Emilia Currás *, Enrique Wulff **

Integration in Europe of human genetics results obtained by Spaniards in the USA: A historical perspective

(1) Introduction

The mobility of the Spanish biochemists from Europe to the USA along 80 years (1927–2006) is approached in a historical perspective. Human genetics academic community, has paid tribute to this displaced Spanish community with awards like the Nobel Prize, or others honors due to European Foundations. An opportunity to understand this extraordinarily satisfactory history, of one small European community overseas, is offered by the vertical / horizontal integration methodology. To piece the puzzle together, continuous reference is made to the theory of systems. To test and use this holistic history, the circulation of knowledge produced on cancer has been seen as inextricably related to time by using algorythmic historiography.

Francisco Duran Reynals and Severo Ochoa are selected as examples for the vertical integration. The former as conducting the work of one important collaborator, his wife; and the second because of the establishment after his work of a specific Spanish research school in America. The simultaneity at the Columbia University of several young Spanish scientists (Mariano Barbacid, Manuel Perucho and Ángel Pellicer), serves to design the horizontal integration. And a holon hierarchy is constructed to reflect the criteria of subsidiarity and acceptability. Focused on the Spanish discoveries and contributions to cancer research.

The transatlantic knowledge flows generated by the Spanish biochemists elite in the USA from 1927, define a network of geographic displacements. The social structure thus visualizes the identity of the international mobility of the scientists going out from Spain to Europe / USA, and their return to Spain. A model of professional drainage to the USA, retaining 80% of the Spanish cancer investigators, is developed.

(2) Background

The little interest shown by Spanish scientist in accessing the foreign scene in order to research in any branch of human knowledge is known from old times. In certain historical times, the Spanish researchers, and the scientists in general, seem to have felt a certain inferiority complex in front of their companions, in such tasks, of other foreign countries. According to the data, referred in several specialized documents, the European countries have been those before which they have felt greater degree of inferiority. These countries were the Scandinavian Countries, Germany and France. Such a feeling of distrust with themselves even let to attribute to foreign scientists, the inventions and the discoveries their own nationals have performed. The most shocking case is the one of the Elhuyar brothers, discoverers of the metals Tungsten and Cesium, that have been attributed to Scandinavian scientists.

The fact that the science and the technique does not appear as a fundamental element in the development of Science in Spain, is due, perhaps, to its little economic level, in certain historical periods, to operate them at international commercial level. What is to say that, although a Spanish can be the discoverer of an invention, facing the public opinion a foreigner appears, like the proprietor of such an invention. Let us mention, as a relevant example, the case of the autogyro, invented by Juan de la Cierva. Today it is called helicopter and is presented as a North American invention. Although it is also true that, the helicopter displays certain modifications improving the autogyro.

* Universidad Autónoma de Madrid, Madrid, Spain; email: emilia.curras@uam.es.

** Consejo Superior de Investigaciones Científicas, Cádiz, Spain; email: enrique.wulff@icman.csic.es.

What we are saying, has taken place mainly during centuries 18th and 19th. In the 20th century, mainly after World War II, and the incorporation of Spain to the partnership of countries with a certain level of development, the Spanish scientists have felt the anxiety to appear in the world-wide ranking, what is obtained, little by little. Now, the causes behind the absence of such a desired incorporation, are of different nature. Here, it comes into play the economic level. Nevertheless, we do not have to be so pessimistic. We have in Spain, and you the Historians of Science must know it better, some excellent investigators, who have made research works in foreign countries. Let us mention like examples: Santiago Ramon y Cajal — Nobel prize —, Julio Palacios, Blas Cabrera, Emilio Jimeno, Augusto Pérez-Victoria, ..., all these scientists have returned to Spain, where they have followed their lines of investigation and have created their schools.

Later, after the publication of the agreement by which each student who reached the Degree of Doctor had to spend two years of studies abroad, the Spaniards who have passed by Universities of different countries, in order to perform research works, have been numerous. Some between both the historical and the present researchers, have remained in their welcome countries, either because of professional prestige reasons or because of economic reasons. In Spain, it is not yet easy to find a job satisfactory, it depends on the individual.

This communication has been concentrated only in those that, mainly, they have dedicated their investigations to the human genetics, in concrete to the studies of the cancer.

