Interview with Professor S. Gracovetsky

Professor Serge Gracovetsky kindly granted us this interview while he was in Amsterdam for a university seminar on the biomechanics of the locomotor apparatus.

“The Spine Engine: A unified theory of the Spine?”

ASN: Professor Gracovetsky, can you describe the path that has led you to devote your career to the study of the spine?

SG: I graduated from the Ecole Polytechnique Fédérale in Lausanne in 1968, with a degree in nuclear physics and I also obtained a Ph.D. from the University of British Columbia in 1971. My meeting with Harry Farfan in 1974 gave me the opportunity to work in the biomedical field. At that time, Harry was at the heart of a renewed effort involving a number of research scientists, such as Alf Nachemson, which culminated in the foundation, in Montréal, of the International Society for the Study of the Lumbar Spine which is now the undisputed leader in this field. The atmosphere was electric and I was carried away by this "brainstorm". I then spent about ten years trying to understand the characteristics of a "normal" spine, by means of mathematical simulations and analyses in the pathology laboratory. The many contradictions between experimental data and the theories of the time gradually led me to reject many widely held beliefs and, in 1983, led to the formulation of a hypothesis combining the essential aspects of the work of many authors into a coherent theory able to explain the structural and functional development of the locomotor apparatus. This was called the "Spinal Engine" theory, which was the subject of numerous criticisms, but has never really been replaced. It therefore appears to partially correspond to reality. This theory led me to develop instruments to measure clinical spine function. One of these instruments, called a "Spinoscope", led to the creation of a company that operated for a number of years.

“If the leg cannot rotate the pelvis, then what rotates the pelvis ?? It has to be the spine. But how ??”

ASN: Can you describe your work environment before your recent retirement?

SG: I was working in a company called "Spinex", which comprised a very large research department, exclusively designed to develop commercial applications of our research. Work started at the Concordia University in Montréal (Faculty of engineering and computer sciences), where I was a faculty member for 27 years. Today, I am more specifically interested in the medical decision process, i.e. to understand the elements which lead doctors to arrive at a diagnosis for the cause of our eternal nemesis, low back pain. Since 1992, my main areas of interest have been expert systems and structuring of knowledge in order to more clearly understand why a clinician adopts one treatment strategy rather than another. I have tried to integrate spinal function as measured by various instruments, with more conventional methods such as radiology, pain assessment and clinical observations in order to establish a multidisciplinary approach.

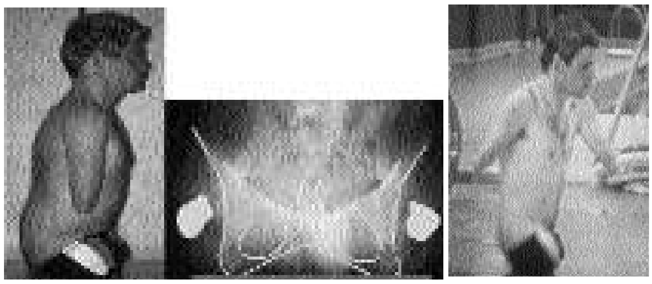
ASN: You mentioned Professors Farfan and Nachemson with whom you worked. In what context did you conduct these collaborations?

SG: My collaboration with Harry Farfan involved 7 to 8 hours a week and lasted approximately from 1974 to 1985. We conducted a large number of studies and published many papers together. Harry had exceptional intuition and vision, extending well beyond conventional medicine. He believed that spinal problems were due to excess mechanical torsion. Nachemson, an impulsive and brilliant man, saw most spinal problems in terms of disk compression. When Farfan and Nachemson were on the same podium at any congress organized anywhere on the planet, you could be sure of a fierce, and well-reasoned, battle of wits. My own work was greatly influenced by the jousting between these two exceptional personalities. The spinal engine theory actually represents a compromise between these two extreme points of view supported by Farfan and Nachemson. This theory demonstrates the irreducible link between compression and torsion phenomena which are an integral part of the principle of human locomotion.

