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Do the Images of Neuronal Pathways in the Human Central Nervous System Show Feed-back ? A Comparative Study in fifteen Countries.

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ABSTRACT: In the human brain, the neuronal pathways are networks which support our learning, memory and thought, and which work with permanent feedback. However, only 19% of illustrations of these neuronal pathways, in the 55 analysed school textbooks coming from 15 countries, were showing feedbacks. The neuronal pathways related to movements were generally introduced by linear spinal cord reflexes, and sometimes mostly reduced to reflexes. In consequence, in most countries, the scientific knowledge taught with these images of neuronal pathways was linked with an implicit ideology: A clear behaviourism associated with reductionism, and even sometimes with innatism or spiritualism. Two thirds of the few images with feedback were related to vegetative functions: the neuro-hormonal control of female and male reproduction, and of heart and breathing rhythms. Nevertheless, even for these vegetative controls, there was not any feedback in several of the 55 analysed textbooks. Only in three countries, the double innervation (gamma and alpha) of striated muscles, with the regulatory function of the neuro-muscular spindle, was illustrated with only one image in each of the three corresponding textbooks. Few images illustrated neuronal pathways in the brain, and only exceptionally as the neuronal networks (with feedback) which are the supports of our memory and of our thought. The persistence of the

same kind of images in school textbooks of these contrasted countries suggest that the conceptions of human brain are less linked to national socio-cultural contexts rather than to international dominant ideologies.

KEYWORDS: Feedbacks, human brain, school textbooks.

Résumé

Dans le cerveau humain, tous les trajets nerveux forment des réseaux qui sont les supports de nos apprentissages, de notre mémoire et de nos pensées et qui fonctionnent avec de multiples régulations (feedback). Cependant, l'analyse des images de trajets nerveux dans 55 manuels scolaires de 15 pays montre que seulement 19% d'entre elles illustrent des régulations. Les trajets nerveux impliqués dans les mouvements sont en général introduits par des réflexes spinaux linéaires, et parfois quasiment réduits à des réflexes. Il s'avère ainsi que, dans la plupart de ces pays, les connaissances scientifiques illustrées par de telles images de trajets nerveux véhiculent aussi, à leur insu, une idéologie implicite: une pensée béhavioriste et réductionniste, parfois même innéiste ou spiritualiste. Les deux tiers des quelques images qui présentent des rétroactions illustrent des fonctions végétatives: le contrôle neuro-hormonal de la reproduction chez la femme et chez l'homme, et du rythme cardiaque ou respiratoire. Cependant, même pour ces fonctions végétatives, il n'y a aucun processus de régulation présenté dans plusieurs des manuels scolaires analysés. La double innervation (alpha et gamma) de tout muscle strié, associée à la fonction régulatrice des fuseaux neuromusculaires, n'est schématisée que dans trois pays (avec une image seulement dans chacun des trois manuels scolaires). Très peu d'images illustrent des trajets neuronaux dans le cerveau et nous n'avons trouvé qu'une seule image de réseaux neuronaux cérébraux en tant que supports de notre mémoire et de nos pensées. La présence des mêmes types d'images de trajets nerveux dans les manuels scolaires de ces pays pourtant très contrastés entre eux, suggère que les conceptions sur le cerveau humain dépendent moins de spécificités socioculturelles nationales que d'idéologies dominantes transnationales.

Motsclés: Cerveau humain, manuels scolaires, régulations

Introduction: Theoretical Background and Research Question

The scientific content of Neurosciences is evolving very fast, especially during the last 20 years with the emergence of cognitive sciences and of the cerebral imagery. The concepts of cerebral plasticity and epigenesis are now central in the research field (Changeux, 1983, 2002; Edelman, 2000), as well as the connexionnism and the concepts of emergence, enaction and umwelt (Varela, 1989; Stengers, 1997; Stewart, Scheps, & Clément 1997; Buisseret, 1999). We know that our leaning and our memory are configured in our neuronal networks (Changeux & Ricoeur, 1998) and that any process in our central nervous system is controlled by several regulations, with neuronal feed-back.