(3) Vertical / horizontal integration of human genetics

The concept of discipline can be defined through the communication structures established between the scientists in the context of the systems theory.[1] On the other hand we advance that human genetics seems important for the history of the human species, because inside the proteins or inside the nucleic acids "it exists more preserved history than in any other level of biological interaction".[2] The study of the development of science, in itself, and in a broad perspective, requires a special dedication and an adequate methodology. It appears that both the vertical integration of science [3] and its horizontal catalogue, can be suitable methods.

Ignacy Malecki and Eugeniusz Olszewski [4] identified trends in science towards complexity, and vertical and horizontal integration. After them it could be said that because the orientation towards the problem is typical of the human genetics, and in particular of cancer, the criteria of visibility of the research theme is vertical, in first instance. But that as the empirical empirical work occurs in the frontier between diverse horizontal strata, new disciplines have resulted, like biochemistry and molecular biology.[5] [6] So the organizational principles are horizontal in cancer research, and this is also because common instruments or methods are employed, that act as an horizontal integration factor. As elaborated by Emilia Currás [7] the vertical / horizontal integration is based on a non-linear progress. A dissipative structure that makes appreciable an unified approach. The research can be mapped from one vertical stratum to another one and through the different conceptual spaces of the diverse horizontal stratum. The strong nonlinearities, the dissipative structure, of many of the disciplinar components interdependencies in research, make appreciable the unified approach, the holistic vision.

[1] R. Stichweh (2000): "Systems theory as an alternative to action theory? The rise of 'communication' as a theoretical option", *Acta Sociologica*, vol. 43(1), p. 5–13.

[2] E. Zuckerkandl, L. Pauling (1965): "Molecules as documents of evolutionary history", *Journal of Theoretical Biology*,vol. 8 (2), March 1965, p. 357–366; http://profiles.nlm.nih.gov/MM/B/B/N/V/_/mmbbnv.pdf.

[3] E. Currás (2002): "Vertical integration of sciences: an approach to a different view of knowledge organization", *Journal of Information Science*, vol. 28 (5), p. 417–426.

[4] I. Malecky, E. Olszewski (1972): "Regularities in the development of contemporary science", *Organon*, vol. 13, p. 193–212.

[5] F.L. Kiselev (1990): "Molecular oncology", in: R.V.Petrov (ed.): *Medical dimensions of molecular biology* (Moscow).

[6] J.A.Witkowski (1986): "Somatic cell hybrids : a fusion of biochemistry, cell biology and genetics", *Trends in Biochemistry Sciences*, vol. 11, March 1986, p. 149–152.

[7] E.Currás (2002): *Towards a theory of information science* (Delhi).

(4) Application to our case study

By following the title of our communication, our case study refers to the Spanish scientists, that have left abroad where they carried out their research. Between them, the cancer researchers have been chosen, in their different variants and peculiarities.

The three following categories were established: a) those which moved there and which remained there; b) those which moved by their wish to innovate, which in their majority returned to Spain; c) those which went abroad in order to study their "post-doc", whom in their majority have not yet returned. They are still young.

And by choosing a group of 40 researchers, it has been catalogued, as well, into: 1) Precursors; 2) Founders; 3) Directors (or former directors) of laboratories in the USA; 4) Researchers in their period of post-doc studies. This list of Spanish researchers presented, as distributed by these divisional criteria, was formulated by Ángel Pellicer, from the New York University School of Medicine.[8]

This group shows a possible decomposition into 4 columns; a vertical integration can be built from them, with the relationships established between them, as well. No doubt exist on the mutual influence between the researchers columns. Taking into account that these columns arise as a consequence of the passage of time, which is proved indeed by the own established divisions, a consequence of this time passage. The precursors have been previous chronologically to the founders and as well these last ones, were previous to those that had been directors of laboratories. Naturally, these last ones are previous in chronological sense to the post-doc researchers. As a consequence, into this attempt to establish a vertical integration between the established columns, an integration from the bigger to the minor must be considered, what supposes the introduction of the time factor; a time factor that must imply a path from the older to the modern.

It is beyond any doubt, with respect to the scientific influence, that the researchers who went to the USA in early times have influenced those that went abroad afterwards. Some have been the models to be followed and others became their responsible senior researchers, directors of scientific works, or important collaborators.

