The Fascination of Abdus Salam with Astrobiology (#)

1. Salam's bold attempt to trace handedness to biomolecules to Parity

What was most striking in Salam's character and intuitions was his fascination with the natural sciences, especially the life sciences (Fig. 1.1).



Fig. 1.1. Nobel Laureate Sir Francis Crick and Professor Abdus Salam during a break at the Main Hall of the International Centre for Theoretical Physics (ICTP), now called the Paolo Budinich Lecture Hall, at the International Symposium on Contemporary Physics, which took place in Trieste from 7 to 29 June, 1968. This was the main event organised on the occasion of the inauguration of the elegant Main Building of ICTP in the grounds **o**f Miramare Park, near Grignano. This event took place only four years after the inauguration of ICTP had taken place in the building that had been assigned to it in Piazza Oberdan in the same city of Trieste. Those of us that were fortunate enough to participate in the Miramare Symposium were particularly impressed with Salam's far-reaching vision of Physics, in which there were no artificial barriers between the basic sciences of biology and physics (Photo, ICTP Archives)..

Paul Davies in his memorable "Salam Lecture" has discussed the fascination of the Pakistani physicist with biology (Davies, 2001):

One person that was convinced that physics plays a direct role in life, at least in its genesis, was Abdus Salam... His work on molecular chirality was a bold attempt to trace the well-known handedness of biological molecules to parity violation in electroweak interactions a subject that he, himself founded.

As commented by Gordon Fraser (1943-2013), the late English scientist and divulgator working at CERN, Geneva (Fraser, 2008):

Salam's forays into these realms [astrobiology] were disapproved by most of his Trieste colleagues.

However, Fraser goes on to comment that since at the time there was at least one astrobiologist at the ICTP (the author), who supported Salam, not everyone was insensitive of the great physicist's attention to astrobiology. Soon afterwards Andre Brack, who had attended the Salam discussion of chirality at the first Trieste Conference in 1992, also included a comment in the text of his Ettore Majorana talk in Erice, Italy (Brack, 1993).

The subject of the biological handedness of the macromolecules of life (chirality) was the focus of attention of Salam's last research topic. His approach also invoked the electroweak interaction, but was original in appealing to further physical concepts that may apply at the end of chemical evolution. The first unifying principle in biochemistry is that the key biomolecules: amino acids, sugars, and natural lecithins (phospholipids), have the same 'handedness', or 'chirality'. Chiral molecules and their corresponding mirror images may be defined by left (L), or right (D) optical / rotatory dispersion.

Remarkably, this is true for all organisms with the exception of bacterial cell walls, which contain D-amino acids, as in the case of *Bacillus brevis* or *Lactobacillus arabinosus*. However, we may state in general that living systems translate their genes, following the rules of the genetic code, into proteins composed of twenty L-amino acids. (Recall that the Murchison meteorite has up to 80 amino acids, withut exposing a special chiral preference (Knevolden et al., 1970).

The search for the origin of chirality in the effects of the weak interaction started in the 1950s. In a substantial body of previous work by many authors, the parity- violating electroweak neutral current has been suggested as the main physical force inducing observed biochirality. Abdus Salam's approach also invoked the electroweak interaction, but was original in appealing to further physical concepts that may apply at the end of chemical evolution. He pointed out a particular cooperative phenomenon that may have taken place, namely, a phase transition beneath a certain critical temperature T_c . Amino acids that had been synthesized earlier from various precursors entered into a new phase which was a Bose condensed mode. Abdus Salam asked the present writer to prepare a paper for the Journal Chirality (Chela-Flores, 1991) at the same time as his own paper in the Journal of Molecular Evolution (Salam, 1991), in order to reach a wider audience of scientists interested in the pharmacological, biological, and chemical consequences of molecular asymmetry, and some of the arguments in that paper may be relevant here.

The physical concepts: cooperative phenomena and condensation led Salam to suggest that the electromagnetic force is not the only force which can produce chemical effects: the Z^o component of the electroweak force, in spite of the fact that its effects appear to be negligible at low energies, may play an active role in chemistry. Based on physical concepts Salam was led to suggest that the electromagnetic force is not the only force that can produce chemical effects: he argued that a

component of the electroweak force, in spite of the fact that its effects appear to be negligible at low energies, may play an active role in chemistry.

