tractable. Another interesting question is whether there is any evidence of bacterial life elsewhere in our solar system. The successful descent of the sophisticated Phoenix probe in the polar region of Mars on 26th May 2008 may provide valuable data in this regard. Some other probes have landed on Mars in recent years. Also orbiting satellites by ESO and NASA are exploring moons of the outer planets such as Jupiter and Saturn. Such explorations of our solar system will elucidate our understanding of the origin and evolution of life on the earth. There are billions of galaxies in our Universe. Each has billions of stars including our Galaxy. Life developed on the earth relatively fast and hence it seems likely that it has existed elsewhere. During the last decade astronomers have already discovered over 250 planets orbiting some nearby stars. Presence of methane has been discovered on one of these planets. Over the next ten years, more than 2000 planets are likely to be found around many stars. Both NASA and ESO are planning to launch satellites to search for any spectroscopic signs of ozone, carbon dioxide, methane, water etc. towards earth like cool planets. Finally, the question: are we alone? Our scientific civilization is only a few thousand years old, negligible compared to the age of 5 to 10 billion years of most stars. Over the last few decades radio astronomers have made searches towards several selected nearby stars using some of the large radio telescopes for any signals that may have been sent by an extra-terrestrial civilization. No signal has been detected so far but the results have helped in determining upper limits on the power flux density incident at the earth. I plan to summarize these results and their implications. Recently the SETI institute in California has set up a special radio telescope for such searches. Much more exciting is the proposed search with the Square Kilometer Array (SKA) that is planned to be constructed during the next decade by more than 17 countries including India. The sensitivity of SKA will be at least 50 times higher than any existing radio telescope. Over the next 20 years, SKA will search towards millions of stars for any signals sent by an advanced civilization and also any leakage signals from their radars or fixed and mobile transmitters.

GOVIND SWARUP

Origin of the Human Species (Mind) Requires Divine Intervention

Central to our ability to explore and understand the origins and evolutional development of the universe, and even of life itself, is the human brain. All that mankind has come to know and will understand in the future, is processed and stored in this most complex and sophisticated organic system. This structure is also the physical repository for human cognitive and ethical performance. This presentation will emphasize the unique structures and patterns of neural organization that are responsible for our intelligence, as well as man's ability to morally and ethically manipulate the environment and its population. The origin and evolution of the human brain itself will be examined from an anthropological standpoint demonstrating the neuro-anatomical similarities and differences between our brains and those of our closest subhuman relatives. In addition, while acknowledging the closeness of man to subhuman primates (i.e. the chimpanzee) in a genetic sense (99% identical), it will be emphasized that there are small significant differences involving the DNA of the neocortex. While this may, in time, help to explain the incredible and unique capabilities of the human mind when compared to that of the apes, something will still be missing. We will argue that at some time in the biological evolutionary course divine intervention with the introduction of a soul/spirit was required to create the unique human species. We will further argue that with the infusion of a soul/spirit at the time of human conception we are, in a sense, witnessing a replication of the creation process of mankind itself. The latest advances in molecular genetics and neuro-imaging will be presented to support the thesis that divine intervention was necessary in the origin and development of man emphasizing that: 'we are created in the image and likeness of God'.

Robert J. White

Giorgio Bernardi was awarded degrees at the University of Padua and the University of Strasbourg (France). He spent most of his scientific career with the Centre National de la Recherche Scientifique (CNRS), first at the Centre for Research on Macromolecules in Strasbourg, then at the Jacques Monod Institute in Paris. Since 1998 he has been the President of the Stazione Zoologica Anton Dohrn in Naples and head of its Laboratory of Molecular Evolution. He has published over three hundred and fifty papers in the fields of molecular genetics and molecular evolution, as well as the book *Structural and Evolutionary Genomics: Natural Selection in Genome Evolution* (2004). He is also the Editor-in-Chief of *GENE* and the Chairman of the International Society of Molecular Evolution.

