Professor Alexandre Petrovic, who died November 2003, was a world-renowned personality and a famous researcher; with his passing we lost one of the greatest scientists and thinkers of our speciality. Most orthodontists had heard his name, many read his articles, and some knew him personally.

It can be said that his character was as well known as his scientific pre-eminence. It is true that he was dictatorial, despotic, tyrannical, unpredictable, demanding—but also very exacting and rigorous. His lifelong friends appreciated his faithful friendship and his vitality combined with much charm; humor; special interest in good wines, good food, good jokes; and his tremendous culture. No one could ignore his charisma and strong personality. He held fast to his opinions and said what he thought. He did not go with the flow.

He loved beauty and perfection in the works of God and in the works of Man. When listening to a piece of music or watching a ballet or any other human performance, he expected it to be perfect; otherwise, after a few minutes, his face would become sad and he would say, "It's not good!"

He was brilliant and everyone could share in his passion for life and work. His life was devoted to medical research and biology from the time he began his medical studies. A better understanding of the laws that govern the living world was, for him, the way to intellectual satisfaction and personal achievement.

He was rigorous, and people who had the privilege of writing with him know how many hours and dictionaries were necessary to find the exact word to precisely express his ideas. He continuously fought, even in everyday life, people not using appropriate semantics. One would be amazed, when considering his tremendous amount of laboratory work, by his written and published work (consisting of 400 publications, of which 160 are directly related to our speciality).

He was proud that his research life was recognized by the IADR award he received in 1994 in Seattle; but most rewarding for him was to be recognized and appreciated by colleagues and friends around the world. He considered his personal scientific achievement a public property, and so he loved to share his expertise and knowledge with everyone who showed sincere interest. He appreciated other people's work and always supported and recommended his dedicated team members.

He met many personalities during visits to foreign countries or in his own laboratory in Strasbourg. In addition to these individual visits, most of the leading researchers in craniofacial growth gathered in Strasbourg for the symposium he organized every 2 years; these symposia were an opportunity for people to discuss and compare results and thinking, in a warm and friendly atmosphere.

Every year from 1975 to 2001, Petrovic attended the Moyers Growth Symposium in Ann Arbor, Michigan. He was an orthodontic globetrotter invited all over the world. For 16 years, he was Visiting Professor at Louisiana State University, New Orleans; since 1992, he gave lectures at Universita Cattolica del Sacro Cuore, in Rome. He was invited on a regular basis to São Paulo, where he was conferred Professor Honoris Causa of the University Camillo Castelo Branco in 1989, and where he had the opportunity to study the effects of the Planas appliance.

The originality and significance of his research work are related to the fact that: (1) he was a physician and exclusively a researcher; (2) he spent his childhood in Strasbourg, with his father in charge of the cancer surgery department in Strasbourg Hospital, a very famous one at that time; and (3) he had a deep interest in philosophy and the new fields of thinking.

Throughout his life, Petrovic kept in touch with his father on physiopathology and cancer research. When he was about 8 years old, the family went back to Belgrade, where he attended a high school specializing in philosophy and music. He wanted to be a physician, but, unfortunately, the communist regime at the end of the war did not allow him to have the same profession as his father. He then decided to be an orchestra conductor. In 1947, when he was close to finishing his music courses, he had the opportunity to flee and return to Strasbourg. He immediately enrolled in medical school. This brief life...
overview explains how medicine, philosophy, and music became integral parts of his everyday life.

He was always seeking the most relevant techniques for his research. Even during his medical training, he used grafts and transplants in histologic studies of endocrine glands. This is the basis for his studies about the action of hormones on bone and craniofacial growth. In 1954, he was in a famous laboratory in Holland for his training on tissue and organ culture; and in 1961 and 1962, he was in Montreal to master the technique of radioautography. He routinely used these techniques, and started his research on the mandibular condyle in 1964 in Chicago, where he was director of his own tissue culture laboratory for 4 years. Here he met Tom Graber and developed his interest in orthodontics.

Petrovic was influenced by lectures of Rudolf Carnap on epistemology, Tom Milholm on cybernetic reasoning, and Sir Karl Popper on the philosophy of science. He was particularly proud to meet Sir Popper at the Philosophy Symposium in Vienna in 1982, and honored to be the only scientist invited. Two fundamental ideas are dominant in Popper thinking: Science is not a static statement but an uninterrupted quest to the truth and the refutation-corroboration statement in which the researcher has to find what is destroying his hypothesis and not accumulate confirmation. For Professor Petrovic, rejecting what is wrong was a fundamental aspect for the development of any scientific field. Two mathematicians also influenced him: Rene Thom, with his “catastrophe theory” and Benoit Mandelbrot with “fractal theory”. Alexandre Petrovic used both theories to express huge variations related to occlusal adjustment.