In France, a recent president of the National Committee of Programmes for the Life and Earth Sciences, was claiming that *"the cybernetic approach can be an extraordinary pedagogical tool, offering us a language and a formalism very easy to use"* (Calvino, in an interview by the SNES[1]), and proposed to introduce in the syl-

1. SNES = Syndicat National de l'Enseignement Secondaire

labuses the concepts of homeostasis and of servomechanims. Carpenter (1984) developed in his book on Neurophysiology a simple formalism of cybernetics to illustrate the control of any movement by the double innervation (gamma and alpha) of every striated muscle. He insisted on the importance of this control, indicating that, for instance, the solear muscle of the cat is innervated by 150 motoneurones α and 100 motoneurones γ (Matthews, 1972).

How these perspectives are introduced in the biology syllabuses? A first survey has been recently conducted by Clément, Mouelhi, and Abrougui (2006) to analyze the French and Tunisian syllabuses and textbooks. They indicated a strong influence of behaviourism and hereditarianism in biology syllabuses, but identified a recent introduction of the concept of cerebral plasticity in France textbooks.

Textbooks always constitute an important step in the didactic transposition (Bruillard, 2005; Bernard, Clément & Carvalho, 2006). We analysed the content of the textbooks as the expression of the interactions between the three components of the KVP model (Clément, 2004, 2006): K stands for the scientific knowledge related to the nervous system and more precisely to the human brain; **V** stands for the values as ideologies, philosophies, or ethics which are generally implicit behind the precedent points; and **P** expresses the social practices of the authors and publishers of the textbooks, reflecting practices, the teachers, and the social context in general.

For instance, the reduction of neuronal pathway to linear transmission, without any regulation from stimuli to responses, illustrates the influence of behaviourism (Clément *et al.*, 2006) as well as of the reductionnist ideology (Canguilhem, 1981). The reduction to reflexes is probably also a sign of the influence of hereditarianism (innatism). The separation between brain and body, the former controlling the latter, could also be a new way to express the Cartesian dualism with the separation soul/body.

Our work is analyzing the current syllabuses and textbooks from 15 different countries, using some concepts of the Didactics of Biology. The didactical transposition, defined by Chevallard (1985) for the didactics of mathematics, has been already adapted to biology education (Clément, 1998, 2006). We took into consideration the interactions between scientific knowledge (K), values (V), and social practices (P) (the KVP model) at each level of the transposition and we compared the textbooks from 15 countries to investigate whether some of the KVP interactions were present and to what extent existing differences were related to some sociocultural features of these countries.

Material and Methods

This work was part of the European project of research BIOHEAD-Citizen (Biology, Heath and Environmental Education for better Citizenship), coordinated by Carvalho, Clément and Bogner (2005). A great part of this project dealt with the critical analysis of syllabuses and textbooks for six topics, and "Human Brain" was one of them. We have analyzed 55 school textbooks that are used in 15 countries. Eleven countries are located in different parts of Europe (North and South, West and East). All these countries differ in terms of their own history and their economical, social, cultural and religious characteristics. The other four countries are non-European and are included in the "French Speaking Communities," despite the fact Arabic is the official language in Morocco, Tunisia, and Lebanon.

In the 15 countries, we used the same grid that was elaborated collectively within the BIOHEAD-Citizen project. We analysed only the answers of the part of the grid reproduced in the Table 1. For this analysis relating to the topic "Human Brain" in the textbooks, we chose this part of the grid because it was, highly significant of the possible reductionism in the biology teaching and of the possible presence of implicit ideologies.

Table 1
-Part of the Grid Used to Analyse the Chapters Dealing with Human Brain

C–2. Grid -Analysis of the Images with (Neuronal) Pathway for Human Brain	
Image on pages	Total
Categ 1: only Stimulus → CNS (Central Nervous System)	
Categ. 2: Only CNS → Response	
Categ. 3: Stimulus → Spinal Cord → Response	
Categ 4: Stimulus → Brain → Response	
Categ. 5: Several stimuli, and / or several Responses	
Categ. 6: with feedback(s) Brain → Response → Brain	
Categ. 7: Muscle double innervation gamma + alpha	
Categ.8: other voluntary movements or sensori-motor coordination with feedbacks	
Categ. 9: Neuro-hormonal regulation	
Categ.10: Other examples of regulation	

CNS = Central Nervous System, including spinal cord and / or brain. One image by box: Just indicate the page number (e.g., p. 23). In the column at right, indicate the total number of images of each category.