ASN: What are the general principles of your Spinal Engine theory?

SG: The main idea is that locomotion is an activity which takes precedence to all other activities. The individuals of a species must move in order to survive and enjoy vital bodily freedom. However, we need to define certain limits to this hypothesis. According to this theory, the animal must travel from point A to point B by consuming a minimum of energy, in a constant

«Are the legs really necessary ???»

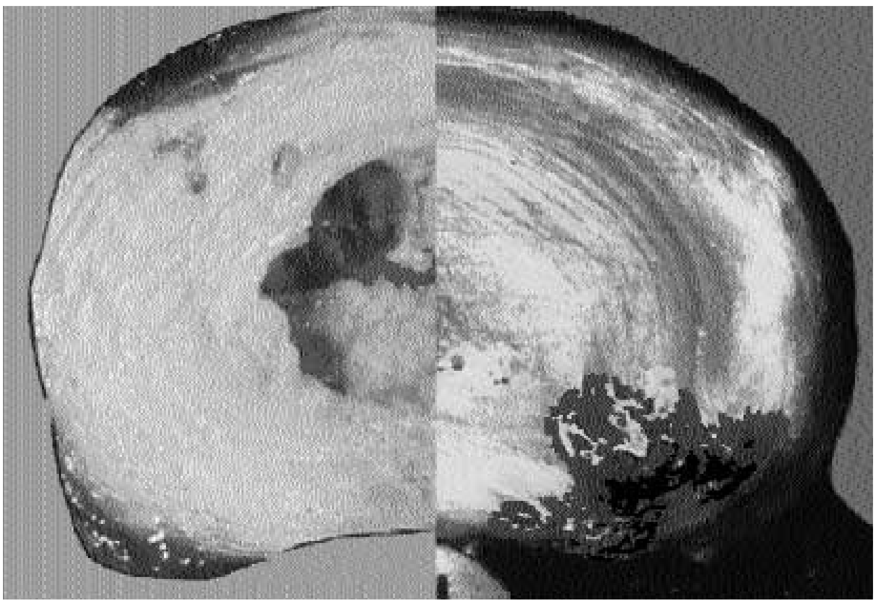


gravitational field, with, as a corollary, that while walking, the various structures (bone, ligaments and muscles) must be submitted to a minimum of stress. Anatomy therefore emerges as the solution and not the given parameter of the problem.
All of the possible solutions to this problem have led to many anatomic configurations, and our anatomy is only one expression of these numerous possibilities. The human body as we know it today, is mainly the consequence of the need to effectively walk on two feet in a constant gravitational field. The spinal engine oscillates within this gravitational field.

ASN: What, then,is the role of the spine in the locomotion?

SG: I consider the spine to be the "primary" engine, in the etymological sense of the word. This primary engine, so obvious in our ancestors the fish, has not travelled towards the lower limbs over time, although its role has become more obscure and may appear to be secondary to the role of the lower limbs. However, this logic is faulty, as we are able to "walk" on our knees with relatively little adaptation, which demonstrates that our legs are not truly essential to human locomotion. A wooden leg is just as effective. It would be conceivable to cut the femur one centimeter above the knee without significantly affecting walking. This therefore raises the question: how far can we cut the femur before affecting human locomotion. The answer is that the lower extremity can be completely removed without interfering with the primary movement of the pelvis. This statement may appear somewhat excessive, but it is supported by the facts.

