One Hundred Years of Imagination: Gerald Holton as Historian, Scientist, and Humanist

Author: Dr. Jorge Luis Contreras Vidal

With the essential contribution of Dr. Lorraine Jennifer Daston

And with the collaboration of Dr. Sergio Octavio Valle Mijangos, Mtro. Daniel Iván García Vivas and MSc. Xenia Pedraza González.

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Contenido

Preface

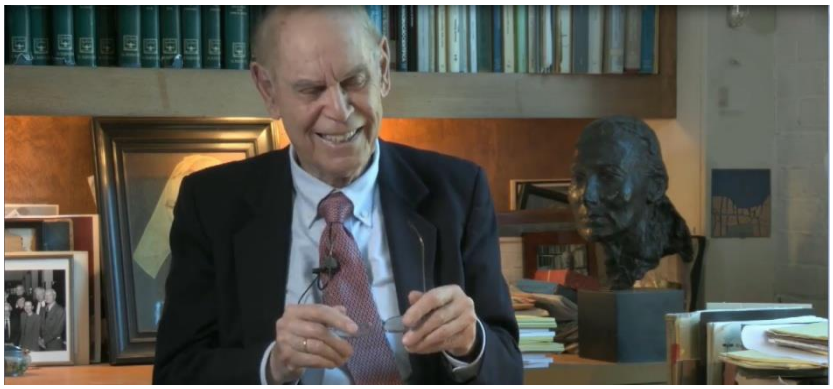
To write a book about a man of Gerald Holton's stature and genius is indeed a great pleasure, but it is also a very difficult and responsible task. When the idea of doing so arose, I did not have the exact picture of what to include. His work is too vast and it, along with part of his biography, is on the internet, so what to say about this person that was otherwise new and original.

I made attempts to contact his students, friends, family, colleagues and former students. I searched the internet, sent emails to various departments at Harvard University to get help from them, to get their opinions and experiences with this brilliant professional, but all efforts were unsuccessful.

Of these darings of mine, Holton never had the slightest idea, nor does he. When he reads this book he will find out and possibly even reprimand me because he always insisted that he did not want me to disturb anyone. That I should write about him, he authorized me to do so, but from my vision, as I had originally communicated to him, but my intention was to honor him in the best way and not to write anything that he would not agree with or that might disturb him. We were both, I think, in a way right, and I had only the help of Lorraine Daston, his favorite student, but of this story I will tell later, as well as of the reprimand I received from Holton for having done so. A well-deserved reprimand and from which I learned a lot because you always learn from Holton, of which I have no doubt.

Having failed in my initial attempts, as I already related, it was then that I thought that the best way to achieve this book was through the personal vision I have of Holton, whom I have known since 2017. A personal vision perhaps limited, but full of enthusiasm and a lot of love. A personal vision full of subjectivities and imagination but, without a doubt, very sincere and honest. A vision based on the books, video interviews and articles to which I have had access, but above all founded on the mutual exchange of emails.

Holton, with that kindness and humanism that characterizes him, has maintained with me a notorious communication and, above all, I have received from him a lot of help. Holton, in spite of living in the United States, a country whose different governments,



since 1959 to date, have maintained and maintain a blockade on Cuba in different aspects of social, political, cultural and economic life, has not cared if I am a communist or not, if I live in a communist country or not. He has only been interested in the fact that I am a professional dedicated to making the teaching of physics better and more motivating for all those who study it and want to study it.

Holton lives above his time, he is worth and shines on his own and is an extraordinary humanist. His attitude towards life is very similar to that of Albert Einstein, according to my point of view, in some senses, since Einstein was branded as a communist, however he decided to live as he thought and so does Gerald Holton, expressing his views, his ideas, without being afraid to do so, always keeping an open mind that flies higher than the petty issues that try to manipulate the different spheres of reality in which one lives. He, like Benito Juárez, also puts into practice that beautiful phrase that "Among individuals, as among nations, respect for the rights of others is peace" (Tamayo, 1967, pp.248-250).

Thanks Gerald Holton for calling me friend and for all the advice that has come from you to help me in this work of educator of Physics and its History. A big hug from me and may this book serve, not to exalt more your figure that in itself reaches **and** embraces even the most remote place of the universe, but to bring you closer to all lovers of science, especially Physics and, above all, to those who still hesitate to study it or are unmotivated to do so because they have been taught it very poorly.

For all of the above, and for all that remains to be read in this book, is that I express what José Martí once said: "He who does not know how to honor the great is not worthy to descend from them", an aphorism written by Martí on May 1, 1883 and published in the newspaper *La Nación*, of the city of Buenos Aires, on June 16 and 17 of that same year. Well, dear and esteemed Gerald Holton, this book is the way in

which I wish to honor you in the course of your100 years of life.

And if Einstein, your most admired man of science, on the occasion of the seventieth anniversary of Gandhi's birth, in 1939. Published in Out of My Later Years, New York, Philosophical Library, 1950, said of Gandhi: "Future generations may not be able to believe that such a man ever walked this earth in the flesh and blood". Paraphrasing this great scientist, I assure you that the present and future generations of physicists do believe and will believe that a man of your greatness is and will always be guiding their steps, because your work and actions are like light and love: simply inexhaustible.

Finally, just to say, that for the writing of this book I have also counted on a selection of Holton's books and essays that I downloaded from *DASH* (Digital Access to Scholarship at Harvard) and on some videos containing interviews, words of thanks and speeches given by him, such as:

1. *The Einstein Revolution, Chapter 3: Einstein, the Miracle of the Year, part 2, where he was interviewed by Dr. Peter Galison, one of his excellent students.*
2. *J. L. Sert A nomadic dream. With script and direction by Pablo Bujosa Rodríguez.*
3. *BBVA Foundation. 100 years of Albert Einstein's General Theory of Relativity. Interview Prof. Gerald Holton. Professor of Physics and Professor of History of Science. Harvard University. USA. Interview by Luis Quevedo. Journalist specialized in science.2013*
4. *BBVA Foundation. Interview with Gerald Holton. Frontiers of Knowledge Award in the Humanities.*
5. Gerald Holton's acceptance speech for receiving the *Frontiers of Knowledge Award in the Humanities.*
6. *Greetings from Gerald Holton to the writer of this book and to all the participants in the Latin American tribute to him on June17, 2021.*

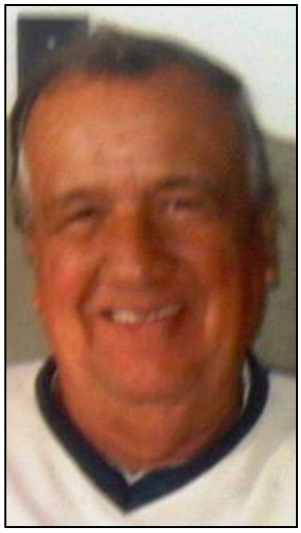
In addition to books and articles that will be referenced throughout this work and the faithful copy of the Latin American tribute that was made to him on June17, 2021.

The photos and images that do not involve Holton I borrowed from Wikipedia and those photos that do involve him, using my computer's Print Screen, I worked on them in Paint, after having copied them from the afore mentioned videos themselves. I recommend everyone to look for and watch the videos mentioned, which are referenced at the end of this book. Very well done and instructive videos, I would say great, so you can get a real idea of the depth and objectivity with which Holton deals with the different subjects he is asked to comment on.

Dear Holton, dear friend, a big hug.

Your friend, Jorge Contreras

DEDICATION



To Luis Contreras Díaz de Villegas, my old man, my “viejuco”. To the one who taught me to wake up every day with a new dream and to fight for reality to overcome it without letting myself be defeated by the demons of tiredness, laziness, hopelessness and fear of not achieving every goal I set for myself. To you, my father, who had the audacity to leave very early to illuminate my steps and intellectual concerns from spirituality and to keep you by my side whispering to me every second: Go ahead, my son, do not faint, you can do it!

ACKNOWLEDGEMENTS

From my father I learned that gratitude never expires, that it has no expiration date and that it is for life, that to be grateful for every good, just and noble deed, it enlarges the soul and purifies the spirit within us. That is why I am grateful:

To the Rector Daniel Iván García Vivas, of the Universidad Mundo Maya, Campus Campeche, Mexico, for the organization of the Latin American tribute to Gerald Holton, on June 17, 2021. Rector Daniel

is always willing to carry out and support any action that generates excellence in the educational process, regardless of the level at which it is carried out and who always puts the Principle of Greatness very high. We also thank the directors and teachers who under his guidance made possible the realization of the tribute, among whom are Ms. Samaria Sitlali Hernández Martínez, Dr. Lizette Adriana González Gómez, Ms.Jennifer Astrid Pech Patand and Ms. Jackeline Castañeda Romero.

To Dr. Sergio Octavio Valle Mijangos who has been by my side for some years in the writing of several books and articles. Undoubtedly, he is an excellent professional who knows how to combine his desires, aptitudes and professional attitudes with the responsibilities of a manager, something that few can achieve.

Xenia Pedraza González and her husband Yosbel Lazo Roger, general director and manager, respectively, of the company GESICAP in Ecuador, who never say no to the request for mutual collaboration and whose were a key piece in the development of the tribute mentioned above. We also thank them for their willingness to publish this book in their company.

And finally, to whom better than the very, very special thanks to the illustrious Dr. Lorraine Jennifer Daston, Executive Director of the Max Planck Institute for the History of Science in Berlin, Germany, for writing for this book and enriching with her ideas this work, which more than a scientific value, contains a wealth of feelings that go beyond the prison of words.

To the memory of Ms. Jackeline Castañeda Romero, who was an English teacher at the Universidad Mundo Maya, Campus Campeche, who sadly passed away weeks after having served as a translator in the afore mentioned tribute. Our Eternal gratitude to Jackeline.

1. Very brief introduction

In this book I recreate the friendship I have maintained with one of the most dignified, kind and humanistic human beings of all times. Gerald Holton is among those people who are born to be imitated, to be followed in their walk, to learn from them because they are an inexhaustible source of wisdom, peace and much love.

I try with each of the headings to prepare the reader to reach a maximum understanding of the lecture written by him, to be given in the homage we are paying him. This lecture contains profound, brilliant ideas, written to be read and listened to in such a way that they seem so simple that anyone might think that he could have written the same thing, but beware, it is not so.

The greatness of geniuses lies, essentially, in making the invisible visible to the eyes of almost everyone, in deciphering the apparently indecipherable and making it look like the most natural thing in the world, in giving free rein to the imagination to explain with objectivity the phenomena and facts that most people ignore, despite the fact that they live among them. The geniuses seek to mesh in their minds, and in ours, what exists in universal concatenation, but that only they can thread consistently and then position it in the minds of other mortals.

Gerald Holton, like every genius, wrote the lecture with the above characteristics, hence I urge you to read it a thousand times, to pay due attention to each of the headings so that you all come to admire the beauty of it and to follow the light of knowledge that it radiates.

And, for those who question why I call him a genius, I will say that I do it because one of the essential characteristics of them is their remarkable imagination and Holton has been able to describe how they have used this human faculty in their discoveries and classifying them in visual imagination, metaphorical imagination and thematic imagination with eloquent examples and this can only be done by a genius with Holton's imagination.

2. The genesis of a friendship and a tribute to Gerald Holton

When I started communicating with Gerald Holton, I always thought that positive exchanges would arise from it, both professionally and for the National Commission of the Physics Career in Cuba, which I currently preside. This commission counts, as members, with relevant Physics professors coming from each one of the universities of the country. It prepares the Study Plan under which future Physics teachers will be trained for the different educational institutions, including secondary, pre-university, polytechnic, adult and university education.

The teaching of Physics in Cuba has gone through several study plans, ranging from Study Plan A to Study Plan E, and it is the latter under which teachers are trained for this science at present. In this Study Plan, the History and Epistemology of Physics has been inserted as a subject and it is thanks to Gerald Holton that we have a vast bibliography to teach it now a days.

Not everyone understands that the History of Physics is essential in the preparation of future physicists, whether they are going to work in the classroom as teachers or in the laboratories as scientists. It is a titanic task to make them aware that they must know the concepts, principles, laws, theories and models in all their historical evolution and not only in a pragmatic way. Only Gerald Holton is capable, from his work, of generating the importance and love towards the History of Physics and from this to the study of Physics as a science.

Personally, having had contact with Gerald Holton's books, a few years after graduating as a physicist, made me grow professionally in an exponential way. I understood, with the study of his works, that Physics can only be learned in a solid and deep way, if the whole system of knowledge that it contains is studied from its own birth until it reaches the present state in which it is. This learning is what I have tried to imbibe in all the teachers and students with whom I have had personal contact and in all those who have read the books I have written on this subject and which, in one way or another, have been dedicated to Holton, whom I consider my teacher.

The year 2017 was crucial for my life as a professional. That year I started communicating with Holton through email and I still do it today. Since 2017 I learn with

him and always, as far as our friendship goes, which will be eternal, I will.

3. From Arnold B. Arons to Gerald Holton: the way to know his work

All teachers should be educators of attitudes and values in their students. This can be achieved through their personal example and the analysis of the attitudes of other people or outstanding celebrities in different spheres of reality. Holton and Arons have used their classrooms, books, projects and articles to, from the science they teach, Physics, together with philosophy, history and epistemology, form and deepen in their students the most remarkable attitudes and values, forged by the geniuses that this science saw and continues to see born.

But not only Arnold and Holton have forged attitudes and values in their students from the scientific ones related to Physics, in their writings they go beyond any particular science and go into other fields such as psychology when dealing with Freud or music, when mentioning Mozart. Professors, Arnold, now deceased, and Holton still among us, for our good and pride, have possessed a very broad scientific and general culture and this has resulted in their notable influence in the instruction and education of several generations, as well as in the attitudes and values of their students. Both were awarded the Oersted Medal, which recognizes outstanding contributions in the field of physics education.

There are teachers who take care to prepare themselves well in the science they teach. Others, in addition to the above, are concerned with writing books according to their particular vision of how science should be approached so that it is really understood and comprehended by their students.

The illustrious Arons and Holton, are among the professors who achieved a high level in Physics, history, philosophy and epistemology, from their books *"Introduction to the concepts and theories of the Physical Sciences"* (1952), by Holton, "*Evolution of the concepts of Physics*" (1970), by Arons and the *"Physics Course Project"* (1971) created and led by Holton, Rutherford and Watson.

How did I get to know the above books? In 1988 I received one of the most important gifts in my life as a professional in Physics, a life dedicated to the formation of teachers of this same science. Fernando Contreras Díaz de Villegas, one of my uncles, now deceased, gave me Arons' book, which he had, and it is a secret that must remain between us, borrowed from the library of the university where he worked, in Managua, Nicaragua, and which he did not return because he considered it to be the perfect gift for me, who was already in love with Physics. It is possible that if my uncle had not committed this crime, this book and others would never have been written.

In the preface of Arons' book you can read:

> ... the course on which this text is based is part of a required core curriculum instituted at Amherst College in 1974. It aims to develop the student's knowledge of physical phenomena, concepts, and theories and also to place their technical content in historical and philosophical perspective...throughout the text is the fundamental assumption that one of the main criteria of knowledge and understanding is the student's ability to deal with verbally expressed ideas as well as with problem solving (Arons, 1970, p.5).

Arons' book has 1007 pages, really impressive its volume, but it is a jewel for those who want to learn Physics from a totally different point of view, to the one that usually can be found in other courses and books about this science.

In my particular case I was prepared, during high school, by books written by Cuban authors, under a very high influence of those used in the former Soviet Union. These "Cubanized" books had a high level of conceptualization of Physics, but almost no history of Physics, philosophy and epistemology, and the associated mathematics was very demanding. They also had the difficulty of assume examples that did not correspond to Cuba as a Caribbean island.

In Cuba it does not snow, for now, we will see later with climate change and its terrible consequences, and in the book there were problems and situations to analyze related to snow. Today those difficulties of assume examples that did not correspond to my country as a Caribbean island do not exist in Cuban textbooks, at least those dedicated to Physics, but they still maintain a mathematical level that overshadows physical knowledge and, fortunately, the situation of the history of Physics, philosophy and epistemology is being achieved in the new books to be edited, a task that I am in charge of as a good student of Holton, although may be he thinks differently.

When I read the book of Arons, for the first time, because I have resorted to it thousands of times, it was that I began to be interested in the books and the figure of Holton and it is because at the end of the preface of "*Evolution of the concepts of Physics"* you can read:

> ... above all I wish to acknowledge the debt I owe to Professor Gerald Holton. The influence of his excellent text is evident, not only in the chapters reprinted here, but also in the structure and spirit of the course. He read and critiqued large portions of the manuscript and his encouragement played a major role in the accomplishment of my task (Arons,1970, p.6).

The admiration, and pride in Holton's work and knowledge, is evident in Arons' words. But not only did Arons feel pride and admiration for Holton, but Holton also felt and feels the same for Arons. Holton writes about him:

> ...Devoted to teaching (...) to making students love the subject of the course;

> constantly thinking about the best ways to do it; writing as a scholar and educator (...) being an honorable model of honesty; and all of this with the highest standards for his College, his students and himself... I remember with pleasure some episodes...in which Arnold and I collaborated. The first was early in my career. Still as an instructor I had to teach one of those long introductory physics courses at Harvard, but I rebelled against the use of those narrow physics texts for students. Instead, I wrote my own text, emphasizing the humanistic aspects, including the history and philosophy of science. Arnold contacted me from Amherst, Massachusetts, where he said he was using my book for his course.
>
> At his invitation I went there to lecture in his physics course. From the moment I entered the classroom with him, I could feel that there was a special, warm understanding between Arnold and his students. This was a very enjoyable event for everyone. Above all, this was my introduction to Arnold, and we quickly became good friends. Some years later, Arnold had a sabbatical leave and decided to spend it writing his own textbook. He suggested, and I quickly agreed, that he would make an extended visit to Harvard University. I was glad to have him sharing my office. In fact, he asked me if he could incorporate the three chapters of philosophy of science from my book into his. This was happily done. Years later, when I started the national curriculum named "*The Physics Course Project"*, again on the model of my first book, Arnold kindly accepted the invitation to come to Cambridge to join our team and help us with the writing of the new materials..."(Authors' Collective, 2016,p.4).

After some years of having had Arons' book in my hands, one fine day we found another book entitled *"Introduction to the concepts and theories of Physical Sciences"*, published in 1952 and written by Holton. This book was in the library of my university, at that time known as Instituto Superior Pedagógico "Félix Varela", which is today the "Félix Varela" branch of the Central University "Marta Abreu" of Las Villas, located in the city of Santa Clara, Cuba.

The next day, in the middle of the morning, I went straight to look for the book, to

borrow it and, to my surprise, unpleasant by the way, the book was not found, it was the only copy, almost recently received, and it seems that someone had taken it without authorization and never returned it. The only thing I can say about it is that it wasn't my uncle this time. At this time he was in Germany doing his doctorate.

Then, because of Arons' book, I knew that Gerald Holton existed and that's when I decided to investigate how I could contact the latter. Finding out his email address I write to him, I introduced myself to him and made him see my interest in being able to have in my hands his book "*Introduction to the concepts and theories of the Physical Sciences"*, which was not available on the internet in PDF format and free to download, only as a printed book at a certain price in US dollars, money which I did not have and even if I had had it I had no way to do it, which is very complicated to explain here and if I did, many of you would understand better first the General Theory of Relativity of Albert Einstein than my explanation on why I could not pay Holton's book and less from Cuba.

A few days after writing to Holton, and surprisingly, he answered me and let me know of his interest in the activities that we carried out in Cuba for the good development of Physics and its teaching. How happy I was to see that in the inbox of my mail and frequently I found Holton's answers. You have to be a child of his vocation to know how much it means to exchange with a scientist and a genius of the stature of Gerald Holton. To describe how I felt, and still feel, to find Holton among my friends is really impossible, words cannot always encompass feelings; the latter speak a language that only comes from the heart and the soul. In this last point, The Little Prince, by the writer Antoine de Saint-Exupéry, was absolutely right.

When in the previous paragraph I used the phrase "surprisingly Holton answered me", I want to clarify that there are illustrious people, scientists and geniuses, who ignore what is written to them and never answer because they consider themselves, it seems, superior to others. I would like to know what Einstein and Chaplin would have thought about it, but I'm sure they would think something very similar to Holton.

Holton, who is illustrious, a scientist and a genius, showed me that he is a humanist, that he is humble and that he does not hide in the heights he deserves, on the

contrary, he is always ready to help and advice who ever needs it, as it has been in my case. Holton was kind enough to indicate me the way in which I could get all the books written under the afore mentioned project and he sent us by ordinary mail his monumental work *"Introduction to the concepts and theories of the Physical Sciences",* which we have studied and used in our classes and in the books we have written, as well as *"Evolution of the concepts of Physics",* written by Arons.