Note: An annex was present, giving more information on the definition of the ten categories.

Results and Discussion

General Results

A team from each country filled the same grid (including the part reproduced in the Table 1) for each chapter dealing with Human Genetics. Most of the 55 textbooks were Biology textbooks, but some were dealing with psychology at the end of secondary school (Portugal), or more generally with science at the primary school. The chapters related to Nervous System and Human Brain were generally developed at the end of the secondary School, the last year and/or the year before, depending on each country. The situation was very diverse for the earlier years, with or without teaching the human brain. In most of the countries, this topic was totally absent at the primary school. Due to this diversity, we grouped together in the same column of Table 2 the results obtained from the two last school years, and in another column all the other school levels.

Table 2
Occurrences of Images Showing Neuronal Pathways, only Linear ("Linear") or with Feedbacks ("Feedback") in the Analysed Textbooks, from Each Country

Participant Country	Number of textbooks	under16 years		17-19years		TOTAL	
		linear	feedback	linear	feedback	linear	feedback
Estonia	2	0	0	0	0	0	0 (0%)
Lithuania	1	1	0	-	-	1	0 (0%)
Italy	8	11	0	1	0	12	0 (0%)
Cyprus	1	15	0	-	-	15	0 (0%)
France	16	23	1	72	19	95	20 (17%)
Lebanon	4	26	2	10	6	36	8 (18%)
Tunisia	4	5	0	17	5	22	5 (19%)
Malta	2	7	2	-	-	7	2 (22%)
Portugal	3	7	3	3	0	0	3 (23%)
Romania	1	–	–	32	10	32	10 (24%)
Finland	2	5	1	4	2	9	3 (25%)
Germany	3	5	2	4	1	9	3 (25%)
Hungary	4	0	0	7	3	7	3 (30%)
Morocco	2	9	0	2	5	11	5 (31%)
Senegal	2	5	0	4	6	9	6 (40%)
TOTAL	55	119	10	158	55	277	68
%	100%	92%	08%	74%	26%	80%	20%

The results in Table 2, indicate that in Estonia (two books, one with 8 pages and the other one with 5 pages on Human Brain), there were no images with a neuronal pathway, and in Lithuania there was only one image (Stimulus → Brain → Response) in 40 pages relating to Human Brain. In the other countries, there appeared important variations, but in all cases the linear pathways with no feedback at all consisted the majority of images (80%), indicating a strong reductionism as well as the influence of behaviourism. In two countries (Italy and Cyprus), there was not any image with feedback. In contrast, some countries presented images with feedback in a proportion just below 20% (France, Lebanon, and Tunisia), other countries about 20-25% (Malta, Portugal, Romania, Finland, and Germany), and for Hungary, Morocco, and Senegal, 30 to 40% of the images presented pathways with feedback. Thus, when pathways were presented, the linear pathways (without any feedback) for nervous tracks were the dominant ones in all the textbooks from all countries.

The Control of Movements: A Massive Dominance of Linear Patterns without any Feedback

In textbooks presenting images, the example of the motor reflex was always present, because this pathway is simple. Nevertheless, the reduction of the nervous pathways to reflexes is carrying implicit behaviourist messages, sometimes associated to hereditarianism when the examples are focused on innate reflexes.

Figure 1 was commonly used for the youngest students in several countries, showing a typical behaviourist schema: Stimulus and receptor → Brain as a black

box → Muscular response. This represents an important message, because most of our movements are controlled by this kind of reflexes (when we are walking, standing on, etc). Nevertheless, it also suggests that there is no feedback in our movements, presented as only controlled by our sensory perception without any reference to gamma and alpha muscular innervation.