What has been referred assumes the establishment of vertical relationships, between the Spanish scientists who have performed their research in the USA. Logically, not all the scientists have had some influence on all the chronologically posterior scientists. It would be necessary to study case by case. Perhaps, some examples of direct influence could be cited, like Maria Luisa de Ayala, that followed the research lines of her husband Francisco Duran Reynals.[9] A very outstanding case is Severo Ochoa — 1959 Nobel Prize — who has established a school and has been the master of many Spanish researchers, nowadays of international reputation, like Margarita Salas and Santiago Grisolía.

If it is desired the establishment of the collateral relationships of influence of each group on the other (others) one, it should be resorted to a horizontal integration between the groups formed. It seems comprehensible, that the horizontal interrelations must imply an interaction mutual and reciprocal, ie, the influences carry an arrow which marks two directions. Indeed, in the practical cases, one knows that some Spanish scientists coincided at the same laboratory, or in the same university, and that they worked there in closer subjects, by making themselves mutual consultations and putting themselves in discussion on the results obtained. Important examples are those of Mariano Barbacid and Ángel Pellicer in 1979, in the USA (Columbia University). As well, Manuel Perucho has coincided with Mariano Barbacid in the Columbia University on 1979.

When the vertical integration of the interrelations between the Spanish scientists is applied, and when the horizontal integration is put in action, positive results will be concluded from the research performed. In the cancer studies case, between many others, Joan Massagué must not be forgotten, whom studied the molecular mechanisms of inhibition or stimulation of the cellular growth and, that managed to be elected as a member of the United States National Academics of Sciences, in 2001.

[8] Á. Pellicer (2004): "Contribución de los científicos españoles en Estados Unidos a la bioquímica", in: E.Muñoz (ed.), *Cuarenta años de la Sociedad Española de Bioquímica y Biología Molecular* (Madrid, 2004), p. 227–248.

[9] T.F. Glick, A. Roca Rosell (1999): "Francesc Duran Reynals (Barcelona, 1899 – New Haven, USA, 1958). Virus and cancer: a controversial theory", *Contributions to science*, vol. 1, p. 87–98;
http://www.cat-science.com/admin/articles/pdf_990101/07_Virus_and_Cancer.pdf.

Carlos Cordón-Cardo must be also mentioned because of his studies of molecular pathology, what resulted into the molecular study of the urinary bladder cancer. It should be noted that these are examples extracted from different and varied cases. The *Table*, in the Appendix, reflects the performed research and the obtained results.[10] [11] [12] [13] [14]

(5) Implications of the systemic science

The study of the interrelations between the Spanish scientists has been presented by considering, on one side, the vertical integration between them, and on the other side by applying the principles of the horizontal integration also between them. But nothing has been said on how to establish these interrelations and to proceed. The systemic science, based on the system theory plays its role here, to which a greater degree of complexity is to be added, when approaching a definitely scientific theory.

With the purpose not to increase the complexity, nor to enlarge this communication, and assuming that the principles of the systemic science are well-known, it is postulated here that the systemic science implies a mutual and pluridirectional relation of all its components. First, it must be built the reference system, and the first holon must be established, eg, the first cornerstone or element that will form the system. In the case of this communication, this holon is fixed in a Spanish scientist, the Nobel prize Severo Ochoa. As different groups of scientists have been established, we construct as many systems as implemented (data not shown; operated with the HistCite™ software). And then by the interactions, vectors, flows and reflows that influence the system, its evolution can be studied and an holon hierarchy is obtained as a result (see Appendix for the *Figure*). Inside it the coherence relationships are guaranteed by the autonomy and capability of Severo Ochoa, who uses his executive skills for presenting to the National Academy of Sciences of the USA articles by authors in the holons developed at levels 3 and 4 (eg two articles, by Santos & Barbacid in 1983, and by Perucho in 1985) and by writing in coauthorship with authors of the holon in the second level (8 articles with M. Salas between 1965 and 1967). Therefore, the acceptability of the results inside the 4 holohierarchical levels, that expresses the capability for the coordinated action and mutual agreement, develops the definition of holon in terms of autonomy and ability to cooperate. The three integrants of the second holon were trained in the laboratory of Ochoa, the five from the third holon in the Salas' labo, and the three at the fourth were trained at Barbacid's labo. The criteria of subsidiarity between the holons and the different levels would be, so, the results acceptability.