Francis Collins is a physician-scientist and Director of the National Human Genome Research Institute at the U.S. National Institutes of Health. He was previously awarded degrees from the University of Virginia, Yale University, and the University of North Carolina. He led the successful effort to sequence the human genome, ensuring that all of this information was placed in the public domain. Prof. Collins now leads the U.S. research effort to apply this knowledge to human health. In recognition of these achievements, he has twice been a recipient of the Gairdner Foundation International Award, was elected to the Institute of Medicine and the U.S. National Academy of Sciences, and was awarded the Presidential Medal of Freedom in 2007. He has a deep interest in the interface between science and faith, and is the author of *The Language of God: A Scientist Presents Evidence for Belief* (2006).

Yves Coppens was awarded degrees at the University of Rennes and at the Sorbonne. In France, he worked at the National Centre for Scientific Research, the National Museum of Natural History, and the College of France, where he now holds the position of Professor Emeritus. In his own country he is a Member of the Academy of Sciences and the National Academy of Medicine and he is also a Member of the Royal Academy of Sciences of Belgium. He has received a large number of national and international prizes and honours and is the author of numerous books, including *La plus belle histoire du monde* (1996), *Le genou de Lucy* (1999), *Aux origines de l'humanité* (2001, 2002), *Homo sapiens* (2004), as well as over four-hundred scientific papers.

Fiorenzo Facchini, Professor of Anthropology in the University of Bologna from 1978 to 2005, was Responsible of the Unit of Anthropology in the Department of Evolutionistic and Experimental Biology and of the Museum of Anthropology in the same University. Now he is emeritus professor of the University of Bologna. Member of many scientific Societies, among them the Academy of Sciences of Bologna, the Italian Institute of Anthropology, the Academy of Natural Sciences of Kazakhstan, the New York Academy of Sciences. International Prize "Fabio Frassetto" of the Academia dei Lincei (2002). Coordinator of National Programs on the human peopling in Italy granted by the Ministry of University (1998, 2000, 2002).
Fiorenzo Facchini developed researches in different fields: human growth, genetic human polymorphisms, ancient populations, prehistoric culture, palaeoanthropology, human adaptation and modernization in Kazakhstan. He organized two expeditions in Kazakhstan (1993) and Kirghizistan (1994) to study the human adaptation to high altitudes and co-ordinated a research on the effects of the modernization in Kazakhstan (2002-2005). He is author of about 400 papers published in national and international journals and of many books, among them: *Il cammino dell'evoluzione umana*, Jaca Book, Milano, 1985, 1995; croatian edition); *L'uomo. Le origini*. Jaca Book, Milano 1991 (french, germany, spanish, croatian, japonese editions), *Dizionario enciclopedico di Paleoantropologia e preistoria* (in coll, con A. Broglio e A. Beltran), Jaca Book, Milano, 1993; *Antropologia*, Utet, Torino, 1988, 1995; *Evoluzione umana e cultura*, La Scuola, Brescia, 1999; *Origini dell'uomo ed evoluzione culturale. Profili scientifici, filosofici e religiosi.* Jaca Book, Milano, 2002; *E l'uomo venne sulla terra,* Ed. S.Paolo, 2005 (spanish edition), *L'avventura dell'uomo.* Ed. S.Paolo, 2006; *Le origini dell'uomo e l'evoluzione della cultura.* Jaca Book, Milano, 2006 (french, german, croatian, spanish, hollander editions); *Le sfide dell'evoluzione. In armonia tra scienza e fede.* Jaca Book, Milano, 2008; *Popoli della yurta. Il Kazakhstan tra preistoria e modernità* (a cura di), Jaca Book, Milano (in press).

Cardinal Christoph Schönborn was ordained priest in 1970; was appointed Auxiliary Bishop of Vienna in 1991; Coadjutor Bishop of Vienna in 1995; Archbishop of Vienna in 1995; and Cardinal in 1998. He studied at Le Saulchoir, the University of Vienna, the Catholic Institute of Paris, and the Sorbonne. He taught at the University of Fribourg, where he became Professor of Dogmatic Philosophy. Since 1998 he has been President of the Austrian Bishops' Conference. He is a member of the Pontifical Council on Culture and a number of other bodies of the Holy See, and during the 1980s, in particular, he was a member of a number of important commissions working for interconfessional dialogue. He played an important role in the drafting of the *Catechism of the Catholic Church*. In June 2005 he published an article on evolution in *The New York Times* of notable impact and he has spoken at length on this issue in his catechetical lectures

given at his cathedral in Vienna. In addition, he organised two meetings of the circle of former students (*Schülerkreis*) of Joseph Ratzinger, with the participation of His Holiness Benedict XVI, on the subject of creation and evolution.