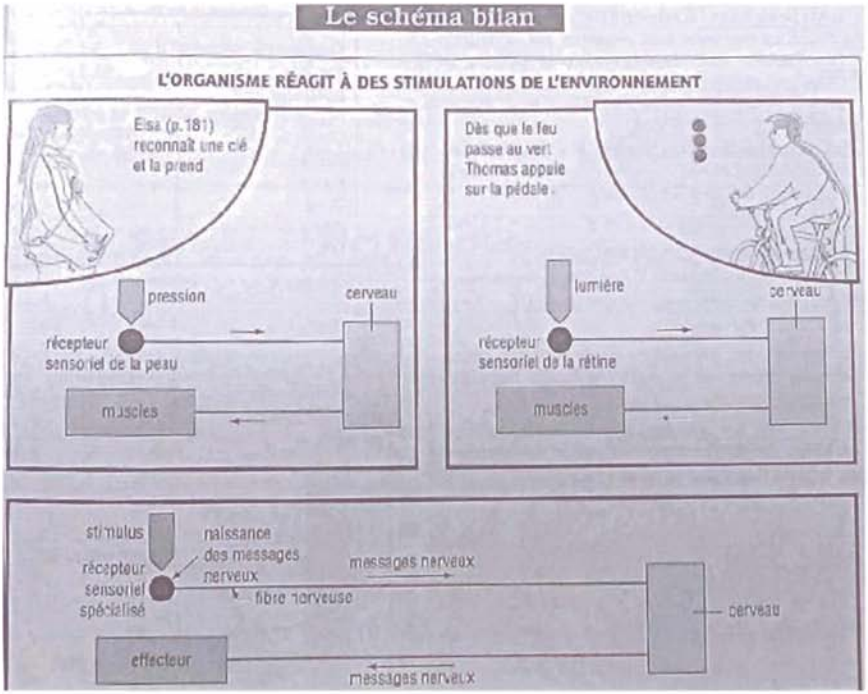

Figure 1. Typical Behaviourist Linear Pathway: Stimulus → Brain → Muscles (French Textbook Biology 3e = 14-15 Years Old Students, Bordas 1999, p. 187).

Figure 2 is an example illustrating a behaviourist pathway including a network of interactions inside the brain, which is no longer considered as only a black box (category 10 of our grid). That is the only image with feedback in the French textbooks for students younger than 16 years old (Table 2) and a special category in our general diagram (Figure 6). This image was just inserted in a larger image, which was nearly the same as in Figure 1, representing a typical behaviourist linear pathway (category 4 of the grid).

For older students, the interactions inside the brain specified the intervention of several cerebral areas, but generally with a totally linear pathway inside the brain, with no feedback (Figure 3).

All the precedent examples concerned controls of movements that imply the brain. Nevertheless, one of the main problems related to the topic "Nervous System and Human Brain" was the great importance of nervous pathways illustrating only reflexes, where the central nervous system was limited to the spinal cord, as indicated in Figures 4 and 5). The linear pathway (without any feedback) was