The results of the performed researchers by the spanish scientists having developed their scientific task in the USA, in the subjects referred to cancer are exposed in the *Table* (see Appendix). Logically, the *Table* can not be exhaustive, if not for other reason because of the absence of data exhaustive in its turn. Nevertheless, it shows the efficacy of the Spanish scientists, in their going out to the USA; that appears not to be without importance.

(6) Transatlantic knowledge flows: evidence from the citations

The triumphant growth of the American science after 1940 has greatly accelerated the importation of scholars coming from Europe. The history of the emigration of the Spanish elite in biochemistry to the USA begins in 1927 with the displacement of Francisco Duran Reynals from the Institut Pasteur (Paris) to the Rockefeller Institute in New York City. And it becomes outstanding after the 1941 arrival of Severo Ochoa to the Washington University School of Medicine, in provenance from the

[10] D. Casacuberta, A. Estany (2003): *¿Eureka?: el trasfondo de un descubrimiento sobre el cáncer y la genética molecular* (Barcelona).

[11] À.Pellicer, "Bases moleculars del càncer" (2005), in: *Dissetè Congrés de Metges i Biòlegs de Llengua Catalana* (València, 2005), p. 15–28.
http://alsina-bofill.iecat.net/documents/ponencies17congres/03%20Pellicer%20Pag%2015_28.pdf .

[12] M.Morange (1997): "From the regulatory vision of cancer to the oncogene paradigm, 1975–1985", *Journal of the History of Biology*, vol. 30, p. 1–29.

[13] E. Wulff (1996): "Historia del descubrimiento del orígen de la formación de los tumores: el programa del Dr. Barbacid en los albores de los estudios sobre oncogénesis", *Llul*, vol. 19, p. 525–549.

[14] E. Wulff (1996): "The natural history of the discovery of hereditary carcinogenesis of the colon – Scientific dynamics in information flow", *Arbor*, vol. CLIV(608), p. 9–31.

Marine Biological Laboratory in Plymouth (UK). Without the attraction power of these precursors' personalities, the direct exit from Spain of all the others biochemists, founders and developers, of the Spanish elite of cancer researchers can not be explained.

The history of the Spanish biochemists bastion in the country with the biggest scientific development, is the same than the one defined by the knowledge circulation that it produces. And it is the history of the stratification of this community, the history of its social structure. [15] For the purposes of this communication we define "social structure" as the strong ties that are created along the research career (doctorate and bachelor''s degree obtention, post-doctoral options) and along the mobility dynamics (the going out from Spain to Europe / USA, and the return to Spain). The network of geographic displacements generates a general image of this social structure.

Although, occasionally, the "older" scientists do not have their initial publication in the databases, the obtention of their C.V. through internet is not always available. It is why, in first instance, it seems adequate to identify the international mobility of scientist by the employment of bibliometrics methods.[16] [17] [18] Two recent contributions[19] [20] honor the Spanish biochemists that moved to USA in order to attend regular university courses. The first one was Marino Martínez Carrión in 1959. Spanish doctorates in the universities of Bolonia (Izpisúa in 1987) and Heidelberg (Muñoz in 1995) also migrate to the USA after the European integration of Spain (1986).

Let us begin our analysis by the question: who exactly have been the Spanish elite of biochemists in the USA along the last 80 years (1927–2006), which is the circulation of the knowledge produced by them on cancer? In this particular historical case we built our work by using the recent contribution on the history of the SEBBM (Spanish Society of Biochemistry and Molecular Biology).[21] It is a prosopographical description written with a close knowledge of the basis of the spanish network of biochemists in the USA. It codes a set of 40 biographies through a typology of four relations: (a) a type of initiational relation — the precursors (four biographies); (b) a type of basical relation — the founders (five biographies); (c) a type of "political" relation — the conduction of a laboratory in the USA (twenty biographies); (d) a type of "developmental" relation, for the young that are in a initial stage of her / his career in the USA (nine biographies).