Govind Swarup was born in 1929 in Thakurdwara, U.P., India. He received an M.Sc. in physics from the Allahabad University in 1950 and a Ph.D from Stanford University in 1961. After his M.Sc., he spent 4 years at the National Physical Lab at Delhi, two years at CSIRO, Australia, a year at Harvard, and 6 years at Stanford, including two years as a Faculty member in the Dept of Electrical Engineering. He joined the Tata Institute of Fundamental Research (TIFR) in 1963 and became Professor of Eminence in 1990. He was Professor Emeritus 1994-99. He is currently INSA Honorary Scientist at NCRA-TIFR. He was Visiting Professor at the University of Maryland, the University of Groningen and the University of Leiden. From 1965 to 1969 he set up a 530m long and 30m wide radio telescope of a unique design at Ooty. From 1987 to 1996 he directed the design of the Giant Metrewave Radio Telescope proposed by him. He has made many pioneering contributions in the field of radio astronomy. He has authored over 111 research articles, edited 4 books and has two patents on (a) a fixed mirror line focus solar concentrator and (b) preloaded parabolic dish antenna and the method of making it. He is a Fellow of the Royal Society of London and all the national science academies in India. He has received over 20 national and international awards, including: the Padmashri Award (1972) (a national honour award), the S.S. Bhatnagar Award (1973), the P.C. Mahalanobis Medal, the Tskolovosky Medal of the USSR, the Meghnad Saha Medal, the Third World Academy of Sciences Award in Physics, the John Howard Delinger Gold Medal of the International Union of Radio Sciences (URSI), the C.V. Raman Medal, and the Khwarizmi International Award, Iran.

Gereon Wolters was born in 1944 in Leiffarth, Germany. From 1965 to 1972 he studied Catholic theology, mathematics and philosophy at the universities of Innsbruck, Kiel and Tübingen. 1977 PhD in philosophy, University of Konstanz. 1986 Habilitation for philosophy and for history of science. Since 1988 professor of philosophy and history of science, especially biological science. Since 1986 visiting professor at the University of Zurich (Department of Zoology). Since 2004 member of the German Academy of Scientists (*Leopoldina*) (Halle), section for philosophy of science (since 2006 chairman) and member of the senate of the *Leopoldina*. 2008-2012 chairman of a *European Science Foundation* Program 'European Perspectives in the Philosophy of Science'. Publications include: *Basis und Deduktion* (1980); *Mach I, Mach II, Einstein und die Relativitätstheorie* (1987); 'Einschränkungen der Forschungsfreiheit aus ethischen Gründen' (1991); ed. (with James R. Lennox) *Concepts,Theories, and Rationality in the Biological Sciences* (1995); 'The Idea of Progress in Evolutionary Biology' (1997); 'Evolution as Religion' (1999); 'Darwinistische Menschenbilder' (1999); 'Evolving Concepts of Nature' (2000); 'Hans Jonas' Philosophical Biology' (2001); 'Eugenetica in Vaticano' (2004); 'La materia di cui è fatta la vita: concezioni filosofiche del vivente' (2006); ed. (with Peter Machamer) *Thinking About Causes: From Greek Philosophy to Modern Physics* (2007).

For the biographies of the Academicians of the PAS, cf. Pontificia Academia Scientiarvm, *Year Book* (Vatican City 2004), p. 12 ff.