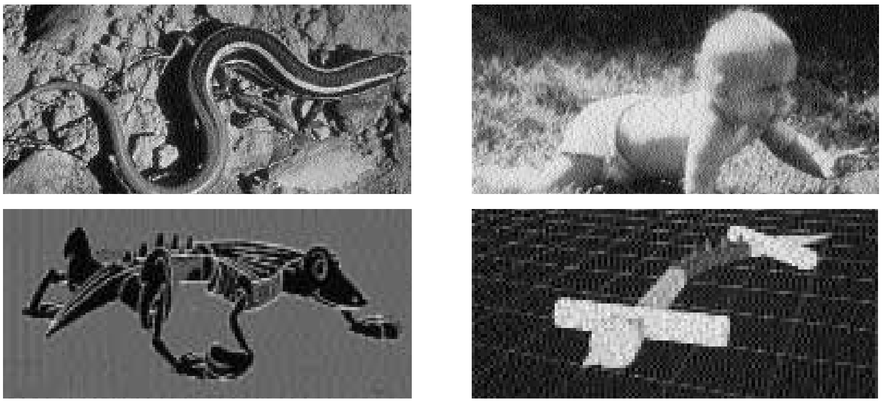
Compression *Torsion*



"Pathology gives data on how the spine is used in life. Any explanation for human gait must incorporate these pathological findings."

Prof. Gracovetsky then showed us a film on his computer, representing a man with no legs and no stumps walking by successively advancing his ischial tuberosities, as if he had legs. The spinal mechanics then appeared to be the engine of this locomotion, which appeared to so closely resemble normal walking.

It is obviously preferable to have legs, but they only amplify the movements of the pelvis, and their functional role remains secondary.



" Only half the available muscle power is used. Each step advances the animal by one shoulder width "

ASN: Can you briefly describe the interrelations between the spine, the pelvis and the lower limbs?

SG: The spinal engine is quite obvious in the case of a snake or a lizard, but when a high level of power needs to be developed, the muscles of the trunk are insufficient. To increase the volume of energy-generating muscles, they had to be displaced outside of the abdominal cavity, to the legs. The first role of the legs is to support the energy sources, which enable us to move at high speeds. However, rotation of the pelvis (as the pelvis rotates around a vertical axis when we walk) with muscles which draw the pelvis downwards leads to a problem of efficacy. This problem is resolved by using the earth's gravitational field as the site of intermediate storage, in which the muscle energy released by the legs with each step is temporarily stored and then recovered during the monopodal stance phase. This energy impulse then ascends up the leg and is filtered by the leg, so that it reaches the vertebral column with the appropriate phase and amplitude. The spine can therefore use this energy to mobilize each intervertebral joint, and to rotate each vertebra and the pelvis in an appropriate fashion. Movement of the vertebral column, especially its axial rotation movement, is therefore derived from the hip extensor muscles.

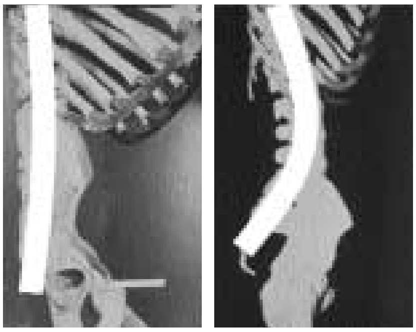
ASN: What happens in the static position?

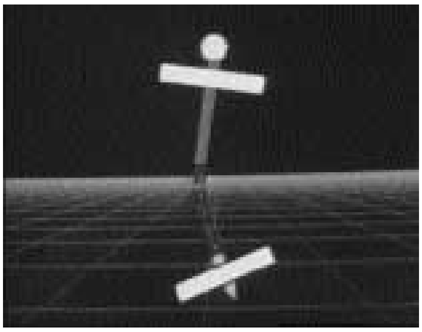
SG: The anatomic structures which connect the spine to the lower limbs are considerable. Take biceps femoris or the hamstrings, for example; the force generated by the hamstrings are channelled by the sacrotuberous ligament, which controls longissimus lumborum and latissimus lumborum situated on either side of the lumbar spine. Part of the sacrotuberous ligament then controls the iliocostalis thoracis muscle up to the superior part of the thoracic spine. Two transverse planes (the right hamstrings control part of the muscles connected to the left side of the thorax and vice versa) constitute another direct link between the hamstrings and the superior part of the thoracic spine. Another important linking element consists of gluteus maximus which crosses the medial aspect of the spine to be attached to latissimus dorsi, which controls arm movements. All of these connections form a sort of cross-pyramid of the back, which ensures very strong mechanical integrity from the upper limbs to the lower limbs.