The pieces of work of the 40 biochemists that migrate from Spain to the USA were 7.187 journal articles, in the period 1927 to 2006. They are professional trajectories enough complete as to generate citable publications. The best model to reach the historical basis of this documentation is to dispose the citations that each article receives by placing the more recent in the first place. As a method for the long-term study [22] this form of emphasize the most recent utility of the information stored in the library of the migrant Spanish scholars, offers a larger basis for the retrospective vision. An extension of the present in order to detect the roots in the past.

194.131 citations can be assigned to these 40 biographies, performed by a total set of 70.711 authors between 1927 and 2006. The average number of citations per member of Group I (the precursors, with dates of entrance in the USA between 1927 and 1953), was 725, the median 1173. In the Group II, the founders (1945–1959), the mean was 1812, and the median 2275. In the Group III, the directors of laboratory (1971–1993), the values were for the mean 1999.7 and for the median 2429. At last, for the Group IV of scientists in the initial phase (1988–1996), the mean is 1829, and the median 1659.

[15] J.R. Cole, S. Cole (1973): *Social stratification in science* (Chicago).

[16] G. Laudel (20003): "Studying the brain drain: can bibliometric methods help?", *Scientometrics*, vol. 57 (2), p. 215–237.

[17] A.S. Pierson, P. Cotgreave (2000): "Citation figures suggest that the UK brain drain is a genuine problem", *Nature*, vol. 407 (7), September 2000, p. 13.

[18] The citation data for the complete universe of the 40 elite scientists that we study can be supplied under request to the authors.

[19] See Note 11.

[20] See Note 8.

[21] See Note 8.

[22] E. Trist (1973): *Organizaçao e financiamento da investigaçao* (Lisboa).

Even though the number of journals in biochemistry and, the number of biochemists, has grown quickly between 1945 and 1988, when the authors are considered after the citations they receive, the average assigned to each one remains almost inalterable. The association is meaningful between the Groups II, III and IV, with F = 69. These three adjacent time intervals (1945–1959), (1971–1993), (1988–1996) resemble between them. The constant prolificity in the publication and in the acknowledgment through the citations reflects the stable stimulus to research and to publication in the North-American universities.

A substantial difference exists with the initial period (1927–1953), because F = 0.2 for the four groups. The migrant scholars, precursors of the biochemistry made in the USA by Spaniards, were born between 1899 and 1911. The production frontier, defined a fitting line, reveals two of the precursors as outliers, in the right side of a graphical display. One (Grande Covián) was politically punished until 1950, and this is the motive of the isolation effect concerning him.[23] The other one, the Nobel Prize Severo Ochoa, appears in the right upper zone. And the intensity of his intellectual contribution in terms of citations and his slower tendency to depreciation along the time are emphasized.

The percentual scheme of acknowledgment follows the same model for the four groups, so far as it concerns the citations origin. The USA acknowledge the Spaniards in 42% of the occurrences, Spain recognizes them in 4.5% of the times, and the rest of Europe in 33% of the chances. Also, there is no meaningful statistical difference (F = 0.21) in the acknowledgment patterns [24] between those authors that returned to Spain (647/67/449), and those that remained in the USA (848/63/669). For the cancer research the knowledge circulation is like this: 831/54/586. This pattern seem alike to the identified for the authors that remained in the USA. And, indeed, 80% of the Spanish cancer investigators studied do not return to Spain.

Nevertheless, outstanding differences appear if taking into account the demography of scientific authorship. If the criterion is, where they have written the doctoral dissertation, we find that the citation maximum rate appears for those authors that have presented their dissertation in non-Spanish European universities (1001/87/806). After them, come those whose dissertations have been presented in Spain (866/69/635). And in last position, the scholars that have performed their dissertations in the USA (649/44/588).

Therefore, the production of the Spanish biochemists, does crystallize in a professional drainage model to the USA that favours the circulation for the doctors coming from Europe, that gives priority to the national doctoral diplomes obtained in Spain, and that only in the last term, gives preference to the USA framework for the obtention of the title of doctor. It must be noted, that it was in 1956, that the first member of this group of Spanish biochemists presented his dissertation in the USA (Joan Oró, at the Houston University) and that 1959 was the first time that one of these scientists (Marino Martínez-Carrión) has displaced himself to the USA to attend regular university courses there.