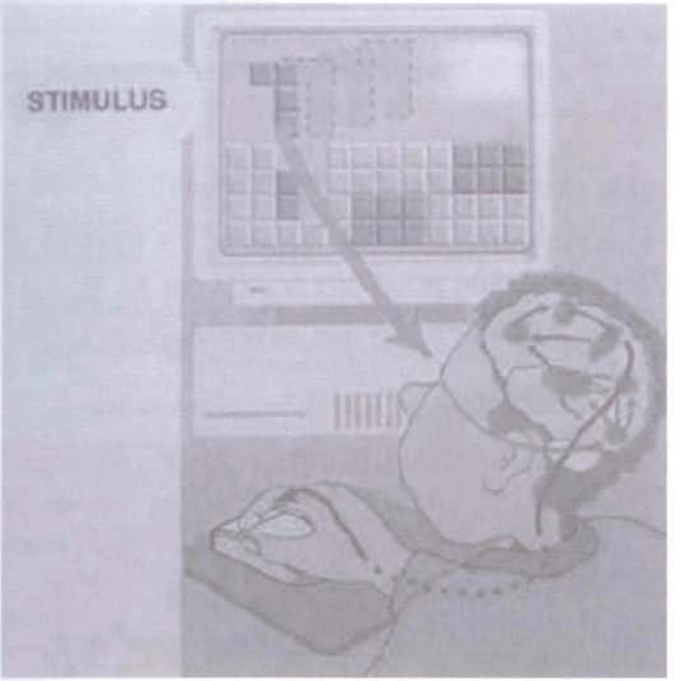

Figure 2. The Same Pathway: Stimulus → Brain → Muscles, but with Feedbacks between Several Cerebral Areas: The Brain Is Not Totally a Black Box. (French Textbook Biology 3e = 14-15 Years Old, Nathan Publisher, 1999, p. 197).

sometimes more complex with the command of several antagonist muscles that were involved in the same movement (category 5 of our grid, Figure 4). The usual example in all the countries, and especially in France and Tunisia (Clément *et al.*, 2006) was the myotatic reflex. The central nervous system was only the spinal cord (Figure 4), and the origin of the reflex was a sensory receptor that was generally not known by the students, that is, the neuromuscular spindles (Figures 4 and 5). In fact, this receptor has also an important role in the control of any muscular contraction, as a comparator between the wished contraction (transmitted to it by the gamma innervation) and the obtained contraction (coming from the alpha innervation, which is set in motion by the brain being informed by the sensorial nerves coming from the neuromuscular spindle, playing here its sensorial function).

When textbooks were introducing images of neuromuscular spindles and presenting their sensorial function, it would not be so complex to introduce also the gamma innervation and the mechanisms of regulation of muscular contractions for the human body movements. This was done and was illustrated by one image only in Lebanon, in Romania, and in Tunisia, but it was limited to the example of myotatic reflex (Figure 5), including only the spinal cord and not the different areas of cerebrum and cerebellum, which are implied in any voluntary or even automatic movements, as are the areas drawn in Figure 3 (for more information on these points, see Clément *et al.*, 2006).