The reasons for the proposed chemical role of the parity-violating weak interactions may be found in some calculations in quantum chemistry of Stephen Mason, Alexandra MacDermott and George Tranter working in the United Kingdom. Independent calculations of Ayaz Bakasov, Tae-Kyu Ha and Martin Quack from Zürich gave some support to the previous assumptions that Salam had used from quantum chemistry in his own work.

Cyril Ponnamperuma, who was also attracted to this original approach to the question of chirality, proceeded to test these ideas in his own world-renowned Laboratory of Chemical Evolution at the University of Maryland. Although these experiments failed to confirm the model, the experiments were continued by other groups, particularly by Wang Wenqing and co-workers in Beijing. Today, the robust growth of the field includes very accurate verification that organic contents of some ancient meteorites show the same asymmetry as the molecules of the living cell. These results were discovered in the later part of the 1990s. They suggest a rationalisation why the protein amino acids of the living world are left-handed.

2. Abdus Salam's Promotion of Astrobiology at the ICTP

In a meeting in May 1991, Salam suggested to organize a series of conferences on Chemical Evolution and the Origin of Life, which took place for the first time in October, 1992 (Fig. 2.1).



Fig. 2.1. The opening session of the first Trieste Conference, October 1992. Cyril Ponnamperuma is first on the left; Abdus Salam is first on the right.

We should underline that the word "astrobiology" was not widely accepted in the early 1990s. Salam requested the astrobiology pioneer Cyril Ponnamperuma to direct this initiative, coordinated by the author. (Fig. 2.2).



Fig. 2.2. Participants of the first Trieste on Chemical Evolution and the Origin of Life. Trieste, October 1992. (Front row: Professor Abdus Salam is fifth from the right, sitting between Cyril Ponnamperuma on his right and JCF on his left.) Proceedings (Ponnamperuma and Chela-Flores 1993). Standing in the back row fourth and fifth from the right Andre Brack (jacket and tie) and J. William Schopf.

In 1993 and 1994 Ponnamperuma directed the second and third conferences (Figs. 2.3 and 2.4).



Fig. 3. Participants of the second Conference on Chemical Evolution and the Origin of Life. Trieste, 1993. Proceedings (Chela-Flores et al., 1995).



Fig. 2.4. Participants of the third Trieste on Chemical Evolution and the Origin of Life. Trieste, 1994. Proceedings (Ponnamperuma and Chela-Flores 1995).

In Ponnamperuma's left us at a relatively early age, the fourth Trieste Conference on Chemical Evolution and the Origin of Life was co-directed with the planetologist and astrobiologist Francois Raulin (Fig. 2.5), who was well acquainted with the native Sri Lankan scientist, who later took the American citizenship.



Fig. 5. Participants of the fourth Conference on Chemical Evolution and the Origin of Life. Trieste, 1995. Sidney Fox is in the second row sitting down next to JCF, fifth from the left, Chris McKay is in the same row, first from the right, next to J. Mayo Greenberg, Frank Drake, John Oro and the family of the conference co-Director Francois Raulin.Proceedings (Chela-Flores and Raulin, 1996).

From 1997 till 2003 the Trieste conferences were co-directed with Raulin and, to our good fortune, also with the American planetologist and astrobiologist Tobias Owen (1936-2017) accepted to come

to Trieste as co-director (cf. Fig. 2.6 and 2.10). The fith Triexste conference was dedicated to the memory of Abdus Salam (1926-1996), who had passed away preematurely just before our event.



Fig. 2.6. Participants of the fifth Conference on Chemical Evolution and the Origin of Life (*Chemical Evolution: Exobiology. Matter, Energy, and Information in the Origin and Evolution of Life in the Universe).* Trieste, 1997. Conference proceedings (Chela-Flores, Owen and Raulin, 1998). In the second row, seated from left to right: D. De Vincenzi, Frank Drake, Jill Tarter, Antonio Lazcano, Richard Darwin Kaynes, co-Directors Francois Raulin and Julian Chela-Flores, Sidney Fox Herrick and Margaret Baltsscheffsky, J. Mayo greenberg, Wang Wenqing, M. V. Ivanov and for the first time at the ICTP Trieste conference, the co-Director the well-known planetologist Tobias Owen.