ASN: Can you place the configuration of the human locomotor apparatus, as we know it, in the context of evolution?

SG: The presumed starting point (as it is only a hypothesis) is that primitive fish, 450 million years ago, moved in the same way as modern fish, i.e. by a lateral inflection movement of the spine. Fish which subsequently ventured onto dry land were faced with several problems, the first being to move by planting their fins into the mud by means of an alternating movement. This axial rotation movement combined with the lateral flexion movement resulted in the movements of flexion and extension. Thus, the simple need to move over small pebbles led our fish to invent flexion and extension movements. This same flexion-extension movement subsequently allowed galloping and the development of the lower limbs, as the para-axial muscles gradually moved outside of the abdominal cavity to become hamstring muscles, in order to increase the brute power available for locomotion. Some of these vertebrates subsequently returned to the sea, while retaining their capacities for flexion-extension movements acquired during their "stay" on dry land. These animals are marine mammals, which also breathe in a very different way from fish. The hypothesis that these marine mammals are descendants of terrestrial

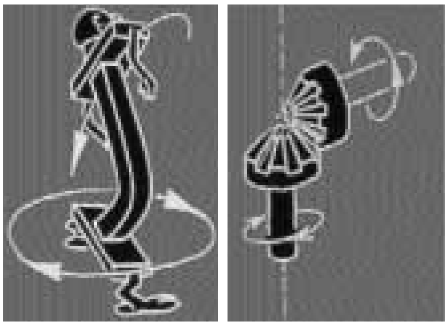
"Solution: Change locomotor design to advance by one body length at each step"





"Lordosis is a unique feature of the human spine"

"Lateral bending with lordosis induces an axial torque"



mammals are descendants of terrestrial quadrupeds, at their turn descended from marine animals is now generally accepted.
The inevitable increase in the muscle mass of the legs then made an upright posture possible. Finally, the need to advance and therefore to pivot the pelvis in two alternating ways, gave rise to the spinal mechanics that we now know today.

ASN: When we listen to you speak, we have the impression that you are neither a doctor, nor a biomechanical engineer. How would you describe yourself?

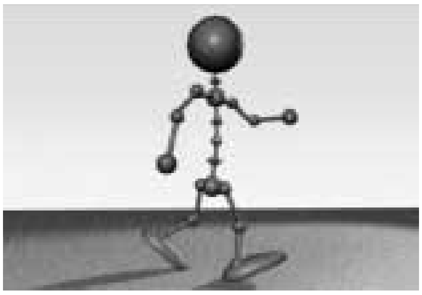
SG: I have never thought about it, but I am certainly proud to have contributed to solving certain problems. The solutions that I proposed were the subject of a great many criticisms, sometimes more destructive than constructive, but in the final analysis, the need to reply to these criticisms was a major element that helped me to present my ideas more rigorously. It is true that I sometimes felt that certain criticisms did not always reflect a disagreement based on good faith, and I sometimes answered in a way that I now regret.

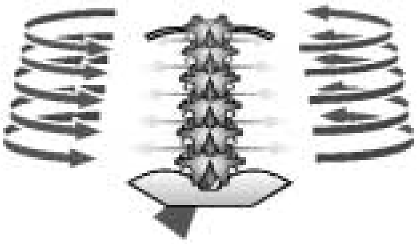
ASN: Don't you think that your theory was the subject of so much criticism because you did not belong to any clearly identified discipline?