This wide and diversified training led him to thorough and elaborate studies of the condylar cartilage, mandibular and craniofacial growth, and physiology of bone—normal and pathologic. Although not very well known in the orthodontic world, he conducted innovative research on otospongiosis in Chicago as early as 1964 with the Otolaryngology Surgery Clinic at Northwestern University. He thoroughly studied NaF effects on bone apposition and resorption processes. The labyrinth of the ear and the 3 bones of the middle ear are the only parts of the skeleton that have no turnover during life. If resorption occurs, then we have otospongiosis. He used these results in his investigations on alveolar bone, adding the study of the action of parathormone, calcitonin, cortisone, and heparin, demonstrating that NaF decreases bone resorption by decreasing osteoclast proliferation and activity.

As early as 1967, Petrovic established that the condylar cartilage in culture has no independent growth potential, as opposed to long bones, the sphen-occipital synchondrosis, and nasal septum. He stated that this was the primary difference between primary cartilage and secondary cartilage.

In 1968, he demonstrated that the condylar cartilage can be modulated with orthopedic appliances, stimulating or decreasing condylar growth. He established that a regulation mechanism exists between the prechondroblasts, which are dividing cells, and the chondroblasts, mature cells synthesizing the cartilaginous matrix. Regulation and adaptation involve feedback mechanisms that must be detected and critically analyzed. He showed that condylar growth may be influenced by extrinsic factors, such as growth hormone, lateral pterygoid muscle, tongue, occlusal interdigitation, retrodiscal pad, and testosterone. He established a cellular connection and used it in proposing a new classification of bone tumors.

One of his creative ideas lies in the way he synthesized his results in a cybernetic diagram, which allowed the continuous incorporation of new results. The initial one was elaborated in 1974; the complexity of this diagram reflects the complexity of the biological phenomenon observed. As Professor Petrovic liked to say, “What is true is often incomprehensible, and what is easily comprehensible is generally not true.” As early as 1975, part of the laboratory activity was devoted to the study of biological cycles. In the same manner, he studied alveolar bone turnover, with collaboration of Jeanne Stutzmann. For this purpose, he chose 4 parameters: Ca45 incorporation, for bone mineralization; and 3 enzymes: for bone apposition, the alkaline phosphatase; for bone resorption, beta glucuronidase; and action of acid phosphatase. Some of the main results were:

- Alveolar bone turnover is higher in the spring than in the fall.
- Alveolar bone turnover is higher in the evening than in the morning.
- Alveolar bone turnover is higher with anterior rotation of the mandible.
- In anterior rotation, apposition and mineralization are higher on the mesial side of the tooth (resorption being higher on the distal side); it is the opposite for posterior rotation. This means that in cases of anterior rotation, the natural drift of the tooth is distal, and in posterior rotation, the natural drift is mesial.
- The highest level of alveolar turnover is achieved with light intermittent forces; the lowest, with heavy continuous forces.
- With the light intermittent forces, alveolar bone turnover is higher in anterior rotation.

Professor Petrovic wanted to bridge the gap between fundamental and clinical research. In this respect, he studied the action of several appliances. These studies were made easier because of his relationships with top clinicians using functional appliances.

In 1985, “the auxologic classification” was introduced, with Dr J. Lavergne and Dr N. Gasson (his daughter). This classification is the coalescence of 2 different types of research: implant cephalometric study (Lavergne and Gasson) and biological studies on alveolar bone (Petrovic). The cephalometric studies led to operational definitions of growth rotations in 1977; in addition, it was established that when the mandible is growing more than the maxilla, the direction of rotation is anterior. As anterior rotation is associated with anatomical features, it leads to a shortening of the occlusion-relevant length of the mandible. The opposite phenomenon is observed in posterior rotation. These observations led to the hypothesis that mandibular rotation could be a regulation mechanism of mandibular length.

It was proposed that in ideal facial growth, the mandible and the maxilla are growing at the same rate, and no regulation is needed. On both sides of this ideal rate of growth is a zone in which growth guidance is possible through either anterior or pos-
terior rotation. But even within this zone of possible guidance, malocclusion may exist. Outside of this zone, no successful regulation is possible. The regulating system is overloaded. These results were summarized in a “tree diagram” (Fig 1). In 1982, the classification was adapted to non-implant patients.