We were fortunate to have amog us Sir Richard Darwin Keynes, physiologist and the greatgrandson of Charles Darwin, who delivered the well-documented lecture: "The Theory of Common Descent," on the seminal work of his famous ancestor (Fig. 2.7).



Fig. 2.7. Sir Richard Darwin Keynes, physiologist and the great-grandson of Charles Darwin, (first on the left) at the fifth Trieste Conference.

In 1999 from 28 November till 8 December, we were fortunate to have a main ICTP event Astrobiology Origins from the Big Bang to Civilisation, which was hosted by the recently founded Venezuelan Institute for Advance Studies, it was the Iberoamerican School of Astrobiology (Chela-Flores et al., 2000). Besides the ICTP we were honoured to receive funds among others from the Alberto Vollmer Foundation, Inc. The School was dedicated to the 70th Birthday of Frank Drake with whom we had the privilege to share the School.



Fig. 2.8. Inauguration of the IASA School. From left to right: John Oro, Philosopher Ernesto Mayz Vallenilla, JCF and Guillermo Lemarchand.



Fig. 2.9 Four Venezuelan astrobiologists at the Iberoamerican Advanced School of Astrobiology, IDEA, Caracas. From left to right: Humberto Campins, Sabatino Sofia, Nelson Falcon and JCF. On the left of Sofia, partially hidden: Antonio Lazcano: on the left of Falcon: Abel Mendez.

Within the main events we recall a special session on Solar System Exploration on the occasion of a landing in the Martian South Pole. In spite of the fact that the lander was lost, the l45 minute live contact with NASA's Christopher McKay (cf., Fig. 2.5) was a very instructive experience for the whole School. The campus of IDEA was a peerfect location for the event (Fig. 2.10).



Fig. 2.10 Participants of the ICTP Iberoamerican Advanced School of Astrobiology in Caracas, Fundacion Instituto de Estudios Avanzados, IDEA, December, 1999. (Chela-Flores, Lemarchand and Oro, 2000).

For this occasion we were able to go deeper into astrobiology due to the presence of Drake and Oró, as well as scientists of the region that had already participated in the Trieste conferences; but we also benefitted from the insights of new contacts with other scientists and humanists: Elinor Medina de Callarotti, Humberto Campins, Jesus Alberto Leon, Ernesto Palacios-Pru, Hector Rago, Juan G. Roederer, Sabatino Sofia, Ernesto Mayz Vallenilla and Raimundo Villegas. Altogether 125 participants attended the Caracas meeting.

The sixth Trieste conference, *Life in the Universe From the Miller Experiment to the Search for Life on Other Worlds*, took place at the ICTP campus from 15-19 September 2003 (Figs. 2.10 an 2.11). This event was dedicated to the celebration of the 50th Anniversary of Stanley Miller revolutionary experiment (Miller, 1953). This seminal experiment took the search for the chemical origins of life to a new level with the laboratory synthesis of compounds required for life under conditions that resembled the early environment of the Earth. Since that time scientists from around the world have developed a multidisciplinary field "astrobiology" (adapted from Johnson, 2004).



Fig. 2.11. Participants of the sixth Trieste Conference. In the front semicircle, Stanley Miller fourth from left to right with white short sleeves. (Proceedings Seckbach, Chela-Flores, Owen, and Raulin, (2004).

As in previous occasions during the ICTP conferences and schools on astrobiology, we had the presence of the American astronomer Frank Drake, who initiated the Search for Extraterrestrial Intelligence with Carl Sagan, Phillip Morrison and others in the 1950s (Fig. 12).



Fig. 2.12. Group at the seventh Trieste conference at the ICTP. From left to right Roberto Aretxaga, JCF and Frank Drake.

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(#) Based on Chela-Flores, J. (2019) and on Chela-Flores, J. (1996).