In one of his emails, Holton tells me:

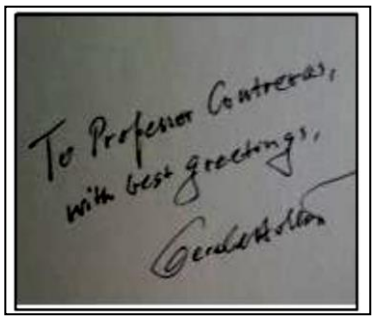
> **...**Dear Dr. Contreras, thank you for your recent e-mail, with information on the various postgraduate courses. It is an impressive list. As we have discussed in our various emails, you would like me to send you a copy of my book, *Introduction to Concepts and Theories in Physical Science*, and I have agreed to send you one. Actually, I only had my file copy; but I just got another copy of the book, and I am willing to send it to you by UPS, with my compliments. By the way, although the copyright of my book in its first publication was held by the Addison Wesley Company, according to my contract the copyright reverted to me when that publisher stopped reprinting the book many years ago.
>
> To ensure the happy utility of our interaction, let me now ask you to email me your agreement (or disagreement) with the following three points:
>
> 1.) You and your institution have the right to distribute copies of my book electronically or in print to students and teachers in Cuba. If you believe that other countries also wish to have the right to make copies for use in their countries, each of them must ask my permission.
>
> 2.) If you wish, you can copy my book by scanning it, for example, to facilitate its distribution in Cuba. In that case, I would be grateful if you or your institution could provide me by e-mail with the URL, link or any other means by which I can have access to the scanned copy of my book.
>
> 3.) In the distribution of my book in Cuba, in any form, please state on it that the copyright is owned by Gerald Holton.
>
> I look forward to your reply, as well as to the successful transfer of the book

> and its usefulness for scientists and students in your country. With my best personal regards, Gerald Holton, Professor of Physics and History of Science, Emeritus, Harvard University.

Before this mail I was literally astonished, not only Holton was about to send me the book that I had wanted so much to have in my hands, but he also allowed me to scan it and publish it in a certain place in my country and also to print it and distribute its copies to all those interested, also inside Cuba.

I replied to this email:

> ...Dear Professor Holton, thank you very much for keeping in touch with us and always wanting to help. You can be sure that your book will have the best of uses in our country and the greatest of respect. In the previous email I told you that you are undoubtedly one of the greatest personalities we have today in the world of Physics and its teaching, so we will not betray the trust you have placed in us, because in the end the big losers would be us. His book will be scanned and will be in each of our universities and will be of great use in the different Physics subjects and, especially, in the History of Physics subject taught in the fourth year of the Physics degree. We will let you know all the results we get with your book and you will be aware of every detail. We are already looking forward to receive your book and start working with it. Remember, if you can and want, to write something to our students and teachers, about how important it is to study Physics and its history, so that it reaches our universities and is read by everyone, which will be something really motivating. Dear professor, trust us. We agree with the conditions that you ask us. A hug and guide my steps in the way of the formation of Physics teachers for Cuba. Sincerely, Jorge Contreras.



It took several weeks for the book to arrive in Cuba and then in my hands, but it arrived and I treasure it with all the love in the world. Every physicist who visits me receives, before the cordial and typical Cuban greeting, my words in the form of a question: do you know what book I have in my bookcase? And without waiting for an answer I show it to

him and above all I emphasize that he should read Holton's words dedicated to me, well, more or less the same as what I am doing with you now.

4. Gerald Holton and the Project Physics Course

Together with my interest in the book, which I have been talking about so far, Holton recommended me the *Project Physics Course* and put me in contact with F. James Rutherford to provide me with all the materials that this project contained and so it was, which, at this moment, is in the hands of all the members of the National Commission of the Physics Career that I preside and that I constantly consult for my classes.

About this project, in an interview conducted by the Brazilian professors Jefferson and Freire to Holton, the latter tells us that:

> The Project Physics Course, which had been idealized for high school, was also used in the faculties... Every year, 200 thousand students started with this book, which was later translated into Italian, Chinese, Russian, Portuguese... Unlike other North American publishers, we prohibited simple translations. We believed that, in each country, there should be a group that would adjust it to the culture of the place, its interests and levels of mathematics. Thus, each of the versions was different and unique. This was one of the unfolding of my 1952 book (Jefferson and Freire, 2006, p.319).

In the previous writing I already visualize a Holton, who besides being a physicist, is concerned about didactics and pedagogy, in relation to the teaching of this science and the value he gives to the historical-cultural context where the subject will be taught and to the interdisciplinary relationships that should always be established from any science in question. He knows how important it is to study by books that we can understand and comprehend in all its dimensions and, for this, the book must be adapted to the conditions where the student lives and knows. That is why it is important for each country to create its textbooks, always taking ideas from the best books on an international scale, but adapting them to its own conditions. In Cuba we have carried out actions on this subject, but still isolated, without forming a system, at least at the university level, but we are getting closer to this purpose, at least that is what I believe and that is what I strive for from the responsibilities that I have.

When I studied physics at university, I used the books of Halliday and Resnick, Saveliev, Sears, Frish and Timoreva, which are still present in the current curriculum to train physicists in Cuba and other countries. They are excellent books, however, in my opinion, these do not have that physical content developed in its full extent from a historical, cultural, philosophical and epistemological approach to science, compared to the books of Arnold and Holton, which are much more attractive to draw attention to the study of a science like physics, considered within the "hard sciences", rejected by many, and reference to it, is the low enrollment and poor retention in those who study it in our universities.

I wrote to Holton about this on one occasion:

> Dear Dr. Gerald Holton, I greet you from Cuba, from the Central University "Marta Abreu" of Las Villas, located in the city of Santa Clara. Some time ago we were in communication and you helped us a lot with your advice and with the donation you made of your book *"Introduction to the concepts of Physical Sciences"*. This book has been very important for us and we keep and use it as a very valuable jewel.
>
> The relations between our countries are getting worse every day, but the interest in scientific and academic collaboration must be above political and economic relations. I ask you, if this does not cause you any inconvenience or problems, to help us in the realization of a videoconference, where you can tell us your ideas, works and above all what you think about the situation that exists at international level about the rejection of people to study sciences such as Physics and Chemistry. In my country I am the president of the National Commission of the Physics Career and the enrollment of students to study it is practically null. I am sure that a videoconference with you would be very useful and motivating for our teachers and students. I look forward to your reply. Receive our fraternal greetings and a hug. Jorge Contreras.

To which he replies:

> Dear Professor Contreras, I am glad to hear from you to continue our conversation about teaching physics. I am sorry to hear about the lack of

> interest of students. In this age of rapid progress in the sciences, and the great role they play in our daily lives, science education is essential all over the world. I wish I could help with your plan for a videoconference on teaching physics, but it is not possible for me at this time. My life has been disrupted by the sad stroke my dear wife received in September, and I am fully occupied in helping her. I will of course let you know if this situation changes. Please accept my regards, Sincerely, Gerald Holton.

The fact that his wife was not in good health really touched me and his attitude of answering me, in spite of this situation, I consider it extraordinarily praiseworthy and a sign that he knew how to deal with his two great loves: his dear and adorable wife and his beloved profession.

I replied to him:

> Dear Dr. Gerald Holton. We feel very sorry for your wife and hope she gets better as soon as possible. We put our faith and hope in your wife's satisfactory recovery in the shortest possible time. To you, I am always grateful for answering my questions. Reading your books and ideas, we have written a book entitled *La Humanística en el proceso de enseñanza aprendizaje de la Física y la Química*, which we have dedicated to you, for all the effort you have made in favor of these sciences and for the value and importance you have always given to the study of the History of Science. Take good care of your wife and take care of yourself too. Receive a big hug from the Cuban educators. We will keep in touch. Jorge Contreras.

And Holton, as always, does not fail to answer me, despite the sad and complicated situation he is going through.

> Dear Professor Contreras, just a quick note to thank you for your message, which has touched me deeply. I desire a better future for all. My best regards, Gerald Holton.

And I kept worrying about his wife and him.

> Dear Dr. Holton. I hope your wife is feeling better and that you are in good health. I ask you to be very careful in times of this coronavirus. Let's hope that humanity learns from this pandemic and that we become more supportive every day. Receive a big hug from us. Jorge Contreras.

And he always continued our conversations.

> Dear Professor Contreras, thank you very much for your concern in these difficult times. I hope that you, your family and your co-workers will be saved from this virus. So far I am healthy, but I am afraid that the pandemic may change our lives and the way the countries of this world will be governed in the future. With all good wishes, Gerald Holton.

As can be seen in this last email, Holton is not only concerned about people being saved from the coronavirus, he goes further, he also wishes that the situation in which we live serves to achieve transcendental changes at the level of states, that we are different, less selfish and more supportive, in short, better human beings in general, with a greater culture. Faith in the human being, in the improvement of the human being is one of his characteristics; in this he resembles Gandhi and José Martí.

And it is that Holton's books, lead precisely to the need to achieve a scientific and general culture, through the history of science and the analysis of each fact and discovery in particular, in the social and political level of the time in question. This culture is so necessary for all education professionals, since the more teachers are better prepared holistically, the more interesting and motivating their classes will be and, therefore, the better preparation their students will receive.

When I read each of Holton's works, his reading grabs me and with each passing day I fall more in love with Physics and its history. His language is clear and very convincing, but above all very deep and sometimes loaded with a very fine sense of humor. Reading him forces me to surpass myself and because of him I started to teach the history of Physics as a subject at my university, which I still do today.

Based on the knowledge that over the years I have acquired thanks to Holton's influences, I have already written five books where historicism and its value are reflected: *The Theory of Omission in the teaching-learning process of Physics (*2019),

*Humanistic in the teaching-learning process of Physics and Chemistry (*2020), *Genius Attitudes(+). Principle of Greatness (*2020), *From the Didactics of Science to the Teaching of Physics, An urgent need (*2020) and *Humanistic in 3P, From the Mayan World University, Campeche campus* (2021), where the difficulties and errors that appear in the textbooks of Physics are glimpsed by the ignorance of its history, by omitting it partially or totally, and by mathematizing it so much that the so rich and necessary verbalization that should be had in it is lost. The writing of these books and their contents has undoubtedly been motivated by the influence of Holton's books and ideas.

Holton taught me that through the history of science it is possible to form praiseworthy values, behaviors and attitudes in students, teachers and human beings in general. That is why, in my books, I have had as an essential objective to humanize the scientists, the geniuses, in such a way that they are honored for their discoveries and creations, but that they can also be seen as human beings, in all the dimensions that life possesses.

The Project Physics Course has been one of my guides for teaching Physics and writing my books, and there are essential ideas in it that can be read at the beginning of the reading:

> In addition to pure Physics, it shows how Physics relates to other sciences (...)and includes aspects of the philosophy and history of science that put the development of the main ideas of Physics in a humanistic and social context (...)the course (...) is assembled in an integrated multimedia system, including text, readers, film loops, films, experiments with specially coordinated laboratory apparatus, programmed instruction booklets, transparencies, student manual and teacher's resource book...(Contreras, 2019, pp.21-23).

The above sets a guideline for how textbooks should be written and how we should teach science in general and Physics in particular.

Holton's books are paradigms in terms of the presentation of Physics in a totally different way from other textbooks and examples of excellence for the field of Physics and its didactics. In Holton, the vast knowledge he has about Physics, but also the genius he has to worry and take care of the teaching and learning of this wonderful science, come together.

I did not have the opportunity to attend Holton's face-to-face or virtual classes, but,

without a doubt, they were incredible classes. The reason to affirm the above are the words that can be heard or read in the video where Holton is interviewed by the science journalist Quevedo, from the BBVA Foundation, in November 2015, for the celebration of the100th anniversary of Einstein's Theory of General Relativity.

This interview is a great class where only using words, no mathematics, Holton explains what is the theory of relativity, from the mental experiment of Einstein falling from a roof and what were Einstein's ideas about the unification of physics. Holton demonstrates his remarkable mastery of didactics and pedagogy to make him understood. The way in which Holton makes use of the method of historicism is really praiseworthy.

Unlike other scientists, Holton has devoted time to teaching from the historical, philosophical, and epistemological perspective of physics as a science. As Holton writes in *What can historians of science and science educators do with each other?*

> ... most of these scientists don't have the time to tell their students how it all happened, and they don't have the training or self-confidence to go beyond their professional boundaries. In addition, the opportunity to infuse science education with history and philosophy of science has been drastically reduced..." (Holton, 2003, pp. 603-604).

We also had a period like this in Cuba. However, this situation has begun to be reversed since the implementation of Study Plan E, where the different types of curricula and disciplines to be studied in Physics are found.

In short, it is from reading books and articles written by Holton that I developed this extraordinate love for seeing Physics in all its dimensions and the passion for the work of geniuses, which has extended beyond physicists and has reached the geniuses in other spheres of reality such as literature, cinema and politics. Thanks to Holton for presenting reality as it is, for making me admire the real actors of that reality, with their virtues and defects, with their attitudes and values, sometimes positive and sometimes negative, but always learning from them.

It should always be emphasized that Holton has been and is a very enthusiastic popularize of science, concerned that it should be part of the life of all the citizens of

this planet and not only of those dedicated to study and teach it. The following words express the above:

> I think that today science education has to be present in all channels, television, magazines. It seems to me that one of the best means is the one that is still widely used by teachers: science news programs, which have a large circulation. We need to attract young people to museums, attract them by all possible means, because almost all the other attractions distance them from what we think of as science. Electronic games, MTV and violent videos take the min the opposite direction. So we have to fight back by any means possible" (Jefferson and Freire, 2006, p. 317).

Without further comment, what Holton has done in terms of teaching physics, in my opinion, is unprecedented. You have to read his works to see how important it is to study science and in particular Physics. We learn from his books and attitudes towards life and, therefore, they are present throughout this epigraph, which is a tribute I pay to this great professor. Honor to who honor is due!

5. Gerald Holton as a professor

And now I'm going to close my eyes and in my reverie I'm going to see Holton teaching. Yes, I'm seeing him, he's a teacher:

- Permeated by dissimilar scientific knowledge, encompassing the natural sciences, mathematics and social sciences.
- That acts in front of his students, where the classroom is a theatre and his students, more than spectators, act together with him, enjoying the play that, between all of them, they perform.
- Knowledgeable of the most general laws that govern nature, society and thought, which makes him, have a mastery of the philosophy of education and science, to apply these ideas to the teaching-learning process that he directs and researches.
- Fully aware that philosophy, in any of its aspects, cannot be alien to him and that he must apply it in the preparation and teaching of his classes.

- That knows about psychology and that applies the different psychological currents that he considers most relevant to the teaching- learning process that he directs.
- That never sheds his humanism and that through his example he instills it in his students.
- That fervently believes and has total faith in the human betterment of his students.
- That sees in his students his own sons.
- That does not sleep in peace until his students achieve the goals and knowledge to which he aspires.
- That is not oblivious to what is happening on our planet and that is how he makes it known to his students, reasoning together with them.
- That is open-minded in the face of changes and positions to be taken in relation to the teaching-learning process that he directs and investigates.
- That facilitates active, creative and critical learning.
- That possesses an excellent sense of humor.
- That strives to possess a high scientific and general culture.
- That is full of values and attitudes and serves as an example to all his students.
- That always demonstrates before his students a:

➢ pedagogical professionalism

➢ pedagogical authority and pedagogical requirement

➢ professional identity

➢ pedagogical responsibility

➢ pedagogical justice

- ethics and pedagogical tact
- ecological and humanist sensibility
- attitude and spirit of criticism and self-criticism and intransigence in the face of what has gone wrong
- flexibility and objectivity of the assessments it makes

And the fact is that Holton, as a teacher and as a human being, not only instructs, he educates at every moment, with every action. He fits perfectly within the aphorism of the illustrious Cuban, José de la Luz y Caballero, where one can read that "anyone can instruct, only those who are a living gospel can educate" (Rodríguez, A. C., 2001, p. 205). You, friend Holton, are a living gospel.

Holton is also one of those professors who researches and the results of his research are quickly incorporated into his classes. An example of this was his discovery of "thematic ideas", which he incorporated into his books and his activities as a teacher and mentor to his students, as well as the humanistic elements that animate all true progress and knowledge, as he recounted in his acceptance speech for receiving the Frontiers of Knowledge Award in the Humanities (BBVA Foundation, 2021, September 25).

Anyway, Holton is that teacher that, at least for me, I would always like to have by my side.

6. Gerald Holton: work, genius and life

Gerald Holton, as he is known, is a physicist, historian of science, especially the history of physics, and educator eager to make physics reach all students in an enjoyable way, without leaving the scientific rigor, but where the most important thing is to grasp and understand the essence of the phenomena to be studied. To this end, he not only teaches the discoveries of the geniuses, but also teaches the way in which they thought, their thought processes, applying in an unparalleled way the historical-logical method in each of their investigations.

Holton also studies and writes on the philosophy of science and is interested in studies on gender issues and ethics in scientific careers to the role of immigrants and

the causes of terrorism, among other varied topics.

All of his contributions have been recognized by various appointments and honors. Below are some of them:

- Member of the American Physical Society.
- American Philosophical Society.
- American Academy of Arts and Sciences and other similar European societies.
- President of the History of Science Society and of several national commissions in the United States.
- Founding editor of the quarterly Daedalus and member of the editorial board of Collected Papers of Albert Einstein.
- "Oersted Medal" of the American Association of Physics Teachers.
- "Sarton Medal" of the Society for the History of Science.
- Gemant Award from the American Institute of Physics.
- "J. D. Bernal Prize" of the Society for the Social Study of Science
- "Abraham Pais Award" of the American Physical Society.
- Herbert Spencer Lecturer at Oxford University.
- Jefferson Lecturer for the National Endowment for the Humanities
- Ehrenkreuz 1.Klasse in Austria.
- Frontiers of Knowledge in the Humanities Award from the BBVA Foundation for his studies on the cultural dimension of science.

Commissions and trusts:

- Trustee of the Boston Museum of Science, 1965-67.
- Member of the Corporation, 1978-81.
- Patron of the Science Service, 1972-78.

- Patron of Wesleyan University, 1975-89.
- Member of: U.S. State Department National Commission for UNESCO, 1975-80.
- Member of the Council of Scholars of the Library of Congress, 1979-1995.
- Member of President Ronald Reagan's National Commission on Excellence in Education, 1981-83.
- Co-author of the report A Nation At Risk. Trustee of the National Humanities Center, 1989-93.

Holton's research in History and Philosophy of Science, as well as in education, includes:

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Phew!, possibly expresses anyone who has been reading some of Holton's works and honors and even possibly, feeling tired of reading them, and already is directly in this paragraph. It is truly amazing to see Holton's work, awards and responsibilities throughout his life and perhaps, it may be, I think it is, that it is all because he falls within the spiritual magic circle of coincidences in dates of births and deaths, as I show below.

Gerald James Holton was born on May 23, 1922 in Berlin, so he is approaching his 100th birthday. In this same year, Thomas Samuel Kuhn was also born, but on July 18 and in Cincinnati, United States. Kuhn was also a physicist, historian and philosopher of science, who received his doctorate in Physics from Harvard University in 1949 and was in charge of an academic course on the History of Science at Harvard University from 1948 to 1956. There are many similarities between the two in the professional, institutional, cultural and social fields, but the most important thing is that they developed a beautiful friendship. Also, it should be added that in 1922, Alexander Graham Bell, British scientist, inventor and speech therapist, died and Niels Henrik David Bohr won the Nobel Prize in Physics.

Other geniuses and great personalities like Holton have had similar coincidences.

Some examples to support the above are: Buonarroti, Vesalius and the Frenchman, Calvin, died in the same year, and in the same year, Shakespeare and Galilei were born. Three hundred years after Galilei's death, on the same day, Hawking was born. Newton, on the other hand, was born the same year as Galilei's death, and Einstein was born the same year Maxwell died. The year of Pavlov's birth coincides with the year of Filomafitsky's death. Everything seems to indicate that Russia had, by force majeure, to be the country that most excelled in animal physiology. As if that were not enough, Shakespeare, Cervantes and Garcilaso de la Vega died in the same year and, almost on the same day, so did Cervantes and Shakespeare, considered among the greatest writers of all times. In this same year of 1616, and considering that three great writers died, the Catholic Church put in the index of forbidden books, the work The revolutionibus orbium coelestium (On the revolutions of the celestial spheres), written by the Pole Copernicus.

However, despite the greatness of the year 1922, according to Holton:

> ...to be born in the same and in Berlin was a terrible idea because the Nazis were already imposing their law in the streets, 11 years before Hitler took power. At the time he was born, Albert Einstein was informed that he could be assassinated by the fascist gangs that already ruled the streets, as was the Foreign Minister, Walter Rathenau, so Holton decided to flee his country, something that his family also had to do later (BBVA Foundation, 2021, July 21).

Holton's parents were Austrian: Emanuel, a lawyer specializing in international law, and Regina, a physiotherapist. His parents wanted their son to become a lawyer as well. Forced by the rise of fascism in Germany, and by a physical attack on the young family, they soon returned to Vienna. Family life was typical of professionals in love with Germanic culture; in fact, his parents had first met at a Poetry Club.

It is curious to note now, that in Holton's parents the social sciences and the medical sciences, two diametrically different sciences, are united. In Holton's marriage to Nina, something similar happens, Holton dedicated to the natural sciences and Nina to art, to sculpture and, as if that were not enough, their two sons also took different paths, Tom devoted himself to science, while Stephan to music. Perhaps all guided by an

idea that Holton shared with me at a certain moment when I asked him the following question:

> You are a physicist and a renowned scientist and your lovely wife Nina is also a renowned sculptor. Do you think this combination of science and art has helped you and your lovely wife Nina grow in your two separate professions, maintain a marriage for so many years and live a life of longevity?