Also, it must be underlined that the USA results of one of the Spanish leaders (Mariano Barbacid, 1021/118 /730) obtained the best reward from Europe for cancer studies in 1988 [25] (the research prize by the Dr. Josef Steiner Cancer Research Foundation, University of Basel (Switzerland)). And again in Vienna, 1994, along the sessions of the European Neuroscience Association 17th annual meeting, the Neuronal Plasticity Prize of La Fondation Ipsen was awarded to Barbacid because he was the first to identify and clone the trk oncogen.[26]

The singularities relevant to the exilic and depurated persons after the war 1936–39 [27] appear as a

[23] R. Llavona, J. Bandrés (2003): "Francisco Grande Covián y la psicología", *Psicothema*, vol. 15 (3), p. 345–351; http://www.psicothema.com/psicothema.asp?ID=1071.

[24] The acknowledgement pattern is expressed as the average number of citation by member of the sample; and the computed sample members are those from the USA, from Spain, and from the rest of Europe (eg (647/67/449), expresses the mean citation rate coming from the USA '647', from Spain '67', from Europe '449').

[25] See: http://www.steinerstiftung.unibe.ch/pdf/krebsforschungspreis1988.aspx.

[26] E.Wulff (2006): "La familia trk de receptores de las neurotrofinas y el receptor p75, un caso de caracterización de hipótesis múltiples en la historia del factor de crecimiento nervioso (NGF)", *Actas IX Congreso de la Sociedad Española de Historia de las Ciencias y de las Técnicas* (Cádiz; in press).

[27] N. Coni (2002): "Medicine and the Spanish Civil War", *Journal of the Royal Society of Medicine*, vol. 95, p. 147–150.

natural point of study for this period. Their average citation counts are the lowest (432/21/401). In all the cases, the loss of scientific stature of their native country influences those authors. The reasons for their international mobility, does not prevent for them the return to Spain (Francisco Grande Covián), or the reception as members of prestigious groups like the USA National Academy of Science of the USA (Pedro Cuatrecasas). The election to this honorific position (member of NAS) in two of the cases of these Spanish emigrants (Pedro Cuatrecasas, Joan Massagué) is remarkable because of the disproportionate number of citations that they receive, a fourth part of the total acknowledgment obtained by the biochemical emigrants. These high productivities, by suggesting that the displacement to a new environment develops the abilities that the displaced scientists brought from Spain, equally concern a scientist coming from the exile (Cuatrecasas), than another scientist that received his degree in a seventies Spanish university (Massagué).

Along these 80 years, 1927–2006, the number of these USA reception institutions, have grown at least until 27. And eight were the Spanish centers able to project their post-doctoral training in the USA. And the percentual expression [28], confers 40% of the creativity to the Barcelona campus, 22% to the Valencia campus and 14% to Madrid. From the USA to Spain, 11 Spanish institutions (at least) receive the influence of the emigrants' built biochemistry.

Only 35% of the cases express the return of the scientists to their origin's country. In the rest of the data, punctual cooperations from the USA with Spain are solely indicated. CSIC, as independent from the universities, appears interested in favoring the access to the exterior and in the facilitation of the return mobility.

(7) Conclusions

Along this communication we have advanced that the economics reasons, the innovation, and the prosecution of the post-doctoral studies segmented the Spanish scientific emigration to the USA.

In the first part of this contribution an homology is posed between the cancer research object, the mobility organisation of the Spanish scientists working on it in the USA, and the visibility of the results that they obtain. The history of this mobility is developed by using as a methodology the vertical / horizontal integration of science from the systemic point of view. A group of 40 migrant biochemists is splitted into four columns, vertically displayed after the introduction of time as factor. This vertical influence has permitted the chronological distinction between founders, precursors, laboratory directors and post-doc researchers. The interest behind the application of the horizontal integration is highlighted in the case of the Spanish research on oncogenes, because of the coincidence in Spain and in the USA of the same scientists in the same laboratories. With systemic criteria of estimation the holon-hierarchical identity of the Spanish research on cancer in the USA is studied, and the main discoveries and contributions in the period (1927–2006) are pointed out.