LIST OF PARTICIPANTS

ABELSON John
ARBER Werner
BALTIMORE David
BATTRO Antonio M.
BERNARDI Giorgio
BERTI Enrico
BOON FALLEUR Thierry
CABIBBO Nicola
CAVALLI-SFORZA Luigi L.
CAVALLI-SFORZA Francesco
CIECHANOVER Aaron J.
COLLINS Francis S.
COPPENS Yves
COTTIER Card. Georges
DEHAENE Stanislas
DE DUVE Christian
ESCHENMOSER Albert
FACCHINI Fiorenzo
FUNES José G.
GOJOBORI Takashi
HAWKING Stephen W.
HELLER Michael
HIDE Raymond
JAKI Stanley L.
KAFATOS Fotis C.
KASTURIRANGAN Krishnaswamy
VON KLITZING Klaus
LEE Yuan-Tseh
LÉNA Pierre J.
LÜKE Ulrich
MALDAMÉ Jean-Michel
MARTINI Card. Carlo M.
MENON M. Govind Kumar
MITTELSTRASS Jürgen
MURADIAN Rudolf
NIRENBERG Marshall W.
PASINI Cesare
PHILLIPS William D.
POTRYKUS Ingo
RAO Chintamani N.R.
RAVEN Peter H.
RODRÍGUEZ-ITURBE Ignacio
RUBIN Vera C.
SÁNCHEZ SORONDO Marcelo
SCHÖNBORN Card. Christoph
SELA Michael
SINGER Maxine F.
SINGER Wolf J.
SWARUP Govind
SZCZEKLIK Andrzej
THIRRING Walter
TUPPY Hans
VICUÑA Rafael
WHITE Robert J.
WITTEN Edward
WOLTERS Gereon
ZICHICHI Antonino

Memorandum

1) Every day a bus will leave the Domus Sanctae Marthae at 8:45 for the Academy fifteen minutes before the beginning of the session. A bus will depart from the Academy at the end of each session (about 21:00) to take participants back to the Domus Sanctae Marthae. From 31 October to 4 November, lunch and dinner for the participants will be served at the Academy except on Sunday, 2 November, when only dinner will be served after the visit to the Papal Villa at Castel Gandolfo.

2) Every day, except Sunday, Holy Mass will be held at 7:00 at the Domus Sanctae Marthae for those who would like to attend.

Note
Please give your **form for the refunding of expenses** to the secretariat at least one day before your departure so that you can be refunded immediately.

Standing Rules for Meetings

1. The Academy invites a number of illustrious scholars who have especially studied a given question and have arrived at different conclusions to meet in Rome at its headquarters, the 'Casina Pio IV', situated in the Vatican City, so as to make a joint examination of all the data on the question.

2. The chief aim of these discussions is to endeavour to reach a common view on the subject of the meeting, but when this is not possible to formulate precisely the reasons for this inability. The scholars invited to these meetings undertake in advance to concentrate their efforts on this.

3. A critical examination of these reasons should lead either to agreement on a partial or provisional solution or else to the conclusion that, on the basis of the information presently available, it is impossible to establish unity on the question concerned. In the latter event the scholars involved will be called upon:

a) to define the reasons why agreement appears to be impossible for the present;

b) to specify the kind of research work it would be desirable to undertake in order to solve the problem.

4. The invitation will be addressed by the Academy to only a small number of representatives of each branch of learning: these will be selected from scholars who are not connected with the Academy. These representatives will be joined during the discussions by members of the Academy who are experts in the same discipline. This invitation, moreover, will apply only to the study of one precise question by each branch of learning.

5. The debates will be strictly private and will take the form of papers and talks in the presence only of a few members of the Pontifical Academy of Sciences who have special knowledge of the subject under discussion.