To which he replied:

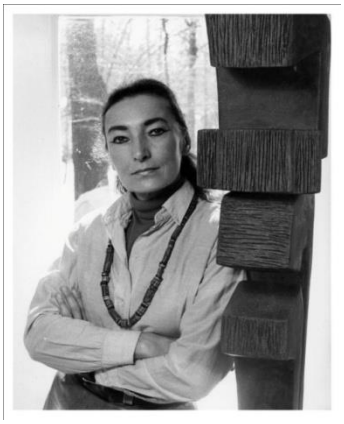
> A variety of interests on both sides is helpful.

And in his family that great variety of interests is very wide and all can be inscribed in two transcendental areas: Science and Art. I would say it's a chess family because chess also fulfills the duality of being an art and a science at the same time. I see Holton as the King, Nina as the Queen and his two sons as his faithful Knights.

But the conformation of this beautiful and attractive family was achieved through enormous difficulties. He relates:

> ...that in 1938, the annexation of Austria by Germany put the lives of the Jews there in danger as well...that he would have been a lawyer according to his parents' wishes...that he had to flee Vienna in December 1938, together with his younger brother Edgar, after the so-called Kristallnacht. From Vienna he came to England because of the Kindertranspot, thanks to which 10,000 children were able to go to England, thus escaping from Nazi Europe. In England, he studied at the Oxford City School of Technology, receiving the Engineering Certificate in June 1940, after having studied Electronic Engineering, which was very boring, with the exception of the part dedicated to Physics.
>
> ...heading for the United States with his family, who had fortunately been reunited, just days before he had to report for imprisonment for the full term, as was required of all adult male German refugees, according to Prime Minister Churchill's directive.

...Since he loved Physics, at the age of 18 he decided to follow that path, but already in a university in the United States. In this country he found an excellent physicist who practically adopted him and allowed him to be his research assistant until he obtained his doctorate at Harvard University. D. in 1947 for his research on the structure of matter at high pressure, as a student of Professor Percy Williams Bridgman, who in 1946 received the Nobel Prize in Physics for his remarkable research in the field he himself founded.



...When he graduated, he was asked to remain at Harvard as an instructor in the Physics Department. His professional academic life had begun, and his association with Harvard has lasted more than 70 years. (BBVA Foundation, 2021, July 21).

As did his marriage to Nina (74 years in total).

I am sure that if Holton had studied to become a lawyer like his father, he would have shone in the same way he has shone in Physics and the history of Physics and today we would know more about the law and its history.

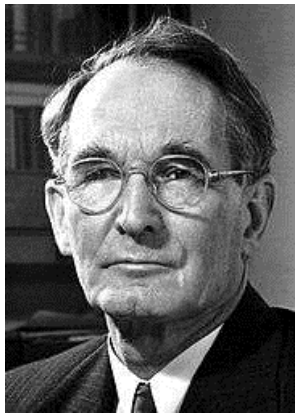
That it is very sad that he had to live through the so-called Night of Broken Glass where a series of lynchings and attacks against Jewish citizens by SA troops and part of the civilian population took place, while the German authorities watched without intervening, as I could read in Wikipedia and about which I am interested to read and learn more.

Note that when studying electronic engineering, Holton says that the only thing he did not find boring was Physics and it is curious because something similar happened to Einstein while studying in educational institutions. To know more about this particular, in the case of Einstein, I recommend you to watch the serial Genius, broadcasted by the National Geography, dedicated to the latter and based on the work referenced as: Isaacson, W. (n/d). Einstein, his life and his universe. Available at:

www.librosmaravillosos.com.

And the fact is that both Holton and Einstein are dreamers of Physics. I say they are, even though the latter is already deceased, because at least I find no difference between the material and spiritual dimension in this world.

In an interview with Holton, he states that he admired Percy Williams Bridgman as an excellent student and remembers him with great respect and affection. He tells an interesting anecdote about him:



> ...Bridgman had given orders not to be disturbed when he was working in the laboratory, where he did not even have a telephone. One day...Holton was in the workshop and answered a call from a journalist who was very insistent on speaking to Bridgman because, he announced, he had been awarded the 1946 Nobel Prize in Physics. Holton considered that that occasion was really exceptional and ran to tell his professor who, after hearing the message about the award, continued with his experiment of high pressures and answered emphatically: Tell them that I will believe it when I see it... (Rivera, A, 2006).

For Bridgman, the essential thing was the facts and the verification of those facts, like any scientist. I believe it when I see it means I have to check it. Bridgman was a man of integrity and very frank. And that same frankness and integrity in science was instilled in Holton, who was also influenced by Albert Einstein. The latter two suffered the same fate when they were forced to leave Germany because of the fascism that prevailed there, as their lives were eventually in danger. Also both of them, in the political and social field, have taken very similar attitudes, as we intend to show below.

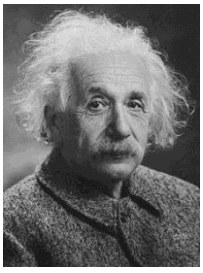
7. Gerald Holton and Albert Einstein: a necessary parallelism

To me, Holton in his actions is very similar to Einstein. They were both born in Germany, they are both Jewish, they are both physicists and of a very similar humanism. Perhaps the fact that Holton came across Einstein's work, read it, organized it and did all this with Helen Dukas, secretary of the relativist genius, enlightened him and filled him with that Einsteinian spirit, which together with Holton's

own, joined indissolubly to create the one that today is already one hundred years old.

Albert Einstein

> I am enough of an artist that I draw freely in my imagination. Imagination is more important than knowledge. Knowledge is limited. Imagination surrounds the world.
>
> **Einstein**



Einstein was born in Germany on March 14, 1879 and died in Princeton, USA, on April 18, 1955. He was of Jewish origin, later naturalized Swiss, Austrian and American. As a physicist he was brilliant and as a human being a humanist and pacifist without equal. He is considered the best known and most popular scientist of the 20th century and, undoubtedly, not only for the science he did, but also for his attitude towards life and the society in which he lived.

His parents were Hermann Einstein and Pauline Koch. Hermann, an electrical engineer and businessman, and Pauline, a music lover who played the piano and taught Einstein to play the violin. Here we see again, as we see in the Holton family, science and art holding hands and both spheres of reality forming part of the same man.

In his political and social actions, Einstein was as great as in the science he did. In the first two scenarios, let us see this brilliant man developing his intelligence for the good of others and of humanity and, above all, within the United States.

It can never be forgotten, since it contains in itself an enormous teaching, that on June 12, 1953, in the New York Times, a letter written by Einstein and sent to Frauenglus, a professor from Brooklyn, New York, who refused to testify before a committee of the American Congress, was published. This committee was created by Senator McCarthy.

The letter read as follows: Dear Mr. Frauenglus:

> ...The problem facing the intellectuals of this country is very serious. The reactionary politicians have succeeded in making the public suspicious of any intellectual enterprise by blinding it with the threat of an external danger. Since they have succeeded so far, they have already moved on to limit the freedom of education and to deprive of their posts all those who are not submissive, that is, to starve them out.
>
> What should most intellectuals do against this danger? Frankly, I see no other system than the revolutionary method of non-cooperation, in the Gandhian sense. Every intellectual who is summoned by one of these committees must refuse to testify. In other words, he must be prepared to go to prison and risk financial ruin, in short, to sacrifice his personal well-being for the cultural well-being of his country.
>
> This refusal to testify should not, however, be based on the familiar subterfuge of invoking the Fifth Amendment to the Constitution for the possibility of self-accusation, but on the assertion that it is embarrassing for an unblemished citizen to submit to such an inquisitorial procedure and that such a procedure violates the spirit of the Constitution.
>
> If enough individuals are willing to take this serious step, the triumph will be achieved. If not, the intellectuals of this country will only deserve the slavery that is projected for them.
>
> P.S.: This letter need not be considered "confidential".

Many people suffered personal tragedies or decided to relocate outside the U.S. as a result of the public or judicial pressure to which they were exposed because of McCarthy's ideas. Among them were Chaplin, accused of being a communist; Oppenheimer, accused of having ties to communism. Oppenheimer, too, was publicly humiliated by a government agency in 1954 for having hesitated to decide vigorously in favor of the development of the nuclear weapons system along the lines desired by top military leaders. Kazan, who was forced to inform on Communist party members; and American husband and wife Ethel Greenglass Rosenberg and Julius Rosenberg,

executed in the electric chair on charges of espionage in 1953 as a result of a McCarthyism trial, were sentenced to death.

Einstein himself was also accused of being a communist. In 1953, and according to a series of declassified documents from the FBI file on him, it became known that Hoover's FBI was anxiously trying to prove -until then unsuccessfully- that Einstein was a communist.

But why did FBI want to prove at all costs that Einstein was a communist?

Einstein, while viewing the U.S. presidential system as a good thing, was also critical of what he saw as the excessive consumption and wealth disparities in this country.

> ...As a result, he joined various movements for racial and social justice in that country. He embraced, for example, the cause of the Scottsboro boys, a group of young black men who were convicted of rape in Alabama after a controversial trial, as well as that of Tom Mooney, a trade unionist imprisoned for murder in California (Isaacson, n. d., p. 502).

When Einstein's friend Ehrenfest wrote to him from Leiden to ask him to help him find a job in the United States, Einstein wrote back:

> ...I must tell you honestly that in the long run I would rather be in Holland than in America. Apart from a handful of really good scholars, this is a dull and sterile society that would soon make you shiver (Isaacson, n.d., p. 522).

The prominent historian of science B.G. Kuznetsov, in his book "Einstein, Life, Death, Immortality", writes that Ilya Grigoryevich Ehrenburg, who was a Soviet writer and journalist from a Jewish family and who, along with other Soviet writers, was among the first to contemplate the newly liberated Nazi concentration camps and to denounce the Holocaust, began to gather reports on the German massacre of the Jews, in what would become the world's first comprehensive documentation of the Shoah: the Black Book on the genocide of the Soviet Jews, with substantial participation in what would become the world's first comprehensive documentation of the Shoah. He began collecting reports on the German massacre of the Jews in what would become the world's first comprehensive documentation of the Shoah: The Black

Book on the Genocide of the Soviet Jews, with substantial participation and support from American Jewish organizations and personalities, including Albert Einstein, wrote some of the latter's observations, among them those related to the atomic bomb.

It seemed especially terrible to Einstein that in many men in the United States, the destruction of Hiroshima and Nagasaki was not associated with alarm over the cultural moral ideals accumulated over the millennia since man's appearance on earth. This loss of memory seemed to Einstein the greatest threat to civilization. He said to Ehrenburg:

> ... In Central Africa there was a small tribe, I say existed, because I read about it some time ago. The members of this tribe gave the children the names of Mountain, Palm, Aurora, Sparrowhawk. When a man died his name became forbidden (taboo) and new words had to be found to name the mountain or sparrowhawk. It is understood that for this tribe there was neither history, nor tradition, nor legend, therefore it could not develop, almost every year they had to start all over again. Many Americans resemble the members of this tribe... I read in the New Yorker magazine a shocking report about Hiroshima. I ordered a hundred copies of the magazine over the phone and handed them out to my students. One of them, thanking me, said ecstatically: The bomb is miraculous!...of course there are others. But all this is very hard (Kuznetzov, 1990, p. 251).

Later Einstein mentioned the renunciation of logic, of reason, of rationalism, as a fatal danger.

In February 1950, Einstein speaks on television to assess the post-war situation in the United States where he expresses:

> ...Establishment of military bases in all possible strategically important points of the globe. Military and economic reinforcement of potential allies. Within the country, concentration in the hands of the military of incredible financial strength; militarization of youth; close surveillance of the loyalty of citizens, especially public employees, by means of an ever more impressive police apparatus. Subtle indoctrination of public opinion by means of radio, press and schools

(Kuznetzov, 1990, p. 252).

That is to say, Einstein was unhappy with certain policies of the American governments and the actions of that society in the face of certain facts. Nevertheless, he was respected and glorified in that country, to such an extent that when he died, President Eisenhower said:

> ...No other man has contributed so much to the vast expansion of knowledge in the twentieth century. But neither has there been any other man more modest in the possession of that power which is knowledge, nor more aware that power without wisdom is deadly" (Isaacson, n. d., p. 712).

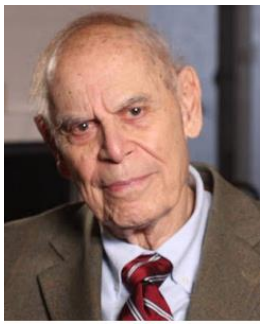
If U.S. President Eisenhower who served as the 34th president of the United States between 1953 and 1961, who was supported for his election by McCarthy (1908-1957), a Republican U.S. senator, known for his investigations of people in the U.S. government and others suspected of being Soviet agents or communist sympathizers infiltrated in the public administration or the military, which is known as McCarthyism, spoke thus of Einstein, for then it is true that he was really great and out of all times.

But Einstein was not only critical of American society and governments, he was critical of everything he considered morally unacceptable.

For example, being in Havana, Cuba, for only 30 hours, Einstein refused a tour of the city that the director of the National Observatory and his wife would give him, and asked that it was better to visit "the poorest neighborhoods, because having visited the parks, the clubs, the residences of the wealthy people the day before, they were now determined to see the opposite" (Altshuler, 2013, p. 122). Einstein was pleased and when he left Cuba, he noted in his diary: "Luxurious clubs next to an atrocious poverty, which affects mainly the colored people" (Altshuler, 2013, p. 123).

Fortunately today Cuba does not live in this situation, but it does suffer from the "subtle indoctrination of public opinion through radio, press and schools" by the US government.

Gerald Holton



However, if we want to analyze the imagination of scientists at work, it will have to be by catching them by surprise.

Holton

Holton recounts:

> ...in the 1940s, anyone who knew a little physics was asked to go to Los Alamos to help develop the atomic bomb, research known as the Manhattan Project, because the Germans were well ahead of the Americans in this type of research, since they had started it a week after the war began, in 1939 (BBVA Foundation, 2021, July 21).

It was for the above reasons that they tried to recruit Holton to go to Los Alamos:

> ...which at that time was not called that, because they were using a code name. In an indirect way I found out what they were doing in that place and it seemed to him that it was an investigation with very aggressive objectives, which was necessary at that time, of which he had no doubt, because the Germans could have gone ahead and the consequences would have been catastrophic (BBVA Foundation, 2021, July 21).

Holton's pacifist attitude is similar to Einstein's, the difference between the two, according to my opinion, is that while Einstein had a reckless personality and projected himself "aggressively" in his interventions, Holton has a phlegmatic personality and this makes him say "the truths" in a way that, apparently, does not bother others so much, at least in a first approach.

According to Holton, he had come to:

> ...England from Nazi Europe thanks to the Quakers (who, in general, stand for justice, simple living, strict honesty and pacifism, so much so that in 1947 the

> Quaker society was awarded the Nobel Peace Prize, N/A) who had taken very good care of me and even my parents. They rescued us and I was fascinated by their way of understanding spirituality, and for that reason I said that I didn't want to be part of something so aggressive, but of a research with defensive purposes, so in the Harvard laboratories I dedicated myself to teach the use of radar and electro-acoustic research. Those two fields were much more in tune with my feelings of spirituality at the time (BBVA Foundation, 2021, July 21).

Holton, in 2015 writes an article entitled "How Terrorism Triumphs", a working paper, belonging to the Department of Physics at Harvard University, where you can read:

> ...One is reminded here of the insensitive and contemptuous remark in a September 1870 letter from Engels to Marx: Terror is, for the most part, useless cruelties committed by frightened people to reassure themselves. However, as examples such as Sarajevo in 1914 and New York on 9/11 confirm, government reactions can in turn be catastrophic (Holton, Gerald, 2015, p.1).

Undoubtedly, Holton with this commentary criticizes his own government and as a subliminal message shows one of his ideas that human beings increasingly suffer from the virus of opinion because we do not stick to the facts, these no longer count. It is true that the events of 9/11 were very hard for the American people, but the actions taken by the American government against other countries they accused of being terrorists were devastating and criminal.

In an interview with Holton, he responds as follows to two of the questions he was asked:

> Q. Do you think current science policy strategies are adequate?
>
> R. Scientists in the US are very worried because the government is not increasing funding in line with inflation, while putting money into programmes like the International Space Station - which most scientists consider to be of no interest - or launching the idea of going to Mars or back to the Moon. Young scientists now have serious difficulties in finding work and many go into finance or politics or journalism... this is very unhealthy. I think that Spain, in recent years, has had problems with politicians who did not support science and now

this is improving.

Q. What do you think of politicians who emphasize application and innovation and neglect fundamental research?

R. Well, you only have to look at the culture of the people who say these things. Years ago I was on a commission convened by Ronald Reagan to look at support for education and science. The president said to us, "I have only one thing to warn you, don't ask me for more money for science; science has been done since the Greeks and it's time to stop looking for new science and start applying what we know. Reagan did not know that the economic and social system depends on new science, which brings new applications. The brake on the advance of AIDS comes from science, and computers? Without science, applications freeze. Without science, better horse-drawn carriages would have been made, but never automobiles (Rivera, A, 2006).

Holton is also among those who believe that certain people, particularly in the United States and in his Congress:

> ...they do not believe in evolution and global warming... because being evangelicals they claim that between facts and faith, one must choose faith and disregard facts. Many claim that science is purely mechanical, and not spiritual. Therefore they believe that whatever comes out of science cannot be accepted by those who want to live spiritually. This is a mistake, but they are stuck in their mistake and we are also stuck in this same mistake. This has no easy solution even through improvements in education. We have to wait, according to Holton, for some change in the cycle of history... and for this we need a long time. (BBVA Foundation, 2021, July 21).

Holton is a good man, as was Einstein, a fair person in all his dimensions, who says things as he thinks them and is sure that it is the right thing to do, but always based on deep studies and truthful evidence. Holton is not a communist, he is a humanist, as was Einstein.

I could notice his sensitivity when, after Hurricane Irma passed through our island, he wrote to me concerned about the human and economic disasters that could have

occurred, to which I replied:

> ...Dear Gerald Holton, I thank you deeply for your concern in hearing from us after the passage of Hurricane Irma. This hurricane hit hard the province where I live, which was the hardest hit in our country. Fortunately, personally, it did not affect me in terms of housing, but it did affect my home's electricity. My university was affected by fallen trees, lack of electricity and some windows that fell due to the strong winds.

I could also notice this same sensitivity in the answer he gave me to a congratulatory message I sent him for the end of the year 2017 as follows:

> ...Dear Professor Contreras, thank you for your kind message of 23/12. I wish you all the best for 2018, and hope that both your country and mine will overcome the current difficulties. Kind regards, Gerald Holton.

Note that he not only wishes me personally the best for 2018, but also maintains the hope that our governments end up understanding each other, that the U.S. blockade on Cuba ends and that we can live in peace in both countries, as it should be. Unfortunately, at this very moment, relations between our countries are at one of the worst moments in history. And the fact is that the love of money, the contempt for the thoughts of others, the unfounded opinion, without being based on facts, on the knowledge of history, does much more damage than the worst of earthquakes or any other event that usually happens in our mother nature.

9. Gerald Holton and his view on Albert Einstein

According to Holton, reading and organizing the papers left by Einstein at Princeton University in the hands of Helen Dukas, his secretary, turned him into a historian of science. From an early physicist he became deeply interested in the history of science. Holton says that he could almost predict what there was of him in those found letters of Einstein, from an old man to a young man, trying to put it all together and seeing, among other things, that Einstein was incredibly interested in Gandhi.

Holton always wonders about what is peculiar about Einstein and what is his particular way of doing science. According to him,

> ...Einstein looks to us like two different people, one of them is the classical philosopher of nature, for whom the ideas of philosophers like Marx, Hume are as important as the ideas of Keppler, Newton and Maxwell. In one way he is a classic, he loves the idea that science is part of unity and on the other hand he is also a rebel, he is like a gypsy, from the beginning of his life to the end, and he opposes everything that is not revolutionary. Einstein was sickened by authority by command, whatever it was (Galison, P, 2014, November 4).

In this regard you can read in the book My Beliefs, the following words:

> ...The power of the teacher should be based as little as possible on coercive measures; so that the only source of respect from the pupil to the teacher is the teacher's human and intellectual qualities...Teaching should be such that what is offered is received as a valuable gift and not as a painful duty (Einstein, 2000, p. 45).

On a certain occasion, Einstein wrote about his attitude towards the war and the militarism that in fact was brewing in Germany. In this regard he said:

> I profoundly despise those who can march happily after music, those people have brains by mistake, their spine would have sufficed for them. How strongly I hate heroism by command, the path of brutalization, the detestable chauvinism! How dastardly and despicable war seems to me! I would rather let myself be cut to pieces than take part in such an infamous activity. However, I believe so much in humanity that I am convinced that this phantom would have disappeared long ago if the interested parties in the world of politics and business had not systematically corrupted the common sense by means of the school and the press (Kuznetzov, 1990, p. 156).

As can be seen Einstein, like Galileo Galilei, had a harsh verb when he castigated the mediocre and absurd attitudes of certain human beings.

According to Holton, for Einstein it was indispensable to simplify matters, to unify nature, to see the unity between two different things in relation to each other. For example, in the Theory of Relativity, to unite mass and energy, space and time, in short, to unite what for other people is eternally different.