SG: I was not trying to solve the problem of human locomotion. Many other scientists more erudite than myself possessed the necessary elements to converge on this vision of the spinal engine. Lowett in 1898 (a century ago!) came close to this solution, but did not take the last step, as it appeared far too incongruous. I can also think of people like Farfan, Nachemson, Pope, Winter and many others. All in all, it wasn't my place to find this solution, but rather all these other people who had infinitely more knowledge and experience in relation to the spine. I felt a need and I saw a gap in the logic of our knowledge at the time. I was very young when I entered this field (I was appointed Professor at Concordia University in Montréal in 1970), with a certain independence of mind, and I started by studying everything that my predecessors had done. It took me 3 years to review thousands of publications on the subject, which I refined to 600 or 700 papers that I considered to be important. There were papers all over my office: on the floor, in cabinets. I was therefore faced with strong and often divergent opinions voiced by honest people and I asked myself how I could incorporate all of these diverging views into an all-encompassing theory, a sort of unifying theory, as is often the case in physics. Then, one day in January 1983, I suddenly had a vision : I saw the spine walking, a sort of slow-motion film. I then had to formulate this vision into a theory which was mathematically sound and publish it, which I did for the first time in 1985.

ASN: What are your current projects?

SG: I made a lot of errors in the way in which systems for the diagnosis of spinal diseases should be designed. I fought for many years to promote the use of a measurement platform, which can be greatly improved. When I started, about twenty years ago, computers were very slow, and measurement systems were relatively inefficient. Currently available solutions will inevitably integrate digital imaging, slightly more advanced tools for the assessment of pain, some of the patient's psychological aspects, and function. This should provide a more accurate description of the patient, which will obviously not be perfect, but





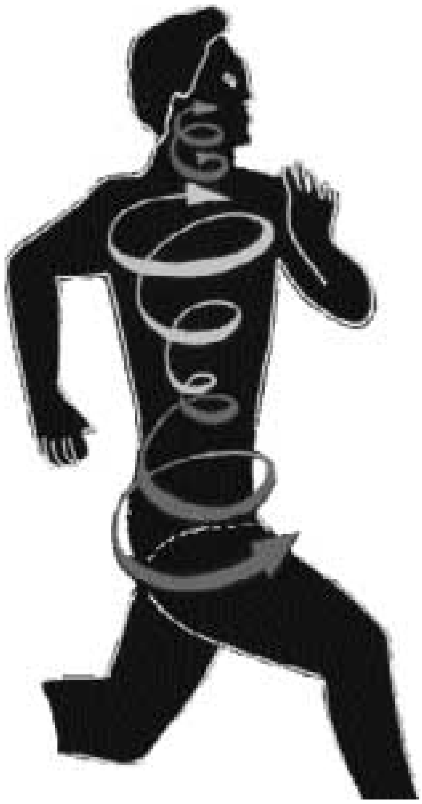
which, in any case, would be better than the system available at the present time. The decision to perform surgery and evaluation of its impact on all of the locomotor apparatus are essential, and I am going to continue to patent several ideas and continue in this direction.

ASN: ARGOS is above all a network of orthopaedic surgeons and neurosurgeons. Do you have a special message for our members and readers?

SG: The diagnosis of spinal diseases, especially low back pain, is problematic in at least 90% of cases. Nevertheless, the current healthcare system expects the doctor to find a permanent solution to an insoluble problem. Health authorities need to recognize that low back pain is a difficult condition to diagnose, and provide appropriate resources to help the medical profession. In my opinion, fees for medical procedures concerning low back pain should be considerably increased so that the doctor can spend the necessary time to establish the preoperative and postoperative diagnoses using appropriate tools, while maintaining the same level of income. ■

***"The leg transfers the heel strike energy to the spine. It is a mechanical filter.
The knee is a critical part of that filter
Improper energy transfer will affect spinal motion
Functional assessment of the spine ought to be part of the assessment of knee surgery"***

Interview by A. Templier



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Serge Gracovetsky wishes to acknowledge the considerable contribution made by numerous individuals: N Newman, M Richards, S Asselin, V. Vidovic, ...

***"The spine is an engine driving the pelvis
Human anatomy is a consequence of function.
The knee cannot be tested in isolation.
It is part of the overall function and purpose of the musculoskeletal system"***