In the second part we have dived into the scientific careers of 40 European scientists who have moved to the USA and (eventually) have made their way back to their home country, Spain. An average count of the citations received by the Spanish biochemists arrived at the USA between 1927 and 1953, 1945 and 1959, 1971 and 1993, and 1988 and 1996, has been made. The geographical origin of the citations (USA, Spain, Rest of Europe, Rest of America, Asia, Oceania, and Africa) and the emigration (authors that turn back to Spain vs. authors that remained in the USA), have been parameters to take into account. As a consequence the isolation and centrality effects of the scientific production of the migrants scholars (as a function of their age) were analysed, and the topography of the knowledge that they produced on cancer, has received special attention. The demography of the scientific authorship and the model of professional drain towards the USA after the universities where the researchers have presented their dissertations (in Spain, in the rest of Europe or in the USA) is highlighted. The election to outstanding positions (like being a member of the US National Academy of Sciences) between the emigrants, is also an aspect considered. As a last point, the US and Spain research institutions involved, are put into a scheme, by describing the most creative Spanish campuses in terms of mobility; and the returns of the scientists to their home country is interpreted.

[28] V.V. Nalimov (1981): *Faces to science* (Philadelphia), p. 250.

Appendix.

Figure. Holon-hierarchical identity of the cancer research, by Spanish scientists in the USA.[29]

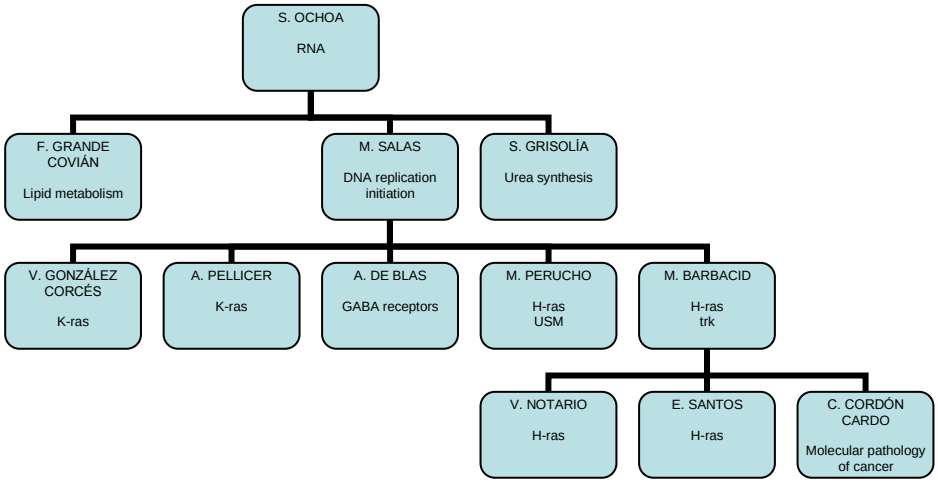

Table. Spanish discoveries and contributions in the USA to cancer research (1927–2006)

Duran Reynals F, 1928.	Hyalurodinase discovery, or Reynals factor of infection diffusion discovery.
Duran Reynals ML, 1980.	Maternal resistance factor to the leukaemia virus.
Perucho M, 1982.	Human oncogene first isolation (T-24), nowadays called H-ras.
Santos E & Barbacid M, 1983.	- ras oncogene mutation point conferring malignant properties to their genomic product identification.
De Blás AL, 1983.	Isolation of the endogenous benzodiazepines.
Pellicer A & González Corcés V, 1984.	K-ras oncogene gamma radiation activation.
Perucho M, 1985.	New diagnostical method of the expression levels of the ras oncogenes in human tumors.
Barbacid M, 1986.	Identification of the trk oncogen as the receptor for the Nerve Growth Factor (NGF).
Massagué J, 1986.	Discovery of the signallement mechanisms by TGF-beta of the cell growth and differentiation factors.
Perucho M, 1992.	Discovery of the mutator phenotype responsible of the colon cancer.
Núñez G, 1993.	Isolation of the gene gel-x, dominant regulator of the apoptodic cellular death.

[29] Abbreviations: RNA.– ribonucleic acid; ADN.– deoxyribonucleic acid; K-ras.– Kirsten rat sarcoma 2 viral oncogene homolog; GABA.– gamma-aminobutyric acid; N-ras.– neuroblastoma ras viral oncogene homolog; USM.– Ubiquitous somatic mutations; H-ras.– Harvey rat sarcoma viral oncogene homolog; trk.– tyrosine kinase.