In an interview Holton is asked: What did Einstein do so well 100 years ago that we are still celebrating his work? To which Holton replies:

> Einstein had been working on his theory for 8 years and his results almost scared him because of the implications of having been able to combine space-time and gravity in such a unique and incredible way, as far as a human being can make such a statement. And since then he has become an icon, because then, a few years later, all this could be experimentally demonstrated. This finding of Einstein is celebrated further than most of those achieved by Darwin, Freud, Copernicus, Galileo (Quevedo, L, 2015, December 28).

As a second question, the journalist himself says to him: Do you remember that phrase of Einstein's where he says that one should be able to explain it to his grandmother? Could you explain it to me, since I am not a physicist? Holton answers,

> ...it wouldn't be easy without a blackboard, but I think there's a way to do it. Focusing on a work I discovered when I was asked to create the archive of Einstein's work at Princeton after his death, I discovered an unpublished manuscript from 1920 in which he said that in 1907, while still working at the Patent Office, sitting in a chair, he had something he called "the happiest thought of his life". It was an extraordinary thing. If a man like him said that, he didn't say it about anything, because he didn't discover things all of a sudden, but in this case he had this funny but profound thought. Einstein said, "If I were not sitting in a chair, but on the roof of my house, and I slipped and fell, accelerated by gravity, if I didn't worry about what would happen to me, and I took some keys or other objects out of my pocket and let them fall, they would fall with me. That means, in a way, we are all in a system of inertia at rest. Even though we are accelerating, we can also say that it is a system at rest. So the gravity pulling us down and the acceleration I experience must be the same. That was the key to General Relativity, that acceleration and gravity...acceleration comes from Mechanics and gravity from Newton, of course. But the two had not been combined in Special Relativity. However, in 1907, thanks to that "glücklichegedanke" he was able to put the two things

> together. It can be explained in wonderful ways, but you need pictures, drawings and a bit of mathematics on the blackboard. The key was that happy thought. For ordinary mortals, it is surprising not to be thinking about death at the end of the fall, but about what you experience while falling (Quevedo, L, 2015, December 28).

For Holton,

> ...the theory of General Relativity was a theoretical statement, beautiful and much admired at the time, but it was unproven even though it provided an answer to a puzzle like the precession of Mercury's perihelion. It solved that, but it didn't promise much more. There were possibilities, for example, because light, which has equal parts energy and mass, would be attracted to a gravitational body like the Sun, if that light were nearby, and would undergo a deflection. That was a prediction demonstrated in 1919, and as a consequence it became very famous. Several similar experiments were carried out, all of them in astronomy, until 1969 when a proof was obtained that could also be demonstrated in a laboratory, inside a terrestrial building. It was produced in the laboratory where my office is, by one of my colleagues, R. V. Pound.
>
> He and a student of his did the following: they placed a gamma ray emitter on the bottom of a building and 70 feet above it, near the roof, about 75 feet up, they placed a receiver. Then they activated both and observed that the gamma ray, which is a photon with equal parts mass and energy, received the influx of the gravitational fields. And that's what General Relativity predicted. Even though at that short distance, compared to astronomical distances, at that short distance they had to do an experiment, and they did it, so well calibrated that the result was one billionth...And they showed that it works not only astronomically, but here as well. A consequence of all this is that General Relativity is now in our pockets and in our cars, in the GPS...which depends on relativistic corrections between satellites and receivers (Quevedo, L, 2015, December 28).

In this own interview, Holton goes on to elaborate on Einstein's thinking and adds that:

...when he died in 1955, he was asked to talk about the history of the Theory of Relativity, he started looking and there was nothing in the publications. Then he was lucky enough to be allowed to go to Princeton to read Einstein's manuscripts and letters and some 40,000 papers. For two years, his secretary, who was still there, he and some students he hired went through his archive and sorted it out so that the researchers could work. That was one of the objectives. But in that years-long task, I had to read some of the material, or almost all of it, and I came to the conclusion that there was a careful work that looked at nature through very particular lenses, like, for example, "the most important thing is unification."

Einstein looked for that from childhood. His first published paper was about capillarity, a very boring subject, but he found it fascinating because liquids go down in a wide straw, but in a thin straw they go up. He says, "There are two opposites, so they must be the same thing. He looked for molecular forces that would explain the upward and downward movement in the two different conditions. It is typical in all his work to see the common aspects of things when other scientists saw the opposites. He brought them together rather than having different theories. For example, his 1905 Relativity article begins, "If you have a magnet at rest and a conductor moving toward it, the current moves to the conductor. If the conductor is at rest and the magnet is moving, the same kind of current is produced". But you have to understand the two different theories, the two equations. In the first paragraph he says: "There are two opposite things, but they must be the same". Special relativity was based on that charm which, for no special reason, is reflected in that subject. I call it theme. That theme that unification is the solution to difficult questions.

But then, reading his work, I discovered that parsimony is another important idea, that is, that, as in Newton's work, there should be as little as possible. Newton's work begins with three propositions: F= m.a, etc., and from this he begins to explain the workings of the Solar System. He also says that very little can be done with much, and he repeats it endlessly; his articles are very condensed. He works with that topic and seven others that I have identified

(Quevedo, L, 2015, December 28).

What does Holton mean when he mentions parsimony and relates it to Newton and Einstein? In the answer to this question I will go a little beyond the principle of parsimony so that you can understand what are the methodological principles used in the scientific thinking and actions of the geniuses.

In Newton's landmark book, "Mathematical Principles of Natural Philosophy", he writes about "the rules of reasoning in philosophy" or "RULES FOR PHILOSOPHY" (Arons, 1970, p. 325). (Arons, 1970, p. 325). He refers to these rules at several points, especially when he deals with the subject of universal gravitation in the third book. Originally the rules say:

RULE ONE

No other causes of natural things should be admitted than those which are true and sufficient to explain their phenomena... The philosophers already say: nature does nothing in vain, and it would be vain to do by much what can be done by little. For Nature is simple and does not waste itself in superfluous causes of things.

RULE II

Therefore, as far as possible, the same causes should be assigned to natural effects of the same kind." "As in the case of respiration in man and animal; of the falling of stones in Europe and America; of light in the kitchen fire and in the sun; of the reflection of light on the earth and on the planets.

RULE III

Those qualities of all bodies which can neither increase nor diminish, and which affect all bodies on which it is possible to make experiments, are to be considered as qualities of all bodies.

RULE IV

Propositions obtained by induction from phenomena, in spite of hypotheses to the contrary, are, in experimental philosophy, to be held to be true exactly or

> very approximately true, until other phenomena appear which render them either more exact or open to exceptions. This must be done to prevent the argument of induction from being suppressed by hypotheses (Newton. I, 1687, pp. 463-65).

More explicitly it can be said that of the rules, the first is known as the Principle of Parsimony, the second and third, Principles of Unity, and the fourth is a belief without which the process of logic cannot be used (Arons, 1970, p. 326).

Note that when these rules are applied to scientific discovery, each of them takes the path of coherence, beauty and simplicity, something that Holton, in his time, called the "Ionian Charm or Spell".

Having clarified the above, we continue with Holton's words about Einstein,

> ...Einstein was once asked how he explained his success, and he gave a funny answer "God gave me two things: I have always been neugierig, which in German is someone who always expects novelties in a passionate way, who passionately pursues any scientific novelty, that on the one hand, and the other is that I am stubborn as a mule. I will not change my mind as I did with Relativity (Quevedo, L, 2015, December 28).

Einstein, according to Holton, had this instinct that led him to have a new and very profound idea. He also tells us, in the aforementioned interview, that he once asked psychologist Erik Erikson, who was born in Germany in 1902 and died in the United States in 1994 and who was also a psychoanalyst noted for his contributions in developmental psychology,

> ...if he could give him an explanation of why Einstein became what he was...and Erikson went to Princeton and talked to his secretary, who had worked with Einstein from 1928 to 1955. So Erikson asked her, "Can you give me any clues that you've picked up over the years? And he said, "Yes, it was his mother. Einstein was a very difficult child. He didn't want to talk until he was three years old until, as Erikson said, he had something to say, in a sentence. Therefore, he may have been looked at strangely. Einstein's relationship with his mother was through music, she played piano, he played violin" (Quevedo, L, 2015,

December 28).

Holton, in this interview, emphasizes the idea that to

> Einstein had a hard time thinking in linguistic terms... but he had a wonderful way of visualizing. As he said in one of his publications: "words come to me with great difficulty, my thinking works like a puzzle trying to fit the pieces in my mind, which amount to ideas and theories (Quevedo, L, 2015, December 28).

And to the journalist's question in the interview: Would you say he is the best scientist in history, Holton replied:

> He is on the level of Galileo, whom he admired, and Newton or Maxwell. He saw himself doing the kind of work that Maxwell would do (Quevedo, L, 2015, December 28).

But Holton does not take sides in giving a definitive answer. However, to one of my questions about it:

> Which scientist do you admire the most and why? It makes me think that perhaps you would answer this question with the name Albert Einstein. If so, who would you rate as the other scientist and why?

Holton answered me: Kepler, Newton, Maxwell, Schroedinger. In other words, Holton takes it for granted that it is Einstein whom he has admired most as a scientist and he mentions not just one in the consecutive list of his favorites, but four of the greats.

And for Holton,

> ...after Einstein, there has been no other scientist with his qualities, because Einstein's qualities have not only to do with his fantastic scientific work. He was also a civilizer. The idea of unification, for example, went far beyond physics for him. It was necessary for people to be captivated by the idea of one world, rather than diverse nations. He was a democrat not only with respect to inertial systems, which for him were all the same, but with respect to human beings. He wanted to make it emphatically clear that for him all humans were equal and this unification of humanity is part of his way of thinking about everything.

> This is something you don't see today among our scientists. Although high quality science is being done, what is lacking is devotion to the cultural context, because we limit ourselves more and more to investigating what is happening here and now because those of us at Harvard are worried that we might be overtaken by those at Stanford, and there is not much time to think about the unification of the world, or about Kant, Mach, or some of these figures. Einstein is on the level of Galileo, whom he admired, or Newton or Maxwell. In fact he had pictures of Maxwell, Newton and Faraday hanging in his house, they were the only pictures of great scientists he had, so he adored them.
>
> Einstein knew he was following in their footsteps, so it can be said that he was part of that area of thought, which reflects the heights that the imagination of mankind can reach (Quevedo, L, 2015, December 28).

But, if you want to know much more about Holton's perception of Einstein, I invite you to read the following work referenced as: Holton, Gerald. 2005. "Who was Einstein? Why is He Still so Alive?" In the Proceedings of the Einstein Forum Conference on Einstein, Bibliotheca Alexandrina, Alexandrina, Egypt, June 4-6, 2005.

10. Gerald Holton and his view of historians and science educators

Reading Gerald Holton I learned that the history of science is essential in the teaching of science and especially Physics. That physics can be taught pragmatically and learned in the same way, but that when taught and learned in this way, for most, it turns out to be an unintelligible, empty and boring science to the point of boredom, which brings to naught the lack of motivation internationally to study it.

Holton knows about this separation between "pure physics" and its history and fights against it, but he does not do it only by warning us with his words, he does it from his position as a scientist and professor, he does it from the writing of his articles and books, in short, he does it from his example and he guides us on how to do it.

Holton tells us that in his high school years, which can be found in one of the interviews he was given and which appears in one of the videos that I insist you should watch,

> ...at the Gymnasium in Vienna, you had to study hard, which was not pleasant.

> In this institute you had to take all subjects, from mathematics to poetry, and from biology to history, because it was not a conventional institute, but it prepared you for the university, to get a doctorate, and for him it was very important because it allowed him to perceive culture as a continuum that encompasses all disciplines, from poetry to mathematics. So when he got his position at Harvard, and he had to teach physics, he decided to write a textbook to teach (Thematic Origins of Scientific Thought. Kepler to Einstein), and in this book, unlike all the Physics books of that time, he decided to do something that was brave and perhaps seemed stupid at the time, by incorporating the history of science, technology and other sciences, not only Physics, but Chemistry, Astronomy as well and a bit of Biology, so that the students would realize how science is part of a tapestry, it is not something that is hanging there on its own, but is woven into a culture. This was much appreciated by his students, and he took it upon himself to teach both physics and history of science students, and in each subject he introduced elements of the other (BBVA Foundation, 2021, July 21).

In other words, for Holton, the true teaching of science must go hand in hand with its history, which is almost never the case, unfortunately, and also with the intra and interdisciplinarity so important in the vision of an integrated, concatenated world, where no phenomenon is an individual, atomized entity, unrelated to other phenomena.

In this regard, he explains in his article "What can historians of science and science educators do for each other", that there is a relative distance between historians and teachers, between their "two cultures".

On the above Holton tells us:

> I will propose some concrete answers to the question of what historians and philosophers of science and science educators can do for each other, including some specific actions, as well as pointing out ways to identify effective allies. But before we get to this optimistic part, a few comments are in order about the difficulties facing the two groups, which should help each other....

...There are great sociological and personal differences between scholars of the history or philosophy of science, on the one hand, and people primarily engaged in science education, on the other hand, differences with respect to professional preparation, concern, reward systems, journals, professional societies, in short, by all those indicators that sociologists use to identify any profession...To be specific: among historians of science, of which there are only a few thousand professionals in the world, the writings in their professional journals are almost by definition of the sort that would rarely find their way into the hands of science educators.....

...Indeed, a department of history of science or history of philosophy could be, in principle, the place where a university, for example, could become a real university, in the sense that historians of science find fruitful materials in virtually every field pursued in those other buildings on campus, whether in medicine or physics, religion or politics, psychology or music, arts and architecture, or the interaction between social groups. In short, those science educators who can be persuaded to turn to the history and philosophy of science, in these, may find fascinating material with which to infuse their own activity.....

...If historians and philosophers of science, for their part, are largely concerned with their own tasks, there is a symmetrical situation in that other culture, that of science educators...But as for the history or philosophy of science, most scientists involved in science education are essentially agnostic with respect to philosophy or history, with some even proudly ignorant of philosophy, as was for example Richard Feynman, or of the history of science, as was Sam Goudsmit....

...Most of these scientists do not have the time to tell their students how it all happened, and they do not have the training or the self-confidence to go beyond their professional boundaries. In addition, the opportunity to infuse science education with history and philosophy of science has been drastically reduced in the United States...So, if a journal containing the latest research results on science education lands on the desk of a typical scientist; well, I leave it to your

imagination to complete that sentence." (Holton, G, 2003. pp. 603-604).

And from Holton's ideas, I think and I am sure that science books, especially Physics, should be written like national or universal history books. Where the historical period where the scientist lived, his main ideas, discoveries, decisions and his actions in society are highlighted. As well as the historical evolution of each concept, principle, law, theory or model, throughout the past and its implications in current and future science.

After all, the history of science is part of universal history. Scientists are not part of a select group living on another planet. They coexist with all human beings and share the same space and time as those men who have made history in the social, political, artistic and technological spheres, just to mention a few. Therefore, those who write science textbooks should take into consideration these ideas and put them in those pages in such a way that their reading becomes enjoyable and motivation flourishes in a natural way, to study these "hard sciences", which until today frighten and scare many, despite the innate beauty that they have.

In this regard, in an interview with Gerald Holton, by Alicia Rivera, in Madrid, for the newspaper EL PAÍS, on November 1, 2006, entitled "Los científicos se enamoran de la Física, la Química, las Matemáticas..." (Scientists fall in love with Physics, Chemistry, Mathematics...), he states that:

> ...it is necessary to explain to society, for example, that every time a door is opened with a photoelectric cell, a theoretical article written by Einstein in 1905 on the photoelectric effect for which he won the Nobel Prize in Physics is implied (Rivera, A, 2006, p.2).

And this explanation should be found in Physics textbooks and also add to it why Einstein did not obtain the Nobel Prize for his Theory of Relativity and his differences with Nazism in Germany, and thus continue linking concepts, principles, laws, models and theories with the history around his discoveries and the time in which they were made.

Some will think that writing textbooks with the above characteristics would be somewhat exaggerated in the amount of pages they would have, but at least science

should be placed with its history to the extent required to reach a deep level of assimilation and thus avoid conceptual errors that are made by omitting essential issues in the process of teaching and learning.

It is not that it is impossible not to omit, because there are too many contents to deal with in a textbook, but it is necessary to be aware of what is omitted and to state it. In this regard, in the preface of the book "Physics, an adventure of thought: the development of ideas from the first concepts to relativity and quanta", written by Einstein and Infeld, we read the following:

> "But the explanation has had to be simple. From the labyrinth of facts and concepts we have had to choose some real path that seemed to us most characteristic and significant. We have had to omit facts and theories that have not been reached by this path. We were forced by our general aim to make a careful selection of facts and ideas." (Einstein, A. and Infeld, L. 1961).

In other words, one can omit, what one should not do is to annihilate the beauty of Physics with omissions.

11. Gerald Holton and his comments on our Omission Theory.

In 2014 an international event took place in Cuba, in Varadero, Matanzas, known as ENFIQUI (Teaching Physics and Chemistry). There I participated in a lecture given by the Argentine professor Edgardo Remo Benvenuto Perez entitled the "Theory of Omission". The idea was about the partial and total omissions that are committed in chemistry textbooks and that can be extended to religious, social and political processes, and to all sciences in general.

Incredible as it may seem, omissions do much damage in the process of teaching and learning of science and in the life of all human beings, to the point that it can become a crime and so it is contemplated in the Legal Law. In one of the articles I have written and published together with Argentine Professor Edgardo Remo Benvenuto Pérez, we call "didactic crime by omission" to everything that is omitted in textbooks and then promotes the commission of conceptual errors by teachers and students.

The most interesting thing is that most of the omissions and the misconceptions that

they cause in the process of teaching and learning science come from ignorance of the history of science.

Well, to the idea of Professor Edgardo about the theory of omission and by his personal request, I began to work on it providing didactic and pedagogical argumentation, as well as examples of omissions in physics textbooks. All this led me, together with Edgardo and other invited authors, to write a book known as the "Theory of Omission in the teaching-learning process of Physics".

In this book we made a categorization of omissions, which are shown below:

1. Omission of a part in a definition, considering that, if this is studied in its entirety in the grade or year in question; the student will not understand it. This is the main technical and didactic oversight.

2. Omission of the name of the scientist involved in works, experiments, among other issues, which are reported in the textbook.

3. Omission of original formulas written by the scientists, and instead writing a similar formula, which was arrived at by another scientist.

4. Omission of original diagrams or figures in the scientists' works and replacing them with incorrect diagrams or figures, due to an erroneous interpretation by the author of the book.

5. Omission of original definitions written by the scientists, and instead writing definitions paraphrased by the author of the book, but incorrect.

6. Omission of content that leads to a false idea about the historical development of a concept, law, principle, theory, model, among others.

7. Omission of the historical development of a concept, principle, law, theory or model, which leads to an incorrect understanding of these aspects, in their finished or final state.

8. Omission of key ideas in the concepts, principles, laws, theories or models, which only have a historical value and do not allow to give them their true value.

9. Omission of information and related concepts on a topic that invalidates the

knowledge and concepts developed, therefore, the learning is incorrect.

Since there were so many omissions that we had found in physics textbooks, which involved conceptual inaccuracies and, some of them, in books of international renown, we felt the fear of being wrong and then the idea of consulting with Gerald Holton arose.

Almost immediately I wrote to his e-mail and sent him the written material for his thoughts on the matter. On December 23, 2017 Holton replied to me as follows:

> ...Dear Professor Contreras, thank you for your interesting submission. As you suggested, here are my responses to the draft of the article you asked me to read and comment on. First of all, I think it is an original contribution, of which I have not seen any similar. It deals at the same time with science, cultural heritage in science, the need to be faithful to historical development, and the best ideas for good pedagogy. I am impressed that this can be done more easily for students in Cuba, since they are fortunate to be taught Physics in three successive years of high school (whereas in US schools Physics is usually given only as an option, and for only one year).
>
> Among the omissions in the textbooks I think also of the omission of the actual subject matter. For example, in our U.S. schools, where we have only one year at best for students, we must try to cut from the text some topics (such as how lenses work) that are best taught in the laboratory section of the course.
>
> Some professors feel that other topics, such as special relativity, can be better taught during lectures, which gives students the opportunity to ask questions about that counterintuitive topic as the ideas are developed in class.
>
> And to introduce students to actual historical articles or book sections, in my Project Physics Course I had many so-called "Readers" produced and handed out to students, each for one stage of the course, containing these additional issues. I look forward to the additional information you mention in your mail, and send you and your family our best wishes for the season and for the coming year. Gerald Holton.

And it was from these ideas that I placed at number 10 in the categorization of omissions:

10. Omission of topics because it is considered better to work on them directly in the laboratory or in class or because they are simply not studied for unknown reasons". (Contreras, et.al.2019, pp. 66-67)

And so, to the pride of the authors of the book "The Theory of Omission and its impact on the teaching-learning process of Physics", the tenth type of omission, was contributed by Gerald Holton, who was kind enough to read the manuscript of the book and give me his opinions about it.