6. The conclusions arrived at will be published in the form of a 'Statement' (to which may be added individual notes) mentioning:

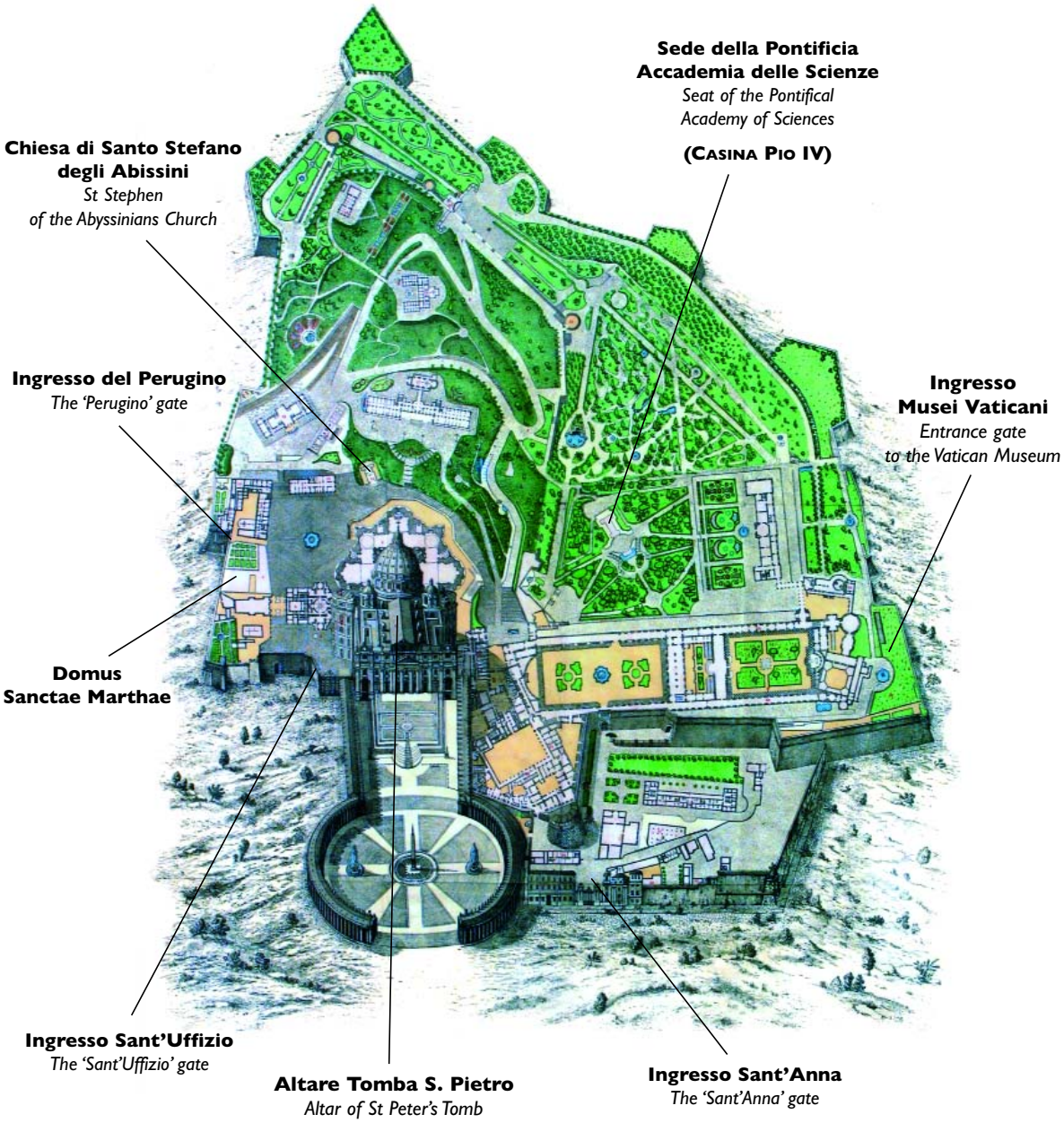
a) the points on which agreement was reached;

b) the points on which it was impossible to reach agreement;

c) the reasons why it was not possible to reach agreement;

d) suggestions about the research work that appears most appropriate in order to arrive at a solution of the difficulties.

7. The 'Statement' arrived at will be immediately printed and transmitted by the Pontifical Academy of Sciences to all the centres of learning which might be interested in it.



CASINA PIO IV
V-00120 VATICAN CITY
Tel: +39 0669883451 • Fax: +39 0669885218
Email: academy.sciences@acdscience.va

For further information please visit:
http://www.vatican.va/roman_curia/pontifical_academies/acdscien/index.htm