It should be emphasized that one of Petrovic’s primary laboratory results concerned alveolar bone turnover as a function of rotation. Results were statistically significant but still “frustrating”. He said, “We previously reported that both the dividing cell index in the lateral subperiosteal area of the ramus and the alveolar bone turnover rate are significantly higher in anterior rotating mandibles…This rule, although valid for statistical populations, shows exceptions in individual cases and does not account in ultimate detail for the biologic reality.

Hence we ranked all of our cases from the lowest to the highest value of turnover rate, and we tested various methods of categorization. The best fitting method was observed when all the children were categorized according to Lavergne’s and Gasson’s classification of growth rotations.”

The final result of long and hard analysis and scientific discussions led to 6 growth categories, described as follows:

- **Growth category 1.** Corresponds to the rotational group P2D. The mandible has a smaller growth potential than the maxilla: the regulating system is functioning correctly, resulting in a posterior rotation of the mandible, but because the growth potential difference is too high between mandible and maxilla, the regulating system is insufficient; the anatomical end result is a basal Class II.

- **Growth category 3.** Corresponds to rotational group R2D. In this case, the growth potential of the mandible is smaller than the maxillary growth potential. There is no adjustment mechanism; here again, the anatomical end result is a basal Class II.

- **Growth category 4.** Corresponds to 1 rotational group (R1N). The maxilla and mandible have the same growth potential; no regulation is needed. The anatomical end result is a basal Class I.

- **Growth category 2.** Corresponds to 2 rotational groups. In this category, the growth potential of the mandible is less than that of the maxilla. In some cases, the regulating mechanism is working properly, through posterior mandibular rotation, and the anatomical end result is a basal Class I (group P1N). In other cases, not only is the regulating system not working properly, but it also is working in a wrong direction, through anterior mandibular rotation, leading to extra shortening of the mandible. The anatomical end result is a severe basal Class II (group A2D). Hence, in this growth category, with the same growth potential, the anatomical end results can be very different.

- **Growth category 6.** The growth potential of the mandible is much higher than the growth potential of the maxilla. In some cases, there is an attempt for regulation through anterior mandibular rotation, but the system is not adequate; these cases belong to the A3M group. In other cases, insufficiency and error of the adjustment mechanism add up, leading to an anatomically strong basal Class III.

- **Growth category 5.** This is where we find a third of our patients. The growth potential of the mandible is higher than

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Fig 1 Tree diagram of facial growth classification (based on the original from Nicole Gasson).
that of the maxilla. This growth category is confirmed by histology, and corresponds to 4 rotational groups, defined cephalometrically. The same growth potential is expressed in 4 different ways. In some cases, there is a good regulation and an appropriate shortening of the mandible through anterior rotation leads to an anatomical end result of basal Class I (A1N). In P1M and A1D, the regulating system is working incorrectly; either through an excess of anterior rotation, leading to an extra shortening of the mandible, or through an excess of posterior growth rotation, leading to an extra elongation of the mandible.

The R3M group, in which there is no regulation (adjustment), leads to a basal Class III. With the same growth potential, the anatomical end results can be Class I, Class II, or Class III, depending upon the morphogenesis of the face.

There are 2 growth categories in which the basal Class I cannot be achieved: categories 1 and 6. In all the other growth categories, successful guidance is theoretically possible through mandibular rotation.

To summarize, the 3 basal relationships do not have a single origin. For example, the distal relationship is related to 4 growth categories 1, 2, 3, and 5. These differences account for a major part in the treatment results of functional appliance therapy.

In the 1980s, Professor Petrovic studied several appliances with respect to the growth categories. For all the appliances analyzed, growth category 5 appeared to be the most favorable, either with fixed or functional appliances. Consequently, in determining the prognosis, the growth category (ie, morphogenetic pattern) has to be taken into consideration more than the appliance.

Professor Petrovic was among the world’s outstanding researchers, due in part to the quality of his contributions. Each of his findings was the starting point of deeper investigation. He made progressive synthesis of all his results through the cybernetic diagram and the auxologic classification; incorporating them, in this manner, in general physiologic laws. Indeed, he applied cybernetic rules that establish that a biologic or a pathologic phenomenon is only one part of a total system. His critical thinking, his intellectual integrity, and his constant attention to the strict application of the rules of methodology contributed to his stature.

**BIBLIOGRAPHY**