That same day I replied to him:

> ...Dear Gerald Holton, I do not know how to thank you for the opinions you have given me on the subject on which I am currently researching: "the omission in Physics textbooks", which I have also called "Didactic Crime by Omission". You, in a few words, have contributed a new type of omission, to the nine I have been able to detect: "omission of real matter", which I will study in more detail and include it as the tenth type of omission, of course referring to it being an idea of yours. I also thank you for the examples you have given me about Physics teaching in your country. I attach another small part that I have written about omissions and that is related to the model of the atom, where I quote part of your work. Receive again a big hug and as far as possible, correct my ideas about the omissions and help me with any other suggestion or criticism in this regard. Next April I will be giving a course on omissions in Physics textbooks at an International Congress on Science Didactics to be held in our country and I would like the ideas that I will give in this course to be of the best possible quality. Thank you again for all you have done on our behalf and on behalf of me, my physics colleagues and my family, we wish you the best in this life.

For me it was a dream comes true that someone like Gerald Holton would take on the task of reviewing part of our work and give his opinions on it. How much humility could be found in a man like Holton, whom we had admired and respected for several years, although he did not know it yet!

12. Gerald Holton and the role of women in science

The road to scientific knowledge has been full of obstacles, both objective and subjective, but this road has been more difficult for women who have dared to walk it. Women in science have been, in most cases, invisible women, condemned to oblivion, because the presence of women in science has been questioned, reviled and denied since the beginning of time. There have been times in the history of mankind when women who have been involved in science have had to suffer humiliation, such as having to pretend to be a man in order to exercise their profession.

Although at the present time, there is a global increase in the number of women in science, this is not yet the case, especially in the direction of scientific activity. Nominations and awards of prizes to women for this type of activity are not significant.

As nothing in the world of science is alien to Holton, therefore, when a scientific or public issue became important, he felt and feels that he could and can contribute to its understanding and improvement, for he also dedicated himself to the general observation that among active scientists in most fields, women were underrepresented and often undervalued, as I have stated in the first two paragraphs.

Therefore, Holton together with her colleague Dr. Gerhard Sonnert, a sociologist of science, initiated a long-term research effort, called the Access Project. Out of this project came two books, Who Succeeds in Science? The Gender Dimension (Rutgers University Press, 1995) and Gender Differences in Science Careers: The Project Access Study (Rutgers University Press, 1995, with a foreword by Robert K. Merton).

Twenty-six years after these works, Holton still brings up these ideas. This can be noted at the end of the lecture he sent me to give during the tribute we were to pay him. In it, he alludes to the joint work of men and women in science.

In one of his interviews that are in one of the videos mentioned in the preface, he says that:

> ...he discovered many women who managed to become great scientists and many others who didn't, but on average what he found is that women, if they came from families with many children, and there wasn't enough money for them all to go to university, it was very likely that families at that time, in the 1920s,

30s, 40s, 50s, would choose to use the money they had to put the boys through university rather than the girls.

This has changed, but this was the first cause of the small differences, the fact that it was harder for girls to get a college education. Then, once they got into a scientific field, and studied science, they discovered, and to some extent this is still true, that if they were the new ones in the class, either alone or maybe in a group of two or three other girls, when the boys went to a soccer game, they didn't take the girls with them. Or then when the lab guys went out for beers, they didn't invite them to go with them, or were less likely to do so in those years. So the girls were left out of these conversations, where you often talk about research problems. This is also important in career development. So these were the kind of small disadvantages that accumulated. Any one of them by itself was not terrible, but the combination of all of them was.

And then they did a study that was definitive, by asking a group of scientists to submit what they thought were their best papers, removing their signatures so that they couldn't be identified, and they asked a group of distinguished scientists to evaluate their quality. And it was found, on average, that the women's papers were as good as or better than the men's. It was also found that women tended to choose problems that were really difficult to solve, and they worked on them for a long time, whereas men chose problems that were easier to solve, and they published a lot of papers on them, whereas women kept working on a single problem that they thought was very important. So for men the important thing was the career, while for women their vocation for science weighed more heavily. That's a big difference, and it's reflected in their ability to work, says Holton (BBVA Foundation, 2021, July 21).

Holton's work on the subject of women in science is transcendental. When we study science or philosophy, to give just two examples, women are almost never, if ever, mentioned. One might think that the reason is that women have contributed very little to the different spheres of reality, but nothing could be further from the truth and Holton knows this and wants us to pay attention to this point.

And for those who have read this book so far and doubt it, I have written below only a very brief summary of the role of women in science. This summary is part of an essay that can be found in the book *Humanística en 3P. Desde la Universidad Mundo Maya, Campus Campeche (Humanistic in 3P. From the Mayan World University, Campeche Campus)*, under the title *La mujer en la historia de la ciencia (Women in the history of science)*, which begins on page 81.

> ...The history of the role of women in the history of science begins in antiquity, except for the cases of the schools of Pythagoras and Epicurus, in classical Greece, women lived in a state of difficult segregation legitimized by the widespread opinion about the basic inferiority of the female sex, and also subscribed by authoritative voices such as Aristotle. In spite of this, and of ancient and medieval historiography, more attentive to private behavior than to intellectual value, some names stand out, such as perhaps the oldest known scientist, Tapputi Belatekallim, who manufactured perfumes in 1200 BC.
>
> After her, there are several outstanding women in the field. Some of them are mentioned below. Hypatia of Alexandria (354-415), the Greek mathematician, astronomer and philosopher who paid with her life for the quality of her knowledge. The astronomer Aglaoinice of Thessaly, author of treatises and teacher of natural sciences. Agnodice, famous in the field of medicine and obstetrics, also protagonist of one of the first female rebellions. In the Middle Ages, the abbess Hidegarda was a committed and competent woman. Among her works are the encyclopedia of natural history, a treatise on medicine and Trotula, to whom is attributed the treatise dedicated to cosmetics and skin diseases.

> Other precursors were Maria Sybilla (1647-1717), a prestigious Dutch naturalist and entomologist. In 1699, at the age of 52, she obtained permission to travel to Suriname with her young daughter in order to document plant life and, above all, arthropods, thus becoming the first adventurer to cross the ocean.

Émilie du Châtelet (1706-1949), known for being Newton's translator, was the most important female figure in physics during the Enlightenment in early 18th century France. A mathematician, physicist and philosopher, Émilie is known for being the French translator of Newton's Philosophiæ Naturalis Principia Mathematica, a translation that is still used today by French-speakers who want to learn about the English scientist's ideas.

Women were also able to carry out some scientific studies, in some cases as a hobby. An example of this was in botany, a science of popular interest during the 18th century, which may have caused the inclination for the care and attention of ornamental plants. Although women were not considered intelligent enough to contribute to formal discourses on classification, they were able, given the taxonomic system, to identify and draw plants and flowers for distraction at home.

Drawing was also an important skill that women developed at home and was often put at the service of science, especially for new plant species. Maria Sibylla Merian (1647-1717) was a botanist on a ship that made excursions to the new world, drawing and cataloging new species of flowers. However, Charles Linnaeus' system for classifying plants based on their sexual characteristics drew attention to botanical debauchery, and by the end of the 18th century, women were no longer motivated to study plant reproduction for fear that they might take away a misguided moral education from nature.

As many of the scientific experiments and conversations about science took place in the house, the women were able to enjoy a space where they could assist their husbands or other family members. Among the handcuffed women was Marie-Anne Pierrette Paulze, who was married at age 14 to Antoine Lavoisier and became his assistant in the laboratory of her own home.

Marie-Anne Pierrette Paulze spoke English and translated not only her husband's correspondence with the English chemists of the time, but also

Richard Kirwan's Essayon Phlogiston, known in English as the Phlogiston Theory, now abandoned as a naive explanation of the phenomenon of combustion. Marie-Anne Pierrette Paulze corresponded with French scientists and naturalists of the time, many of whom were impressed by her intelligence. Her interest in the nature of heat continued after the death of her husband, who was guillotined in 1794. She remarried Benjamin Thompson in 1804 and became the Countess of Rumford, but Thompson's intolerance of her "drawing-room parties" and his refusal to include her in his experimenter's life led to their divorce four years later.

Another very renowned example is that of astronomer Caroline Herschel, who worked as an assistant to her brother, William Herschel, a renowned astronomer who discovered the planet Uranus and other celestial objects. Caroline received a small salary from the English Crown for her work. Early example of a woman paid as a scientist.

She discovered eight comets between 1786 and 1797, and presented the work Index to Flamsteed's Observations of the Fixed Stars to the Royal Society in 1798. This work included more than five hundred previously unknown stars. She thus became the first woman to present a paper to that institution. In 1835, she and Mary Fairfax Somerville were the first two women to be elected to the Royal Astronomical Society.

Other examples of scientific work include Martha Coston (1826-1904), who was the first to design and manufacture a communication system based on luminous flares for ships, which helped save many lives. Henrietta Swan Leavitt (1868-1921) discovered the way to know the size of our galaxy and the scale of the universe. Hedwing Kohn (1887-1964) did painstaking work in spectrometry and pyrometry, now considered standards of enlightenment. Katharine Burr Blodgett (1898-1979) invented anti-reflective crystals, while Yvette Cauchois (1908-1999) created an x-ray spectrograph that made it possible to discover new elements in the periodic table. Maria Goeppert Mayer (1906-1972) gave her name to the

two-photon absorption section unit and Mary Louise Spaeth (1938-) invented the tunable dye laser and developed laser rangefinders.

Rosalind Franklin (1920-1958) obtained the famous photograph that experimentally proved the helical structure of DNA by x-ray diffraction. Martha Jane Bergin Thomas (1926- 2006) improved lighting sources, especially light bulbs and fluorescent tubes. Jean McPherson Bennet (1930-2008) contributed original ideas that are a reference in the study of optical surfaces and Jocelyn Bell Burnell (1943) discovered the beacons of the universe, the pulsars.

They are just a small sample of all the women researchers who have worked, are working and will continue to work in science. Brave and brilliant women who, despite the explicit prohibition and continued denial of their vocation, have managed to make their way and have illuminated humanity with their discoveries.

In the 19th century, the contributions of women were still limited by their exclusion in most areas of scientific research. Facts that exemplify the exclusion to which women scientists have been subjected are the non-admission as members in the academies of sciences. The Académie des Sciences in Paris did not admit a woman as a full member until 1979, when mathematician Yvonne Choquet-Bruhat occupied that position. At the Royal Society of London founded in 1660, the first women to be elected were Marjory Stephenson and Kathleen Lonsdale in 1945. At the Akademie der Wissenschaften in Berlin, founded in 1700, Lisa Meitner was the first woman member in 1949; and at the Akademie der Wissenschaften in Madrid, the first female academic to be admitted was the molecular biologist Margarita Salas in 1986.

The Scottish scientist Mary Fairfax Somerville carried out experiments in magnetism. She submitted an essay entitled The Magnetic Properties of the Violet Rays of the Solar Spectrum to the Royal Society in 1826. She was the second woman to do so. She was also the author of numerous mathematical, astronomical, physical and geographical texts, and was a fervent

advocate of women's right to education. In 1835, along with Caroline Herschel, they were the first two women to be elected to the Royal Astronomical Society.

The first woman member of the American Academy of Arts and Sciences in 1848 and of the American Association for the Advancement of Science in 1850 in the United States was Maria Mitchell, who became known for her discovery of a comet in 1847.

Other notable women scientists during this period were Mary Anning (paleontologist), Anna Atkins (botanist), Janet Taylor (astronomer), all in the United Kingdom of Great Britain. In France they were Marie-Sophie Germain (mathematician) and Jeanne Villepreux-Power (marine biologist).

In Europe at the end of the 19th century, there was a growth in educational opportunities for women. Interest was noted in providing girls with an education similar to that of boys, as turned out to be the case in the United Kingdom, where several schools embraced this idea. The first British college for women, Girton College, Cambridge, was founded in 1869 and was soon followed by others such as Somerville College, Oxford in 1879.

An event such as the Crimean War (1854) helped to boost the study of nursing as a profession, making Florence Nightingale a recognized name. Florence is considered one of the pioneers of modern nursing and creator of the first conceptual model of nursing. She excelled at a very young age in mathematics, and applied her knowledge of statistics to epidemiology and health statistics. She was the first woman admitted to the British Royal Statistical Society, and an honorary member of the American Statistical Association. A public subscription enabled Nightingale to establish a nursing school in London in 1860, and other schools following her principles were established throughout the United Kingdom.

Elizabeth Garrett Anderson became the first English woman to obtain a medical

degree in 1865. Together with Sophia Jex-Blake, the American Elizabeth Blackwell and other women, Garrett Anderson founded the first English medical school to instruct women, the London School of Medicine for Women, in 1874. For her part, the Colombian Ana Galvis Hotz was the first Latin American woman to obtain a medical degree in 1877 at the University of Berne, in Switzerland.

One of the leading Russian mathematicians in this science was Sofia Vasilyevna Kovalievskaya, who was able to work on probation for a year at the University of Stockholm. During this time Sofia wrote her most important paper solving some of the problems that famous mathematicians had devoted great efforts to solve.

In Germany, Elsa Neuman was the first woman in the world to receive a doctoral degree. In the USA it was Elizabeth Blackwell who received her doctorate from Geneva Medical College, New York in 1849, and she also published numerous books on medical education for women.

An unquestionable milestone in the participation of women in science is undoubtedly Marie Sklodowska, who left her native Poland and went to study at the Sorbonne. There in France, working hard with her husband Pierre Curie, she became the first woman to win a Nobel Prize, also shared with Antoine Henri Becquerel in 1903, for radiation research.

Marie could only perform under the shadow of her husband, so much so that she did not receive the Nobel Prize until after his death. She would later become the first person to receive a second Nobel Prize when she was awarded the Nobel Prize in Chemistry in 1911 for her discovery of radium and polonium, and her subsequent research with radium. She is in the select group of people who have won prizes in two different categories.

Lise Meitner (1878-1968), who worked with Otto Hahn, discovered protactinium in 1918. With Meitner's contribution, Otto Hahn and Fritz Strassmann produced the first example of nuclear fission. In 1939 Hahn published his results, but it was Meitner who explained the phenomenon by introducing the term nuclear

fission, in a paper published in the journal Nature.

Meitner is recognized for her research on atomic theory and radioactivity, however, despite paving the way for Otto Hahn, Nobel Prize winner in Chemistry, with her discovery of the fission point, she was never recognized as a co-author because she was Jewish. However, she received recognition for her contributions to physics in 1966, when she was awarded the Enrico Fermi Prize.

Emmy Noether (1882-1935), mathematician, German by birth, known for her contributions of fundamental importance in the fields of theoretical physics and abstract algebra. She was considered by David Hilbert, Albert Einstein and other scientists as the most important woman in the history of mathematics, she revolutionized the theories of rings, bodies and algebra. In physics, Noether's theorem explains the fundamental connection between symmetry in physics and conservation laws.

Irène Joliot-Curie excelled in chemistry by synthesizing radioactive elements and won, like her mother Marie, the Nobel Prize in Chemistry in 1935. Together with her husband, she initiated research in the field of nuclear physics, searching for the structure of the atom, in particular the structure and projection of the nucleus, which was fundamental for the later discovery of the neutron in 1934, the year in which they managed to artificially produce radioactive elements. In 1935, both scientists were awarded the Nobel Prize in Chemistry for their work on the synthesis of new radioactive elements. Both worked on chain reactions and on the requirements for the successful construction of a nuclear reactor using controlled nuclear fission to generate energy by using uranium and heavy water.

Other women Nobel laureates are listed below. Rita Levi-Montalcini (1909-2012), a neurobiologist, graduated from the medical school of the University of Turin in 1939, where she remained until Mussolini's anti-Semitic policies caused her to leave that same year. In 1947 he collaborated with zoologist Viktor

Hamburger at Washington University in St. Louis.

In 1986 he shared, with Cohen (a former collaborator), the Nobel Prize in Physiology and Medicine for his discovery of the substance known as nerve growth factor, which causes the growth of neurons. In 1952, he further developed this experiment to the point of proving that nerve growth was caused by a substance secreted by the tumor.

Dorothy Crowfoot Hodking, British chemist, awarded by the Swedish Academy in 1964. In 1969, she discovered the crystal structure of insulin, a fundamental drug in the treatment of diabetes mellitus. Five years earlier, in 1964, she was awarded the Nobel Prize in Chemistry for her studies on X-ray diffraction.

Other examples are Gerty Cori, Nobel Prize in Physiology and Medicine in 1947 (jointly with Carl Ferdinand Cori and Barnardo A. Houssay); Maria Goeppert-Mayer, Nobel Prize in Physics in 1963 (jointly with J. Hans Jensen); Dorothy Crowfoot Hodgkin, Nobel Prize in Chemistry in 1964; Rosalyn Sussman Yalow, Nobel Prize in Physiology and Medicine in 1977 (jointly with R. Guillemin and A.V. Schally); Barbara McClintock, Nobel Prize in Physiology and Medicine in 1977 (jointly with R. Guillemin and A.V. Schally); Barbara McClintock, Nobel Prize in Chemistry in 1964; and Barbara McClintock, Nobel Prize in Chemistry in 1964. Schally); Barbara McClintock, Nobel Prize in Physiology and Medicine in 1983; Rita Levi-Montalcini, Nobel Prize in Physiology and Medicine in 1986 (jointly with Stanley Cohen); Gertrude Belle Elion, Nobel Prize in Physiology and Medicine in 1988 (jointly with James W. Black and George Hitchings); Christiane Nüsslein-Volhard, Nobel Prize in Physiology and Medicine in 1995 (jointly with Edward B. Lewis and Eric F. Wieschaus); Linda B. Buck, Nobel Prize in Physiology and Medicine in 2004 (jointly with Richard Axel); Françoise Barré-Sinoussi, Nobel Prize in Physiology and Medicine in 2008 (jointly with Montagnier and Haraldzur Hausen); Elizabeth Blackburn, Nobel Prize in Physiology and Medicine in 2009 (jointly with Carol W. Greider and Jack W. Szostak); Carol W. Greider, 2009 Nobel Prize in Physiology and Medicine (jointly with Elizabeth H. Blackburn and Jack W. Szostak); Elinor Ostrom, 2009

Nobel Prize in Economics, the first ever awarded to a woman in the discipline (jointly with Oliver E. Williamson); Ada Yonath, 2009 Nobel Prize in Chemistry (jointly with Venkatraman Ramakrishnan and Thomas A. Steitz); May-Britt Moser, 2014 Nobel Prize in Physiology and Medicine (jointly with John O'Keefe and Edvard I. Moser); Tu Youyou, 2015 Nobel Prize in Physiology and Medicine (jointly with William C. Campbell and Satoshi Ōmura); Dona Strickland, 2018 Nobel Prize in Physics (jointly with Arthur Ashkin and Gérard Mourou); Frances Arnold, 2018 Nobel Prize in Chemistry (jointly with George P. Smith and Sir Gregory P. Winter); Esther Duflo, Nobel Prize in Economics in 2019 (jointly with Abhijit Banerjee and Michael Kremer); Andrea Ghez, Nobel Prize in Physics in 2020 (jointly with Reinhard Genzel and Roger Penrose); and Emmanuelle Charpentier and Jennifer A. Doudna, Nobel Prize in Chemistry in 2020. They are joined by American Andrea Ghez together with German Reinhard Genzel who won the 2020 Nobel Prize in Physics for discovering a supermassive compact object at the center of our galaxy.

Even with the achievements obtained in the 20th century, women definitely reaffirm their role in the world of scientific and technological research, as in other fields of social life, although all kinds of prejudices and obstacles may remain. Proof of this is the percentage of women members of the European Academies of Sciences: Belgium, 5.3%; Denmark, 5.2%; Finland, 6.1%; Germany, 2.0%; France, 2.9%; the Netherlands, 2.1%; and Great Britain, 6.2. (Contreras Vidal, J.L, et al, 2021, 81-90).

Well, after all these data and Holton's studies on women in science, do you have any doubt about how important women have been in scientific discoveries and beyond? I, in particular, have none, and I dare to affirm that neither do you.

13. The woman in science Holton admires most: Marie Curie

Among the questions I once asked Holton was the following:

Within the field of science, which women do you consider most outstanding and why?

To which he answered: M. Curie, for her intuition and persistence.

But I am sure that it is not only these characteristics that Holton most admires about her, and that Marie Curie is somewhat similar in her actions to Holton and Einstein. Not long ago I wrote a book, together with other authors I invited, entitled Genius Attitudes (+) Principle of Greatness, where you can find the main values and attitudes of Marie Curie, some of which I write below.

> ...Marie Curie always reflected a humanitarian feeling and a great sense of social justice. At a certain point Pierre approached her with the possibility of patenting the technique of obtaining radium and having the manufacturing rights all over the world. This would undoubtedly secure the future of his daughter and possible children. The patent would mean a lot of money. However, she rejected the idea as "contrary to the scientific spirit". Curie later wrote in her diary: ...We do not patent anything in our favor and we publish without reservation the results of our research, as well as the procedures for the preparation of radium. In addition, we have given to interested parties all kinds of news requested. It has been an asset for the radium industry, which has been able to develop in complete freedom, first in France, then in the world, providing scientists and physicians with the products they needed (Contreras Vidal, J.L, et al, 2020, p. 104).

Undoubtedly, Curie was a woman out of all times. As far as science is concerned she has no equal, not only among women, but also among men. And as a persevering being I do not consider her to have any rivals of consideration either. Her attitude to life in general was simply extraordinary. She knew and lived in extreme poverty, yet she strove with all her strength to get ahead in her studies, to become a scientist, and she succeeded. Her level of perseverance can be found in the following writing:

> ...Maria does not admit that she is hungry or cold. In order not to have to buy coal again - also out of forgetfulness - she neglects to light the stove, and writes figures and equations, not realizing that her fingers go numb and her shoulders tremble. A hot soup, a piece of meat, would comfort her. But Maria doesn't know how to make soup, and she can't spend a franc, and waste half an hour preparing a piece of veal. She hardly goes into the butcher's shop, let alone the

> restaurant. It is too expensive. For many weeks, he eats nothing but bread and butter and drinks tea. When he feels the need for a feast, he enters a dairy in the Latin Quarter, where they serve raw eggs, or buys a chocolate bar, or fruit...With this diet...he quickly becomes anemic. Often, when he gets up from the table, his head goes out of his head. As soon as he gets into bed, he faints. Later, when she comes to, she wonders why she fainted. She thinks she is ill, but disdains her illness like everything else. It does not occur to her that she is falling from weakness and that her only evil is to starve herself.
>
> How much sacrifice, how much adversity, how much perseverance, how much love for her profession! How great was Marie Curie! Fortunately, life gave Marie a passionate husband, a scientist like her, and between the two of them they faced the hard economic conditions that affected them. They founded a beautiful family (Contreras Vidal, J.L, et al, 2020, p. 144).

Curie, her husband Pierre and Becquerel, won the Nobel Prize in Physics. In 1905, the Curie husband and wife had to deliver their speech, which was mandatory for the awarding of the prize. This speech was prepared by Pierre, but the ideas reflected were of both of them, and they say:

> ...One can imagine that in criminal hands radium can become very dangerous, and at this point we can ask ourselves if humanity extracts advantages by knowing the secrets of nature, if it is ripe to benefit or if this knowledge will not be detrimental to it. The example of Nobel's discoveries is characteristic: powerful explosives have enabled men to carry out admirable works. They are also a terrible means of destruction in the hands of great criminals who drag peoples into war. I am one of those who think with Nobel that humanity will extract more good than harm from the new discoveries (Contreras Vidal, J.L, et al, 2020, p. 146).

Something very similar, wrote her dear friend, Einstein, who supported her in very difficult moments of her life:

> ...The discovery of the nuclear chain reaction represents for humanity a danger no greater than the invention of matches, what must be done is to eliminate the

possibility of abusing the power it represents. (Contreras Vidal, J.L, et al, 2020, p. 146).

However, despite the warnings and good wishes of Curie and Einstein, two atomic bombs were dropped on Hiroshima and Nagasaki in Japan. Hundreds of thousands of innocent civilians died and are still dying today from the remaining radiation. Leukemia and other cancers have affected and still affect citizens of these cities. And, as if that were not enough, nuclear weapons, first in the hands of the United States and today in the hands of other countries such as Russia, Israel, India, North Korea, among others, make our planet unsafe from the threat of global war.

How right you were, dear Holton, to refuse to participate in the atomic bomb project!

I am sure dear Holton that in a certain way that marriage of Marie and Pierre Curie, seemed to you very similar to the one you had for 74 years with your lovely Nina and that you, together with Marie and Einstein, have been equally persevering, humble, detached and enormous humanists.

14. Helen Dukas, the indispensable woman in Einstein's and Holton's lives

In 1955 an unexpected event occurred in Holton's life. When Einstein died, Professor Philipp Frank, Einstein's colleague in the Department of Physics and a supporter of the American continuation of the Vienna Circle philosophy, suggested that a memorial service be organized and that, as one part, Holton present the history of Einstein's achievements. But Holton realized that, apart from Einstein's own essays, there were as yet few solid studies on this subject.

On Professor Frank's recommendation, Holton went to the Institute for Advanced Study, where Einstein's enormous, largely unstudied correspondence and manuscripts were kept, still under the supervision of Einstein's secretary for many years, Helen Dukas. This excursion resulted in Holton, on and off for two years, helping to turn the cluttered collection into a usable Archive for scholars, while he, reading the collection, learned from it to see its historical value. But let Holton himself tell us about this story.

In the book written by Holton, *Victory and Vexation in Science: Einstein, Bohr,*

Heisenberg, and others. A book dedicated to his two sons Thomas and Stephan, he writes about a woman, whom he undoubtedly admired, who was Einstein's secretary.

Holton says,

> ...research in the history of science tends to pay little attention to persons external to an event or human being in essence, whose role often remains in the shadows while the focus is on the subject or human being alone (Holton, G, 2005, p. 16).

In this Holton is absolutely right and I add that this does not only happen in scientific research, it also happens in other areas of life. For example, people talk about how good a baseball team is and how excellent a movie actor is, but when the baseball team loses, then the director of the team comes up and always criticizes it. The same thing happens when the excellent actor does not shine in a certain movie, then it turns out that the actor did not act badly, but that the director of the movie did not know how to direct him well.

Holton goes on to say:

> ...I will draw attention to a woman to whom all historians of modern physics are indebted, but whose role is known in detail only to a handful of specialists, a woman who for twenty-seven years spent more time face to face with Albert Einstein than perhaps anyone else: Helen Dukas, Einstein's secretary and companion, modest but always loyal and extraordinarily effective (Holton, G, 2005, p. 16).

Together, Einstein and Helen, became U.S. citizens in the 1940, as can be seen in the photo that appears in the writing The day Albert Einstein died the story of the photos that went 60 years without seeing the light - Infobae.htm, 2017.

...From her first day on the job in 1928 until Einstein's death in 1955, and importantly for many years thereafter, Helen Dukas was the person who read and typed Einstein's

> correspondence, translated Einstein's letters into English with great style, and took care of storing the vast correspondence and manuscripts. Without his scrupulous passion and devotion to Einstein, we would have but a mere fraction of the collected Einstein papers that have already given rise to so many important studies. For many decades he was also a member of the household and thus saw firsthand both the bright and dark sides of the Einstein families' lives. Upon Einstein's death, she became a trustee of his estate, in accordance with his last will (Holton, G, 2005, p. 16).
>
> ...I met Helen Dukas on August 13, 1959. I had traveled to the Institute for Advanced Study at Princeton on a recommendation from my colleague, physicist-philosopher and friend and biographer of Einstein, Philipp Frank, hoping to consult some of the papers in Einstein's estate while preparing a paper for a conference. After Einstein's death, it had been relegated to the large vault in the basement of the Institute's Fuld Hall. That is where I found her, with the whole scene illuminated only by her rather insufficient desk lamp. She was sitting at the desk, bent over some papers; a long row of large filing cabinets loomed in the darkness beyond. I couldn't help but think of Juliet in the crypt, after Romeo's death ((Holton, G, 2005, pp. 16-17).

Holton's excellent comparison between Helen and Juliet. One has to think about it to feel the enormous sadness Holton felt at seeing Helen in this condition. At this very moment I feel that heaviness in my heart and soul. It should be noted that the woman most attached to Einstein, perhaps the greatest of all geniuses, was under silent, undeclared mistreatment, when she herself had in her possession something of inestimable value, the unpublished documents of Einstein and his unique and unrepeatable experience and life experience, next to a paradigm without equal. I invite you to think just for a few seconds what would have happened if Helen had had these documents in a place where only she knew about them and that death would have come to her without being able to declare it. It is horrifying just to think that the above would have happened. It is similar to what would have happened if the Holy Inquisition had chosen to burn Galileo Galilei at the stake and along with him, all his work.

But let's continue with Holton's comments:

> ...I asked him if I could see some of Einstein's papers. Perhaps on Frank's recommendation, she was very accommodating and led me to the filing cabinets, each crammed with folders of Einstein's correspondence and manuscripts, assembled in an order that only she could have deciphered. In any case, the visit went well for my purpose, and indeed perhaps for hers as well, for a few days later she wrote to me, "It is a real satisfaction to me to be able to help you, and I look forward to it" (Holton, G, 2005, p. 17).

And so Holton goes on to describe Helen, as she allowed him to call her, and to give some of her biographical details. Further on, Holton says, that in front of Einstein's papers, he felt:

> ...like Ali Baba in "The Tales of the Thousand and One Nights", when he shouted "Open Sesame"... (Holton, G, 2005, p. 18).

And that he came to feel that:

> ...No less important than the needs of the profession were Helen's own needs. She certainly seemed to have felt quite lonely after Einstein's death. From what I could guess, she was without office or salary... (Holton, G, 2005, p. 18).

I see here again a humanistic and caring Holton par excellence, concerned about Helen, about her economic condition. I am almost certain that he could have organized all of Einstein's papers without the imperative need for Helen, but for Holton she was essential as a woman, faithful to the legacy of one of the greatest men of science that humanity has ever produced and whom he always admired, since he was very young.

Well, Holton got financial support for Helen and which:

> ...was also needed to microfilm at least the scientific part of the collection. I quote here from one of Helen's letters to me in those days: "The work you have in mind for me fascinates me, but it also fills me with apprehension." And in another letter, "I have been waiting for something like this to come along"... (Holton, G, 2005, p. 19).

Helen, in addition to Einstein's scientific papers, made available to Holton:

> ...what she called the "personal material." That referred to the more personal letters, which she struggled to protect from disclosure but which, in my opinion, were necessary to supplement the "scientific correspondence." If she had a flaw, it was, as Freeman Dyson said in a memorial essay, that she fiercely guarded the presentation of Einstein as a person "without violent feelings or tragic mistakes," rather than allowing everyone to see him as "a complete and fully rounded human being"... (Holton, G, 2005, p. 19).

Undoubtedly Helen was a faithful woman and a boundless admirer of Einstein, but more than all this, a true friend and she surely did what friends do, protect their friend in front of everyone and criticize or advise him alone with him. And I am convinced that Holton admired Helen in this sense because for him friendship is a treasure to be cherished with heart and soul. In one of his mails he told me:

> ...Freud considered that to be happy one needed a job and a love; I consider that one needs a job, a love and friends....

And among the "personal material" that Helen treasured was..:

> ...Einstein's correspondence with Freud, Roosevelt, Romain Rolland and Elsa's letters. So finally there were neatly arranged and catalogued folders on Gandhi, Paul Valéry, Bertrand Russell, Chaim Weizmann, the Queen of the Belgians, Tagore, Schweitzer, Thomas Mann, Bernard Shaw, as well as Einstein's lighthearted verses, joining the files on Schrôdinger, Pauli, Curie, Lorentz, Bohr, Born, Ehrenfest, Infeld, Hilbert, Bose, de Broglie, Bohm, Debye, Eddington, etc., up to Meitner, Minkowski and Wentzel, Wien and Zeeman. By 1973, 130 such folders, some very bulky, had been cataloged, and Ehrenfest's had no less than 165 items. Beginning in about 1976, the solid writing of the Princeton University Press project greatly expanded what we had begun. When John Stachel finished in January 1980, he had 42,000 articles in his large index, which, as he wrote to me, had been based on what he called our "small index" (Holton, G, 2005, p. 19).

Helen's work is praiseworthy, as well as her dedication and level of organization of

everything related to Einstein and, above all, the friendship she maintained with Holton. It is for this reason that the latter confesses that he came to:

> ...respect and even love Helen - as one of my favorite aunts - and I think a little of those feelings might have been for her as well. We trusted each other completely. After the first few years, whenever she got sick, she would allow me to work in the vault on my own or supervise the students, having given me the code to open the vault and the keys to the files and safe inside. During that entire decade of visits, collaboration and correspondence, I don't remember a single time when we were at odds with each other. In 1964, it occurred to him to give me a gift. It was very valuable: a set of reprints of Einstein's published papers that he had kept near his desk, and in some of which he had made corrections and additions. (The set was bound in several volumes, and on the first page Helen had written a dedication to me, "To my assistant..." (Holton, G, 2005, p. 19).

Beautiful, simply beautiful was Helen's relationship with Einstein and with Holton. With Einstein, she was with him until his death and with Holton until his own death because their friendship never waned. Helen Dukas died on February 10, 1982 in Princeton. How fortunate Helen was to have shared with two greats in the history of science, with two men, in my opinion very similar in different aspects of life.

And as a curious fact, just so that you can verify the relationship between Einstein and Helen, I want to end this epigraph by saying that Einstein suffered from an aneurysm of the abdominal aorta which caused him severe pain in the right side of the abdomen and at the request of the doctors he refused to be operated, dying as a result of a hemorrhage of the referred artery in the abdominal region. This aneurysm had previously been surgically reinforced by Dr. Nissen in 1948. When he refused to be operated again, the following happened:

> ...It is in bad taste to prolong life artificially," he told Dukas (he means Helen). I have done my part, and it is time to go. And I will do it gracefully. He did ask, however, if he was going to suffer a "horrible death." The doctors told her it was unclear. The pain produced by an internal hemorrhage could be excruciating,

but it could last a minute or an hour. Turning to Dukas, who was very upset, Einstein smilingly said: "What's all this hysteria about! I have to die one day or another, and it doesn't really matter when (Isaacson, n.d., p. 710).

When Einstein died, only a few of those closest to him accompanied his body to the crematorium, as can be seen in the photo taken from the writing *El día que murió Albert Einstein la historia de las fotos que estuvieron 60 años sin ver la luz (The day Albert Einstein died the story of the photos that were 60 years without seeing the light of day)*- Infobae. htm (2017), and in this there were only 12 people, among these, from left to right: Frida S. Bucky, wife of Gustav Bucky, Einstein's friend and also physicist, engineer, inventor and pioneer of x-ray technology, Hans Einstein, Albert Einstein's son, an unidentified woman, Helen Dukas, and Gustav Bucky. Also present was Nathan, a socialist economist and close friend of Einstein. His body was cremated on the evening of his death, minus his eyes and brain, and his ashes were scattered in the Delaware River. Before his ashes were scattered, Nathan recited a few lines from Goethe.

Not even close to death, Einstein cast aside his objective and realistic sense of life and always counted on Helen's close presence. As Holton could also count on her unconditional help from the moment they met. I am absolutely certain that he knows that we pass through this world very briefly and that the main mission of our lives is to leave footprints, at least one, that will serve as a guide for others that will make this world a much better place than it is.

Holton has left countless footprints and knows that when it is his turn to leave, his earthly mission will have been excellently accomplished, for the good of all other mortals.

And if Einstein was a friend of Nathan, a man of socialist ideas, Holton, for his part, was a friend of José Luis Sert, who was a professor of architecture at Yale University

and later dean of the Harvard University School of Design, who also professed socialist ideas.

15. Lorraine Daston, Gerald Holton's favorite student

To one of the questions I asked Holton about his favorite student, he replied: Lorraine Daston. But who is this remarkable woman?

Lorraine Daston is director of the Max Planck Institute for the History of Science in Berlin, visiting professor of the Committee on Social Thought at the University of Chicago, and a permanent member of the Wissenschaftskollegzu Berlin. Her work covers a wide range of topics in the history of early modern and modern science, including probability and statistics, the wonder and order of nature, scientific images, objectivity and other epistemic virtues, quantification, observation, algorithms, and the moral authority of nature. He has received the Sarton Medal of the History of Science Society (2012), the Dan David Prize for the History of Science (2018), and the Heineken Prize for History from the Royal Netherlands Academy (2020) for his scholarly work. His publications include Classical Probability in the Enlightenment (1988), (co-authored with Peter Galison), Objectivity (2007), (co-authored with Paul Erikson and others) How Reason Almost Lost Its Mind: The Strange Race of Cold War Rationality (2013), Against Nature (2019), and Rules: A Short History of What We Live By (in press). He is a member of the American Academy of Arts and Sciences, the American Philosophical Society, and the Berlin-Brandenburg Academy of Sciences, and a corresponding member of the British Academy.

Upon hearing Holton's response that his favorite student was Lorraine Daston, I set out to find out about her, and upon finding her e-mail address on the Internet, I decided to write to her.

> ...Dear Dr. Lorraine Daston I am Dr. Jorge Luis Contreras Vidal, research professor at the Central University "Marta Abreu" of Las Villas, Cuba. For some years I have been in communication with Dr. Gerald Holton, a communication that has become a friendship, to whom we recently held a tribute, last June 17,

with the participation of professionals from 6 countries: Brazil, Mexico, Ecuador, Peru, Argentina and Cuba. We talked with Holton about our interest in writing a book about him, from our point of view. In the final phase of the book we asked Holton a group of questions. One of them had to do with who his favorite student was, and he answered: Lorraine Daston, recently retired in Germany.

A few days ago he wrote to let us know that his wife Nina had passed away and that in a month or so he would still be working with us on the book, as we asked him for some family and work photos. He just told us who was his favorite student so the idea came up to contact you to help us in one of the epigraphs of the book, maybe the most important of all, because to know the opinion about Holton as a human being and as a teacher would be great and only you can do it. For these reasons we humbly and heartily ask you to help us. That you be the one to write this epigraph that can be titled: My vision about Gerald Holton as a teacher or the title that you think can be the best, the most illustrative. We are at your disposal and waiting for your answer, which if it is positive, if you are in a position to help us, we would not know how to thank you. We are sure that this Holton book deserves it. May this book serve to keep the value of his work always alive. Best regards and take care of you.

To this e-mail Lorraine replied:

Dear Dr. Jorge Vidal. Thank you very much for your kind note. I am very glad that you are writing a book about Gerald Holton, a remarkable scholar and a great soul. It would be my pleasure and honor to write one of the epigraphs. Please let me know how long it should be and by when you would need it. Cordially, Lorraine Daston

Then I said to her:

Dear Lorraine Daston, thank you very much for showing your willingness to collaborate with us to finish the book we are dedicating to our friend Gerald Holton. Surely, no one better than him to deserve it. He is a humble man with a big heart, a humanist par excellence and a scientist without equal. When Holton mentioned his name as your favorite student, we immediately contacted you

because it is essential that you write in this book your opinions about him. I assure you that it will be the most attractive part of this book. At least that's how we see it. You can write about Holton all you want. You can use an epigraph or two or three, no matter how long it is. What really matters to us is what you can contribute about him. He will appreciate it and so will we.

A few days ago I wrote to Holton to tell him that one of the things I most admired about Einstein was precisely what one of his students wrote about him. Below I write it to him verbatim:

"When he approached the chair, in his shabby suit, with pants too short, when we saw his iron chain on the watch, he awakened in us a skeptical attitude toward the new professor.... But from the very first sentences he conquered our dry hearts with his inimitable way of dissertation..."

This mail by which I am writing you is the one from my university, through the one I have in gmail, I will send you the video that Holton sent us when we paid tribute to him. Receive cordial greetings and thank you again for agreeing to help us. I ask that whenever you write to me you do so through my two emails. jcontreras@uclv.cu and luiscontreras9963@gmail.com.

Let me say goodbye with a big hug to you and your dear relatives. Take care of yourself.

And Lorraine writes to me:

Dear Jorge (if I may). Thank you - I am very glad to be able to write about an admired scholar and beloved professor at a little more length. I wrote something on the occasion of Gerry's 99th birthday that I would love to expand on. I know that time is of the essence, and I will try to get it to you soon: I have two more thesis defenses in the next week, but then I will immediately turn my attention to this project. With all good wishes, Lorraine Daston.

And I reply:

Dear Professor Lorraine Daston, we are eternally grateful to you for the help you give us, despite your heavy responsibilities. I am happy to know that both you

and I, and surely many more, wish that Holton will always be honored in the most diverse ways because he deserves it. This book that we are writing is one of those ways that we believe can serve to further highlight his talent and dedication to the sciences and, in particular, to the history of the sciences. We know that this book is only a grain of sand next to the entire body of work of our friend Holton. I anxiously await his writings because I know that he does it from his heart and because he holds in high esteem the one who considers him his best student. I am enclosing the lecture Holton sent us for us to give on his behalf in his honor. For us it was a tremendous honor, perhaps the most important of our professional life. Please receive my warmest regards and best wishes for your excellent health.

And later in time I wrote to her again:

Dear Lorraine, we hope you are well with your family and dear friends. We have been aware of the floods that the German people are suffering and the deaths they have had to suffer as a result. Please receive our expressions of sympathy and concern in the face of such a tragedy. Our hearts and minds are with you. As for the book about our friend Holton, we wish to publish it in Spanish and English and even in German, if it is possible to find a good translator in the latter language. We are not resting in the writing of the book. As I always say, Holton deserves it. We still do not have a definitive title for the book, we think it could be: Gerald Holton, 100 years of History or Gerald Holton; History, Science and Humanism. We would like, in addition to your writing as your best student, to receive your advice on the title you consider most appropriate, which may be a totally new one. Best regards and take care in these pandemic times.

And she replied:

Dear Jorge, thank you for your kind words of sympathy: my family is fortunately safe (Berlin has not been affected by the floods), but the situation in the areas surrounding the Rhine River is truly a tragedy. Fortunately, immediate help has been organized quickly and efficiently, but many lives have already been lost and it will take years to repair the damage. Regarding the title of the collection:

> after reading the beautiful essay Gerry sent you, may I suggest the following? One Hundred Years of Imagination: Gerald Holton as historian, scientist and humanist.
>
> I think his main contribution to scholarship on science is his emphasis on the role of imagination, at once creative but also structured. Of course, this is only a suggestion: you and your colleagues should not hesitate to reject him if you decide that another title would be more appropriate. Today is my last thesis defense. Tomorrow you will have my short contribution (about 1000 words). With best wishes, Lorraine.

And desperately I replied:

> Dear Lorraine, thank you for the suggestion of the title of the book dedicated to Holton. That will definitely be the title of the book we are currently writing. We are anxiously waiting for you to write about our mutual friend and wish with all our hearts that the situation in Germany will improve for the good of all, especially those most affected. The really difficult thing is the deaths because those are never recovered. But Germany is a great country and will pull through sooner rather than later. Please accept our best regards and take care of yourself and your family.

And she finally writes to me:

> Dear Jorge, I am enclosing my brief article for the volume you are so kindly preparing in honor of Gerald Holton. I know that time is of the essence and I hope it arrives on time. With best wishes, Lorraine

And this writing, done by such a worthy and remarkable woman in the world of science and its history Lorraine Daston is what you will read below.

But first I am going to tell you something. Writing to Lorraine was an initiative I took to get a perspective of Holton as a teacher and his imprint on his students and who better than her to describe that facet to me. Whatever Lorraine wrote I would infer from her writing how much he had meant to her as a student and to her other students.

With Lorraine's fabulous and unparalleled writing in my hands, I wrote to Holton and let him know how much I was pleased to have her help with the book I was writing as a way of honoring him in life. And Holton's response was "tough," but very tactful and respectful, as a father does with a son, a response from which I learned a lot, and I'm sure that's what he intended by it.

I did not expect Holton to chastise me for what he considered a nuisance to those close to him. He would tell me that Lorraine was a very busy person, as were the rest of his other colleagues and former students, and that we should come to terms with it. I explained what I had done and why I had done it and apologized sincerely for it. Lorraine, in this regard defended me, clarifying that she had not felt pressured by me, that she had helped me with her writing because she wanted to, which was the absolute truth.

I declare that I could not have felt more nervous waiting for Holton's definitive answer about what happened, but he did not make me wait and thanked me for all the explanations I offered him. If Holton had not forgiven me for my audacity, this book would never have come out even if I had the right to do so. I love and respect him very much, as I once told him: "I consider you my father professionally".

16. The Lucid Imagination by Lorraine Daston

A grateful tribute to Gerald Holton, scholar and teacher extraordinaire.

Nineteenth-century Romanticism succeeded in transforming conceptions of imagination. Imagination, once the faculty that bridged present perceptions and past memories, as well as mind and body, became allied with obscure intuitions and the hidden sources of creativity, especially artistic creativity. Imagination became as powerful as it was mysterious, a source of Byronic inspiration but also of illusions, hallucinations and other distortions of reality that bordered on madness. As a result, it opposed the sciences dedicated to careful investigation and faithful representation of reality. Although almost no one went so far as to claim that science could dispense entirely with the imagination, it became an object of scientific suspicion, to be kept under

surveillance.

In an attempt to both recognize and curb the role of imagination in science, the philosopher Hans Reichenbach, the leading representative of the Vienna Circle in Berlin, scrupulously distinguished between a "context of discovery," in which the imagination could give free rein to its imagination, and a "context of justification," in which all hypotheses and conjectures had to be rigorously tested.

Science thus became schizophrenic, torn between creative impulses totally opaque to scrutiny and transparent, open procedures of proof and refutation. Reichenbach's uneasy compromise between the supposedly dark and irrational and the lucid and rational sides of science dominated much of the thinking about science in the decades after World War II. And this was a period in which there was more intense thinking about the nature of science than perhaps any previous period in history.

The success of the U.S. atomic bomb project inspired awe in the original sense of the word: awe and terror combined. But other scientific breakthroughs in radar, rocketry, computing, vaccines, antibiotics, and space exploration also greatly impressed both politicians and the public around the world with the need for greatly expanded programs to support scientific education and research. In the 1970s there were more scientists engaged in research than in all the rest of the world's history combined, and that number has continued to increase steadily ever since.

It became urgent to understand what science was and how best to ensure that it flourished. This was the context in which Gerald Holton, born in Berlin, raised in Vienna and trained as a physicist in the United States, began his remarkable investigations into the nature of the scientific imagination. Steeped in the intellectual culture that had nurtured the original Vienna Circle, as well as the fiercely empirical operationalism of Harvard physicist and philosopher Percy Bridgman,

Holton was well prepared to appreciate the radical change that Viennese logical positivism underwent when it became American logical empiricism after many of its luminaries were forced into exile by the Nazis, as was Holton himself, as part of the Kindertransport that took him first to Britain and then to the United States. But he also understood the utopian and humanitarian vision that informed both philosophical

projects almost as much as the scientific successes they both analyzed.

Like such Vienna Circle émigrés as Reichenbach and Rudolf Carnap, Bridgman (who advised Holton's doctoral dissertation in physics at Harvard) was deeply committed to the Unity of the Sciences movement, which organized international congresses between 1935 and 1941 in Paris, Copenhagen, Cambridge, Massachusetts, and Chicago.

The tumultuous events that unfolded in those years, as the rise of fascism disrupted and destroyed lives around the world, and the geographic trajectory of the congress venues bear eloquent witness to the transformations Holton described retrospectively in his wonderfully titled article "From the Vienna Circle to Harvard Square: The Americanization of a European World Conception" (1993), a drama about ideas, the exciting ideas of Ernst Mach, Einstein, Niels Bohr, Carnap, Philipp Frank and a galaxy of other luminaries, which Holton recounted with the suspense, intensity and unity of action that any theatrical performance could envy.

Unity as a scientific ideal must have resonated deeply with Holton. Raised at the Bildungsbürgertum in Vienna, he was as steeped in literature and the arts as he was in science and mathematics, and attentive to the exciting new ideas percolating during the most hopeful years of the twentieth century, from psychoanalysis to modernism. His interdisciplinarity was bred in his bones, in contrast to interdisciplinarity that simply juxtaposed one specialized discipline next to another.

As a graduate student at Harvard, he was secretary of the Institute for Unity of the Sciences and later described the "boundless curiosity and generosity of spirit" that animated its debates. Later, when immersed in Albert Einstein's work, including unpublished manuscripts and correspondence, he took note of Einstein's lifelong quest for unity in the fundamental concepts and theories of physics.

Holton's historical investigations of Einstein's scientific concerns bring us back to the subject of scientific imagination, more precisely thematic imagination. As a practicing physicist who ran a laboratory for years, Holton knew and appreciated firsthand the importance of empirical research, and one of his earliest publications was an introduction to Physics focusing on its fundamental concepts. However, he proposed a

"third axis" orthogonal to the abscissa of empirical research and the ordinate of theoretical understanding, and as essential to the advancement of science as both: the third dimension of the thematic imagination.

In his studies of Einstein, Bohr and other scientific stars of the first magnitude, he showed how certain images of the world - too general and pervasive to be called concepts - threaded through their thinking like leitmotifs in a musical composition. Continuity, discretion, and unity were among these beacons of the scientific imagination, a perpetual source of insight (and sometimes stubbornness) and a guide through the bewildering maze of conflicting theories and empirical results. Moreover, it revealed how the thematic imagination could sometimes trump the other two dimensions, giving scientists license to set aside empirical findings or theoretical interpretations that seemed to contradict it.

The Thematic Origins of Scientific Thought: From Kepler to Einstein was first published in 1973 and has been in print ever since. Its case studies on Johannes Kepler, Henri Poincaré, Bohr, and Einstein are still being read, taught, and discussed, which is the true test of a classic. It is one of the few books on the history and philosophy of science that scientists still read, although Holton's revelations about the philosophical roots of Bohr's complementarity principle or Kepler's mathematical mysticism must have shaken sensibilities formed in an age of factual positivism.

Above and beyond these achievements, the book's most fundamental contribution was to restore imagination to its place of honor in science. Or, more accurately, Holton reimagined the scientific imagination. No longer the obscure intuitions of romantic genius or the inscrutable creativity of the context of Reichenbach's discovery, Holton's thematic imagination could be made visible-sometimes literally-and subjected to rational analysis: the lucid imagination. Scientific schizophrenia could be cured, another form of the unity of science.

Lorraine Daston, Max Planck Institute for the History of Science, Berlin

July 2021

17. A necessary clarification on the term Themata in Holton's work

We want to clarify here a little more the term Themata used by Holton or what Lorraine Daston refers to as the thematic imagination in her previous writing. These ideas can be found in The Role of Themata in Science, written by Gerald Holton himself and published in Foundations of Physics, v. 26, 1996.

It must be said that while Holton was studying Einstein's work, he noticed a fact that led to a new and fruitful part of his research on Einstein and other scientists. As shown in Einstein's work, Einstein was recurring again and again, brilliantly but quietly, to a set of fundamental guiding concepts that were neither verifiable nor falsifiable. These concepts included, in his theory building, the primacy of the quest for unity; invariance; formal rather than materialistic explanation; logical parsimony; symmetry; continuum, causality, and completeness. In addition, their opposites, held by other scientists, such as acausality and uncertainty, were strongly opposed.

Holton called all these motivating concepts Themata (sing. Thema). He found that these crucial, style-defining, differing sets of themes were also at the heart of the research of many other scientists, from antiquity to Johann Kepler and Niels Bohr. This idea was subsequently used by other historians of science and by scholars in other fields. Their findings led Holton to publish his book The Thematic Origins of Scientific Thought (Harvard University Press, 1973, revised edition 1988).

Holton says that Newton, Kepler, Einstein and:

> ...many others, made use for their investigations not only of the usual tools and intuitions, but also, powerfully, of a certain kind of fundamentally philosophical conceptions, quietly assumed by them, which I have called "thematic" ideas. The findings of my work on them led me to incorporate also in my books and in my activities, as a teacher and mentor, the humanistic elements that animate all true progress and knowledge (BBVA Foundation, 2021, September 25).

Thematic analysis, according to Holton, is like fingerprints that can characterize an individual scientist or a part of the scientific community at a given time. Kepler worked at the same time with three basic thematic ideas: the universe as a physical machine, the universe as a mathematical harmony, and the universe as a theological central

order.

For Holton, thematic analysis in the teaching of the history of science is one of the nine conceptual tools needed for the complete understanding of an event or case in the history of science. I recommend that you read Ricardo Guzman's article entitled Gerald Holton's Philosophy of Science: An Alternative for Understanding the Nature of Scientific Creation, which appears in Philosophical Notes 28 of 2006, pages 128-129, in order to know, understand and comprehend the tools mentioned above.

According to Holton, the subjects often appear in opposing dyads. And he places the following examples:

- continuity/discontinuity (as in atomism)

- complexity/simplicity

- reductionism/holism

- unity/hierarchical levels

- causality/probabilism

- analysis/synthesis.

He also considers that there are some triads such as:

- evolution/resting state/involution.

- mechanism/materialism/mathematical models.

Holton also considers that some scientists have not needed a set of thematic ideas as is the case of Enrico Fermi, while others have made mistakes by clinging to inappropriate thematic ideas are the cases of Mach and Ehrenhaft.

In my modest opinion, I do not know what Holton will think of what I am going to express here, about thematics, scientists, whether they are scholars, talented or geniuses, become such, because, among multiple reasons, within the processes that occur in the mind there are two, called associations and meaning of the same, which they elevate to their maximum expression.

In my doctoral thesis, Contreras (2008), I worked on associations and their meanings,

but aimed at creating didactic resources for "navigating" within the cognitive structure of learners and materials to facilitate a better understanding of the contents. In the referred thesis I wrote that from the philosophical conception and under the principle of the universal concatenation of phenomena, everything that exists in this world is united, related, associated and that it is the psychic activity that constitutes the reflection of this world, and therefore contains not only the images of the objects and phenomena of the external world, but also that of its links and relations. The latter are nothing more than the associations created with their respective meanings. That associations may be of similarity or resemblance, of difference or contrast, of contiguity and of cause-effect. I quote Vygotsky in the thesis to clarify the necessity of the concept of association, which appears in the elaboration of many problems of the psychology of infantile thought, of the beginnings of ideation, of the process of ideas, and where he emphasizes that the theory of the construction of a higher psychic life is completely inconceivable without the associative and, of course, meaningful scaffolding as well.

When one reads the thematic ideas described by Holton, we see that they relate to the idea of the universal concatenation of all phenomena and to the meaningful associations that all human beings make in one way or another. When he speaks of the opposite dyads mentioned above, to cite just one example, he is undoubtedly referring to meaningful associations by contrast that are taken into account by scientists.

I stubbornly believe that from the family and, fundamentally, from the school, we must teach human beings to think, we must make them aware of their thought processes, that we associate and that we always give a meaning to every association made. If this were done, in my opinion, scholars, talents and geniuses would multiply. Of course, they are born with a genetic predisposition superior to other human beings as far as thinking is concerned, but those less fortunate in this sense can elevate their potentialities if they consciously apply the processes involved in their minds.

18. Gerald and his lovely wife Nina Holton

In one of the emails between Gerald Holton and myself, I asked him a group of questions. Among them were three about the 74-year relationship he and Nina had until Nina's sad passing. The third question and its answer has been discussed previously, but I feel it is necessary to revisit it under this heading.

- You have been with your lovely wife Nina for many years. In your opinion, what is the formula for a marriage as stable and long lasting as the one you and your wife have managed to have?
- Both you and your lovely wife Nina are people who have achieved extraordinary longevity. In your opinion, what factors have contributed to such a long and happy life?
- You are a physicist and a renowned scientist and your lovely wife Nina is also a renowned sculptor. Do you think this combination of science and art has helped you and your lovely wife Nina to grow in your two separate professions, to maintain a marriage for so many years and to live a life of longevity?

Your answers, as always, brief, synthetic. A genius, a scientist of Holton's stature, applies to life the same as to science, the principle of parsimony, since it would be vain to do by much what can be done by little, or what is the same vain to write many words to explain or answer something, when it can be done by few words.

- True love between the two.
- Healthy lifestyle (no smoking, alcohol, etc.), genetics, luck, and again love.
- A variety of interests on both sides is helpful.

As can be seen the word love is not missing in his answers and love is key in Holton's philosophy of life. In the interview conducted by Alicia Rivera, in Madrid, for the newspaper EL PAÍS, on November 1, 2006, entitled "Scientists fall in love with Physics, Chemistry, Mathematics...", he is asked the following question: What is the essential

characteristic of a scientist? To which he replies:

> Maybe my colleagues will smile, but I think that just as some people are in love with money and others are in love with art...scientists are in love with chemistry or physics or mathematics.... The scientist falls in love very young and puts everything aside for that love. Stephen Jay Gould said that science means that at the end of the day, in the laboratory, you know that 99% of your work time has been wasted time, and on top of that you still have to clean the mouse cages. Science is an activity that demands a lot of dedication and time (Rivera, A, 2006, p.2).

And yes, it is true that one must be in love with what one does, with what one lives, with whom one lives for, because otherwise we would not enjoy what we do and any work and feeling devoid of love is an empty and meaningless work and feeling.

But Holton has a different characteristic from those scientists he describes in his answer. We say so, because he did not put everything aside for that love which is science. He knew and has known how to love everything with the same intensity. To love his science and also to love his wife, his sons, in short, his adorable family.

To love his sons, whom he admires and supports. To love Tom, who devoted himself to science like him and Stephan, who took the path of music, the path of art, like his mother Nina. I notice, I imagine you do too, in Nina's gaze towards Holton, an inordinate love, a boundless admiration for this man with whom she has shared her whole life. And in every email from Holton, where he mentions her, there is an idolatry towards Nina without comparison. Nothing, this makes me think that Romeo and Juliet are the reincarnated souls in this unique and great couple by nature.

For Holton, complementarity is a fundamental principle in life. In this regard he says that:

> if a child misbehaves in the end you can end up punishing him, but at the same time you love that child, so you have to be able to do both. That the complementarity of life, the darkness and the light, is a constant of any life experience and one has to be able to manage that complementarity (Bujosa Rodríguez, P, 2014, January 16).

Regarding the principle of complementarity it would be good for readers to read his work entitled *The Roots of Complementarity*, which I quote below so that you can easily find it on the internet: Holton, Gerald. 1970. The Roots of Complementarity. Daedalus 99 (4), The Making of Modern Science: Biographical Studies (Fall, 1970): 1015-1055.

And it was under this last idea of complementarity that Gerry, as she called him, and Nina, his lovely wife who, among other things, painted a mural for him in her own home and gave it to him on one of his birthdays, always loved each other. He never lacked a sculpture, a bust, in his Harvard apartment. For Holton "the arts and the sciences...maintain a relationship of first cousins because, although their tools and products are different, the ingenuity and passion that characterize them are similar" (Preta, L, 1992, p.1).

19. Gerald Holton and the days leading up to his tribute and conference

Upon learning of the award given to Gerald Holton, called the "Frontiers of Knowledge Award for his studies on the social dimension of science", I wrote to him about it:

> Dear Distinguished Gerald Holton. We are delighted that you have received the Frontiers of Knowledge Award for your studies on the social dimension of science. Receive on behalf of all the members of the National Commission of the Physics Career in Cuba the most heartfelt congratulations and we thank you for all your contributions to the field of Physics, History of Physics and sciences in general. A big hug and take care of yourself.

To which he answers me:

> Dear Jorge, thank you very much for your message. I am proud of what you are doing for Physics.

And then, two days later, I write to him again.

> Dear Gerald Holton, it has been a great pleasure for us to communicate with you

and to spread your work in our country, especially among professionals dedicated to the teaching of science and related history. You are a paradigm to be followed by all lovers of science and humanism, which stands out as one of the most praiseworthy attitudes of your life. You are truly admired here and my colleagues always want to hear from you. On my behalf and on behalf of all my colleagues who belong to the National Commission of Physics, of the professionals of my university and other professionals of Latin American universities, we humbly ask you to accept to make a videoconference with us, which does not have to last long, perhaps only half an hour or an hour to be able to see you and listen to you about the importance of the study of the sciences and of the history that concerns each one of them and, above all, of the humanism that arises from them and that we need so much in times as convulsive as those we are living in these moments. We really need you and your advice and, above all, our students, the youngest ones, need it. We thank you in advance if you agree to be with us for just a few minutes. Best regards and best wishes to you, your family and friends. We look forward to hearing from you. Best regards.

His reply was:

Dear friend, dear Jorge, I was very touched by your proposal to make a short conference. I would be delighted to try to do it, but for health reasons, please allow me to think about it for a week or so. With best wishes, Gerald Holton.

To those who followed the mails below:

Jorge: Dear Gerald Holton, of course we will wait for your health to recover to have you with us in a short videoconference. We need you; we need your knowledge and your advice. I can talk to my colleagues and students about the importance of the study of science, of the history of science, of humanism in science, but it is not the same if it is you doing it. My colleagues, students and friends will always be grateful for that meeting with you and will be very motivated. For me, from the professional point of view, it will be the best incentive to go on. Receive a big hug and we look forward to your speedy

recovery and response. Take care and thank you in advance.

Holton: Dear Jorge, dear friend, I hope everything is going well for you and that you are looking forward to the end of the pandemic. This message is a follow-up to mine of May 15, and refers to the lecture you want me to give to the public in Cuba. As I have already mentioned, I am not feeling well lately, and I am now in my 100th year. The result is that I do not feel able to give a spoken lecture, as you suggested. However, I can send you a written lecture on my views on Physics and the History of Science. It is already ready. So, if you like it, you can use it by transmitting it to the audience you have in mind .Please let me know what you wish. With my best wishes and personal greetings, Gerald

Jorge: Dear Gerald Holton, dear friend, of course we understand your reasons for a spoken lecture due to your age and health. May you live another hundred years, as you have done many important things for Physics, the history of science, the teaching of science and for the humanism that should always be present in every action we take in our lives. We will receive with great pleasure and pride your written lecture and with your permission we will send it to our colleagues in Cuba and to other friends of ours from other universities in Latin America who have been interested in your work and who collaborate with us in the national commission of the Physics career that we preside here. We will read the conference for you and we will let you know your results and expectations. From this very moment we are waiting for your written conference and we ask you from the bottom of our hearts to take good care of yourself because we still need you. A big hug to you and your family.

Holton: Dear Jorge, dear friend, I am enclosing my essay, as you requested. Look at it and tell me frankly if it is appropriate for your audience or has something that needs to be changed. With personal regards, Gerald Holton.

Jorge: Dear Holton, dear friend. Thank you very much for your lecture and as always showing your ability to synthesize in a few words what others would need thousands of pages and millions of words. There is nothing to change in the conference and no suggestions to make to you. Next week we will have an

international meeting of colleagues to pay tribute to all his work and his attitude towards life and science, in which physics students will also participate. At that meeting we will read your lecture and send you the evidence of that meeting as a heartfelt tribute to you from all of us who have fallen in love with science, particularly Physics. Thank you again and we will keep in touch. Receive a big hug and never stop taking care of yourself.

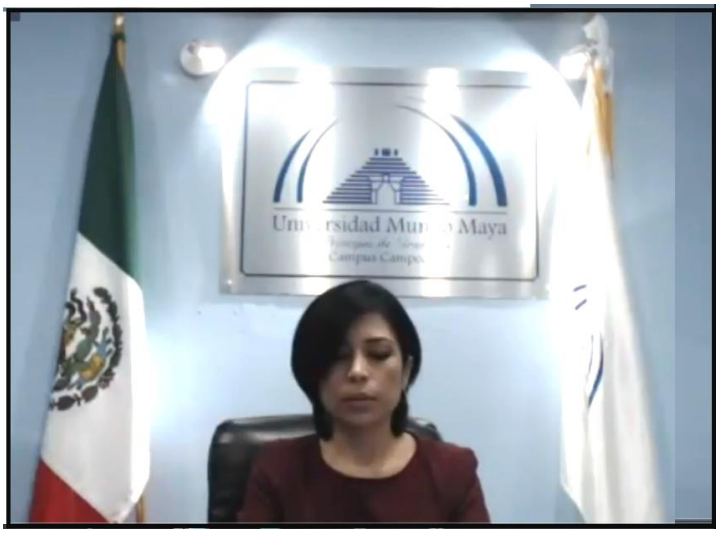
Holton: Dear Jorge, dear friend, just to tell you that I received your message after the essay was received by you. All the best to you and yours, Gerald Holton.

20. Tribute to Gerald Holton on June 17, 2021

This tribute was broadcast live with all invited participants and also on Facebook UMMA Campeche. (Facebook UMMA Campeche, 2021, June 19).

PROGRAM OF TRIBUTE TO DR. GERALD HOLTON

Mtra. Lizette Adriana González Gómez



Good morning. The Universidad Mundo Maya, through its institutional Rector Rosendo García Martínez and the Rector of the Campeche campus, Daniel Iván García Vivas, warmly welcome you to the tribute in honor of Dr. Gerald Holton, Professor Emeritus of Harvard University. They thank the Universidad Central "Marta Abreu" de Las Villas, Félix Varela Campus, Cuba, and its Dean Erich Rodríguez Vallejo for facilitating and supporting this tribute.

To the company GESICAP, Ecuador, and its manager, Eng. Yosbel Lazo Roger and the General Director, Ms. Xenia Pedraza González, for facilitating the promotion of this tribute and for the offer to edit the book in process, about the vision of Dr. Gerald Holton. This book is being written by the Dr. Jorge Luis Contreras Vidal.

To Dr. Jose Iannacone and Dr. Luz Genara Castañeda Pérez of the Universidad Nacional Federico Villarreal of Peru; to Eng. Edgardo Remo Benvenuto Pérez, retired professor of the Universidad Tecnológica Nacional, San Francisco, Argentina, and to Dr. Maurício Abdala Guerrieri, University of Espiritu Santo, Brazil; Dr. Freddy Zambrano Gavilanes, Technical University of Manabí; Dr. Carlos Sifredo Barrios, President of the National Physics Subcommission, Cuba; and Dr. Diego de Jesús Alamino, University of Matanzas, Cuba, for their unconditional support to this tribute.

Next, we welcome Professor Jorge Luis Contreras Vidal from the Central University "Marta Abreu" of Las Villas, Cuba, who will share a brief insight on Professor Gerald Holton.

And it is at this point where, unfortunately, believe it or not, there was a power outage at my university and I was forced to go to a Plan B, considered by me beforehand,

because Cuba was going through a crisis in the energy sector and the possibility of a blackout was possible and so it happened. Plan B was that in case what happened, Professor Xenia Pedraza Gonzalez, would give the lecture for me.

To be perfectly honest I had in mind not only a Plan B, I had plans with all the letters of the Spanish alphabet. A tribute to a man of Holton's stature could not be left undone. It was hard for me not to be able to give the lecture in person because I had done a lot to achieve it, but that's the way things are in life and you have to be content with them, without first, of course, fighting for everything to go well.

Fortunately, for this Plan B I had the support of Mtra. Xenia, a former student of mine, very capable and enterprising, who inspired me and inspires me with all the confidence in the world. And so the tribute continued.

Words by Dr. Jorge Luis Contreras Vidal read by Ms. Xenia Pedraza: I am fortunate to be called a friend by Gerald Holton and for me he is the best paradigm to follow in many aspects of life and profession. Holton is Professor Emeritus of Harvard University and was born on May 23, 1922 in Berlin, so he is approaching his 100th birthday. He is a physicist, historian of science, especially of the history of physics, and an educator who strives to make physics accessible to all students and teachers in an entertaining way, without neglecting scientific rigor, but where the most important thing is to grasp and understand the essence of the phenomena to be studied. Holton also studies and writes about the philosophy of science and is interested in studies on gender issues and ethics in scientific careers to those relating to the role of immigrants and the causes of terrorism and the catastrophic reactions to it that some governments have carried out.

Holton, the scientist who refused to be part of the Manhattan Project for the creation of the first atomic bomb, does not support what can be used to attack others, and was on the editorial board that brought together the works of Albert Einstein. For him, the link between the sciences and the humanities that emanate from them is essential and in this sense he has written books and articles of great value.

Holton has received several awards and the last of them, in 2021, the Frontiers of Knowledge Award for his studies on the social dimension of science granted by the

BBVA Foundation. But the best of all awards is the one that is given to him every day, every time his books and other writings are read.

Mtra. Lizette Adriana González Gómez:

And now, Mtra Xenia Pedraza, also substituting Dr. Jorge Luis Contreras Vidal, will deliver the lecture entitled: "My vision on the Nature of Physics, the History of Science and its teaching".

Go ahead Mtra Xenia:

Before delivering the lecture I will read some other words from Dr. Jorge Luis Contreras Vidal that serve as an introduction to the lecture.

When we asked Dr. Gerald Holton, who in fact never puts his scientific title in front of his name, symbol of his great humility and detachment, to give us a lecture on his vision on the Nature of Physics, the History of Science and its teaching, he told us about his advanced age and his state of health, but, to our surprise, honor and pride, he wrote it down and asked us to dictate it on his behalf, which is what we will do next. Several times we made plans for this tribute and, last Thursday, we received the sad news that his lovely wife Nina had been admitted to the hospital. The day before yesterday we wrote to him to worry about her and to let him know how things were going with his tribute and he wrote back:

> Dear Jorge, dear friend, I am writing to thank you deeply for your message today and your incredible plans for Thursday. It comes at a time when such an uplifting event is greatly appreciated, as for me, right now, there is great concern about my wife's illness. For the time being, with great respect, Gerald Holton.

We hope dear friend, that this tribute will ease your wife Nina's illness and that together you will live hundreds of years more. A big hug to you and may this Sunday you, together with yours, have the best fathers' day. Congratulations to you.

Lecture Reading:

My cordial welcome to all Physics students, professors and research physicists. I was pleased to be asked by Professor Contreras to say a few words about my view of Physics and the History of Science, and how both are essential cultural and human achievements. I am pleased to do so here now, being aware that many of you share my thoughts.

As for Physics, you and I are fortunate to study a subject that is at once one of the oldest, one of the newest, and one of the most valued.

Because Physics was launched by the philosophers of Ionia, in ancient Greece, especially by such of Miletus and Pythagoras, around 600 BC. And Physics is also one of the newest fields, pursuing cosmic background radiation to the edge of the Universe, on the one hand, and semiconductor physics down to the level of individual atoms, on the other.

Almost unlike other fields, Physics also has a wonderful property: it is universal. That simply means that the apple fell about the same in Isaac Newton's garden in Lincolnshire, England, as it does now in, say, Timbactoo (if it has an apple tree). That town, on the edge of a vast wilderness, has its own sociology, its own religion, art, architecture, music, language, and so on. But the demonstration of Physics in their classrooms would work the same as here in Cuba, or in England, or anywhere in the world. In short, Physics is constant throughout geography. Only 2 times 2 is four can affirm the same.

Physics is also constant through time. For what happened in the Universe since the Big Bang, in what comes to us from what happened billions of years ago, we find that the same laws applied then, e.g., E=mc2.

In addition to acting throughout history and throughout space, our field of study has an extraordinary property: beauty, a profound aesthetic sense. Let me explain this briefly.

At the introductory level of teaching, Physics may seem to students to be one little law after another, without much continuity between them. But as students move to the next, higher level, they begin to see the connections between these separate laws and ultimately achieve a synergy between them.

Let me illustrate this. Around 1900, the many formerly separate laws of physics were summarized into three superlaws. One superlaw was mechanics, another was electrodynamics, and the third was energetics.

The physicists of the time fought among themselves to decide which of these superlaws was the best, and no answer could be found. But into this battle came Albert Einstein. He had the inspiration to merge the three superlaws on an even higher level, namely his Theory of Special Relativity.

He was aware, and dissatisfied, that his Special Relativity did not include gravity, and he worked for years to include it. He succeeded in November 1916, calling his new achievement the General Theory of Relativity. As probably everyone here knows, the experimental proof of General Relativity occurred in November 2016. This impressive achievement came exactly 100 years after Einstein's theoretical breakthrough in November 1916. For physicists, these above-human achievements have a blinding beauty.

There is more, besides applying throughout time and space, Physics is also open and constantly expanding. An example is the attempts now to unite Quantum Mechanics with General Relativity.

This brings us to another remarkable fact in Physics. The more adventurous scientists want to bring together all the human achievements of Physics into one Grand Theory, a Theory of Everything, so that ultimately only one equation is needed that can be put on the T-shirt.

It is quite possible that this will never happen. But the quest is part of a motivation of physicists, ever since the philosopher-scientists of ancient Greece, to know how to unify, in a single statement, all relevant knowledge. I call this glorious and eternal quest the Ionian Enchantment.

At this point, I might remind myself that Physics also has enormous practical utility. For example, just think of the far-reaching effect of the construction of transistors, first in 1947, and then used globally in modern life in calculators, computers, cell phones, and so on. In addition, Physics is, of course, the basis of Chemistry, Biology and Engineering.

Dear friends, when Physics is studied or taught from the point of view I have outlined here, it can be taken from the humble first level, such as F=m.a, to its majestic global scope, where one could study how Black Holes are intertwined. Following this approach, I believe that the student will not only like Physics, but perhaps love it.

Let me now share with you some thoughts on the History of Science. The first thing to say about it is that, unlike Physics, which is one of the oldest academic fields, the History of Science as a professional field is one of the youngest.

In its modern version, it was initiated around 1900 by a young man, the Belgian mathematician George Sarton, a man of wide interests and passionate scholarship. His driving idea was to elaborate, over the years, a Synthesis, a kind of Grand Theory, of all the histories of all the sciences. This turned out to be too big a task. So, instead, the histories of the sciences have been followed separately, including the History of Physics.

The big difference between a science like Physics and the history of science is, in short, that one is a statement of facts and the other is a history. Physics tells the facts of a field, while the history of Physics, for example, tells the story of the origins, growth and possible decline of a field, and the story of its participants.

In my research in the field of History of Science I have found countless examples of the variety of human imagination. One example is the history of the atom. Its existence and properties were speculated upon, again, by the ancient Greeks, especially by Leucippus in the 5th century AD.

Leucippus adopted the idea that the atom was extremely small, discrete and always moving in a vacuum. Nothing else exists, and according to this view there are no gods, and no afterlife to hope for or fear.

Obviously, this was contrary to any religion, and therefore this view of atomism was rejected and almost lost. But other views arose, such as that atoms are not separate, not individual, not discrete, but always fused into a continuum of matter, which Newton held.

In other parts of physics it was normal for a long time to neglect discretion in the interpretation of physical phenomena. For example, that light rays come to us in masses of separate quanta, photons, was not thought of until Max Plank, a German physicist, proposed it around 1900, and he himself always opposed the notion. In fact, the first time the Nobel Prize Committee dared to publish a mention of the existence of separate, discrete atoms was in 1926, in its commendation of the French experimental physicist Jean Baptise Perrin, who had demonstrated the existence of discreteness in the structure of matter.

I make a side remark here about the private dimension of the scientific imagination, the part that is practically never discussed in reports on scientific progress. Consider again the struggle over continuity versus discretion in the understanding of Nature, a struggle waged among scientists for millennia. These ideas, and many others like them, are not imposed on us by Nature. They simply come to us as part of our normal, human imagination, because of our human attempts to understand the phenomena of Nature in an orderly fashion.

I have found evidence of this in many cases I have studied. In fact, I believe that only about 50 such useful ideas have been invented and are quietly available to normal scientists in different fields, concepts such as symmetry or causality, or for that matter a Grand Theory of Everything. I call these concepts Themata (singular Thema).

Although I have studied these thematic aids to the scientific imagination for many years, that does not mean that Themata are always necessary. I don't think Enrico Fermi ever needed one. But, anything goes!

Take again the case of Einstein, working on what became General Relativity. Many years ago, Einstein's estate asked me with immense kindness to come, shortly after his death, to his office in Princeton, New Jersey, to help gather and sort his enormous trove of manuscripts and letters, mostly unpublished, some 40,000 documents.

Let me take up just his brief mention of one of Einstein's manuscripts. In it he recalls that one day, sitting on his stool at the Patent Office in Bern, he suddenly thought about what his bodily sensations would be during the fall from his seat. There he generalized it, typically, to think what it would feel like for a man to fall by chance from the roof of his house. (We are seeing here Einstein as so often doing an imaginative, and visual, thought experiment.) Well, during this man's free fall, the force of gravity would not be felt on him. And something taken out of his pocket would stay with him without falling any more on its own.

But now, generalizing further, what would that man feel if he were in an elevator in free space, away from gravity. There he would simply float freely. But now, what if someone could take this elevator and suddenly accelerate it upward? At that point, the man inside would be forced to remain on the floor of his elevator (still in free space). He would feel as if gravity were pulling him. In short - and that is the important opening of Einstein's General Relativity - the effects of gravity and acceleration are equal in the discussion of motion.

Let me give you one last example of free imagination in scientific discovery, as shown in a case from the History of Science. This is the great current research field of superconductivity, the conductivity of electricity in materials with little resistance.

The initial discovery of superconductivity was made in the Netherlands by H. K. Onnes in 1911, in experiments with mercury at very low temperatures: about 4 degrees Kelvin. Since then, continuous efforts have been made to find materials that can exhibit superconductivity at higher temperatures, ideally at room temperature, which could have enormous potential gains in the conservation of energy during the movement of electricity.

A path to high-temperature superconductivity was discovered in the 1980s by two Swiss physicists, by George Bednorz and by Alexander Mueller, who had been his student, and who was also a student of Wolfgang Pauli, an Austrian physicist. Both Bednorz and Mueller received the Nobel Prize in Physics in 1987 for their work.

We had the wonderful opportunity to find out, in open conversation with them, what in their imagination may have been what helped them to make their discovery. A key

decision for them was, of course, to use the right material for their research. They decided to use a perovskite, a multisymmetric mineral.

What motivated that decision? On this, Mueller was really eloquent. He said, "I was always drawn to this symbol," referring to the symmetry of the mineral. And the reason he was so drawn to the mineral was totally "unscientific" and extraordinary. He had been reading the works of the great astronomer Johannes Kepler, writing four centuries earlier, for whom symmetry was an important concept. Mueller told us, "The perovskite structure was for me, and still is, a symbol of - it's a bit of an exaggeration - but of Holiness. It is a mandala, an egocentric symbol, which determined me. I dreamt of this perovskite symbol. In my dreams, Wolfgang Pauli, who was my teacher, was holding it in his hand". And Mueller illustrated his story by sending us an example of an image that some cultures call sacred, namely a Djarmaharaja Mandala.

As so often, here I was amazed at how far the imagination can go, to enable human capacity in its quest for scientific findings.

Dear friends, thank you for allowing me to present some ideas on the nature of Physics and the History of Science. I also thank again Professor Contreras for giving me this opportunity for these remarks. And above all, let us celebrate the international collaboration of men and women of good will. Gerald Holton

Mtra. Lizette Adriana González Gómez:

We thank Mtra. Xenia Pedraza for sharing Dr. Holton's conference and joining the efforts of each and every one of the participating universities and institutions.

Due to time constraints, we will give way to a question or comment from the audience about the lecture we have just heard.

Mtra. Lizette Adriana González Gómez:

Well, to conclude we will listen to Dr. Sergio Octavio Valle Mijangos, research professor at the Universidad Mundo Maya campus Campeche, who will share the conclusions of the conference.

Dr. Sergio Octavio Valle Mijangos:

Thank you and good morning to everyone. I send a cordial greeting to Gerald Holton and wishing his wife a speedy recovery, because that is the reason why he was not present today. I also thank Dr. Rosendo García Martínez, Institutional Rector of the Universidad Mundo Maya for the support to carry out this event. I would also like to thank Daniel García Vivas, Rector of the Campeche Campus of the Mayan World University. To all of you who are connected also thanking you for your time and availability for these topics.

Listening to Dr. Holton's position with reference to science, to the history of science, to how to teach science, in this speech and his perspective of life as a physics practitioner, as a physics teacher and finally as a science teacher, I discover some important challenges and a great opportunity for all of us.

There are five challenges, in my opinion, that can be derived from what we heard. One of them is the issue of the transversality of Physics, of the transversality of the sciences, The sciences are interconnected with each other. Physics in particular, for students, has reversed a complexity, it is a mathematical complexity that originates it. And about mathematics, I want to say in that challenge that because of the precise definitions and structures within mathematics, ICT and current machine learning tools offer an opportunity to organize and improve the discoverability of the mathematical literature thus facilitating research, learning, knowledge transfer. This is complicated in Physics because when mathematics helps, mathematics does not accept polysemy. The hard technical sciences do not accept polysemy, that is why their teaching presents a real challenge for teachers.

The new way of learning science now points towards the use of global and digital libraries and remote laboratories. All this coexisting with informal learning

environments because science is born in informal environments. So it is an important challenge to transmit scientific knowledge.

A second challenge is the changing academic context and what I call critical challenges. A changing context because less and less expensive means are required to make scientific knowledge known. The use of virtuality is currently a critical challenge for everyone and if the current conditions persist, then this element will be updated, the use of virtuality, as an important challenge for those who teach Physics.

I also identify within Gerald Holton's position that there is an element that must be addressed and that is the scientific culture of teachers and students. Scientific culture must be included in the curriculum.

The other topic that seems to be somewhat neglected in science teaching is historicism, the history of science. We have not given much thought to the fact that students or those who practice science should know how this knowledge came about, which is why historicism is important in the curriculum, as Dr. Gerald Holton clearly states. The history of science, why the history of science, because no one can use an explanation, no one can understand, learn new knowledge when he does not know what the preceding discovery is. So we see that Rutherford, Einstein, Bacon, came to certain discoveries, but there was a precedent for them to discover for humanity and that same scientific history is the one that the student should be taken to through the curriculum, in study plans and programs.

One element that right there, in this third challenge, we should be careful about, in order to give Gerald Holton's vision, is what is omitted in the books. There are some concepts that we have taken for valid concepts that probably exist in the sciences. So let's imagine those of us who are teachers how big the challenge is in science teaching.

The fourth challenge is the connection of Physics, in this case, with other sciences. To understand other sciences, one must understand physical phenomena. Many of them start from physics, it helps in chemistry, it helps in biology, so it is important that teachers and students study the connection between the sciences.

One last challenge, challenge number five, which I find in Gerald Holton's position, is

to answer the following question: How do people learn science? We need to study and reflect on the models that we are built on about how people learn science. There are great studies already published that also, as I said before, should be included in the curriculum, in the preparation of teachers and students. Knowing the algorithms of mental work that lead to logical and mathematical reasoning.

So this is how I respectfully allow myself to give my participation and what I believe, from my point of view, must be addressed and taken forward in what Gerald Holton, today, has communicated to us.

I thank all of you, I thank all the educational systems, the universities that were connected, my colleagues from the technical diffusion institute of Tabasco Mexico, the community high school and all those who are here making an effort to learn more about what science is like.

Thank you very much. Good morning to all.

Mtra. Lizette Adriana González Gómez:

We thank Dr. Sergio Octavio Valle Mijangos for his participation.

We thank you for attending this respectful tribute in honor of Dr. Gerald Holton. We thank you for giving him a round of applause.

Have a wonderful day.

Applause

Greetings from Gerald Holton to all those who participated in the Tribute

Hello dear friends! Hello Professor Contreras! I wish I hadn't missed it, but at least I'm sending some quick greetings to you and to the students and teachers who were able to attend. I am so

glad you are doing this for the sake of Physics and History of Science, both wonderful fields that I highly recommend to everyone and today I wish I could have been closer, but this is my best way to thank you once again for what you are doing.

Greetings from Professor Contreras to Gerald Holton

Good morning Gerald Holton, dear friend. Thank you very much for your words. You are a person we admire very much and that is why we pay you this tribute, the one you deserve. The Rector of the Universidad Mundo Maya, in Mexico, who helped us in the organization of your tribute, Daniel Ivan Garcia Vivas, also sends his greetings and we both hope that your lovely wife recovers her health as soon as possible. Receive, our friend, a big hug and take care of yourself.

Certificate given to Gerald Holton, after the end of the Tribute

Upon receiving the certificate he writes to me:

> Dear Jorge, dear friend, I was happy to see the certificate, and I just hope it didn't take you too long to have it assembled.

And in this certificate you can see that several universities, from 6 different countries (Cuba, Mexico, Argentina, Ecuador, Peru and Brazil), were represented by their professionals in the tribute to Holton. That is why we called it Latin American Tribute.

Inevitable Epilogue

When I finished writing the book, I immediately let Holton know and he wrote to me about it:

> Dear Jorge, dear friend. Thank you for your news. I am hopeful that you and yours are well. I also thank you for writing a book about me, although I don't feel I deserve it... I send you my best regards.

Of course you deserve it my friend Holton, you deserve this book and many more things in your long and invaluable life, work and action.

You are an erudite and an excellent professor, as Lorraine describes you. You are a very talented man and a genius. But above all things dear Holton, you are a humanist without parallel, a husband without equal, an exemplary father and a friend that words do not exist to describe you as such.

A hug and all the love from my heart to you and your family.

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