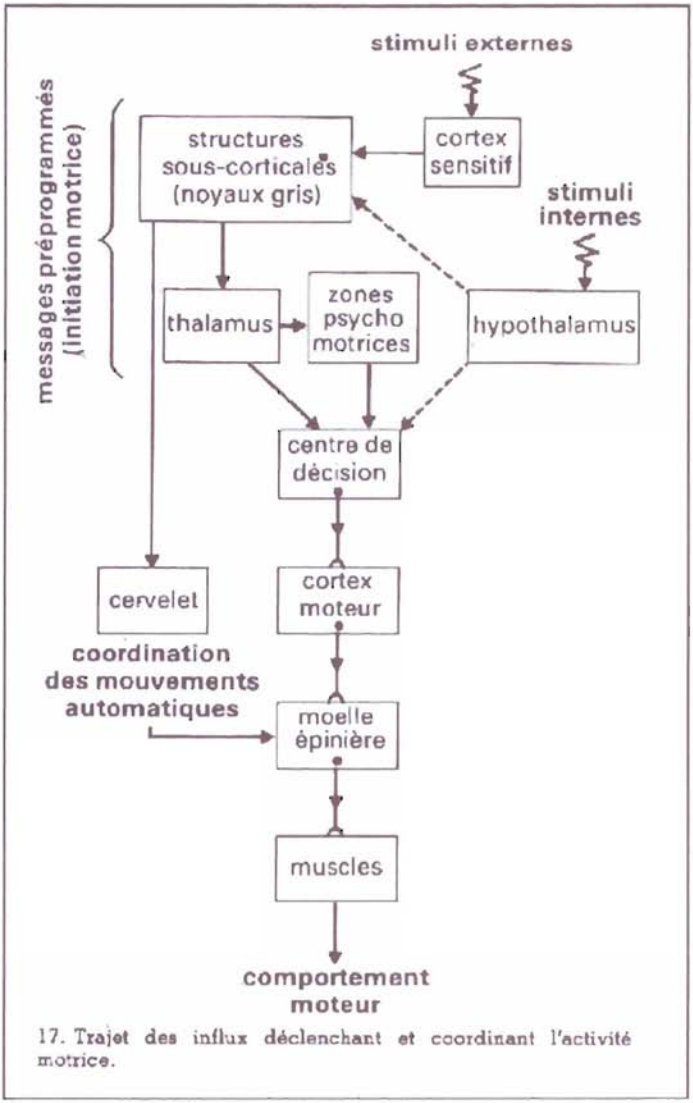

Figure 3. A More Complex Linear Pathway (Textbook from Senegal, 18-19 Years Old Students, Dion, M., & Escalier, J., Nathan Publisher, 1983, p. 273)

The Neuro-hormonal Controls: With or without Feedback?

As referred before (Table 2), there are few images with feedback related to the human brain or nervous system in the 55 analysed textbooks. Only 65 (19%) images with feedback on a total of 342 images illustrating nervous pathways. More than 2/3 of these 65 are dedicated to the neuro-hormonal controls (Figure 6) generally of the human reproduction, sometimes of heart beats (tension) and/or respiration.

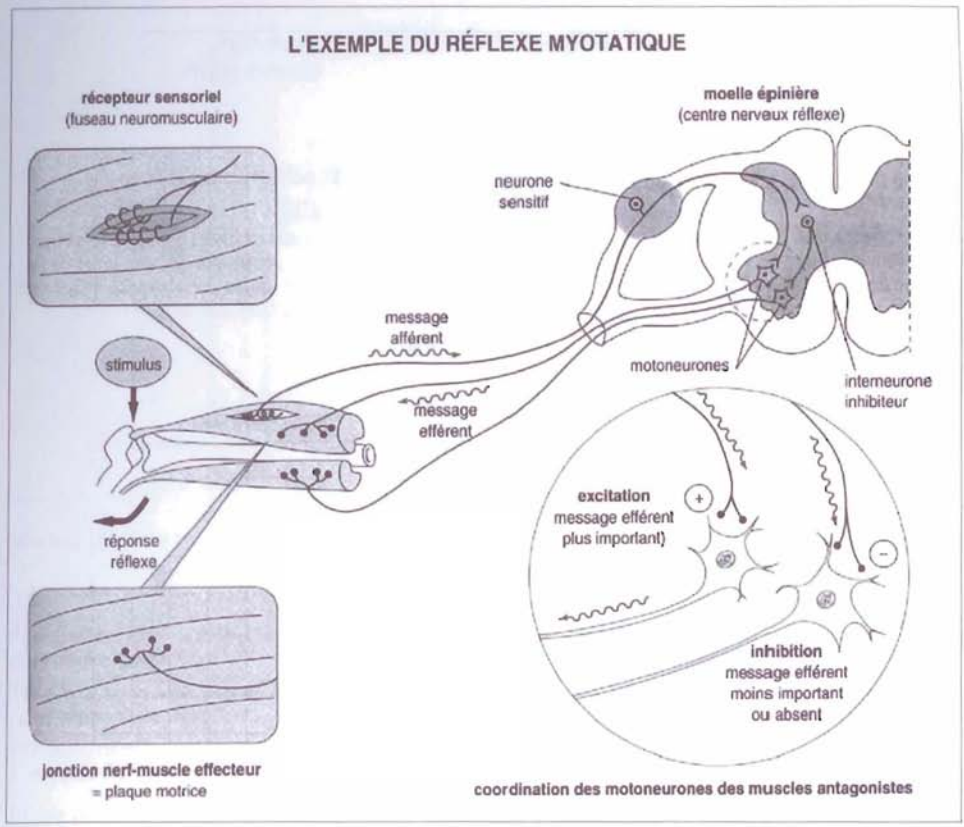

Figure 4. The classical linear pathway (Stimulus → Spinal chord → Muscle. The myotatic Reflex (French Textbook 1ère S = Sciences for 16-17-years Old Students, Bordas Publisher, 2001, p. 191).

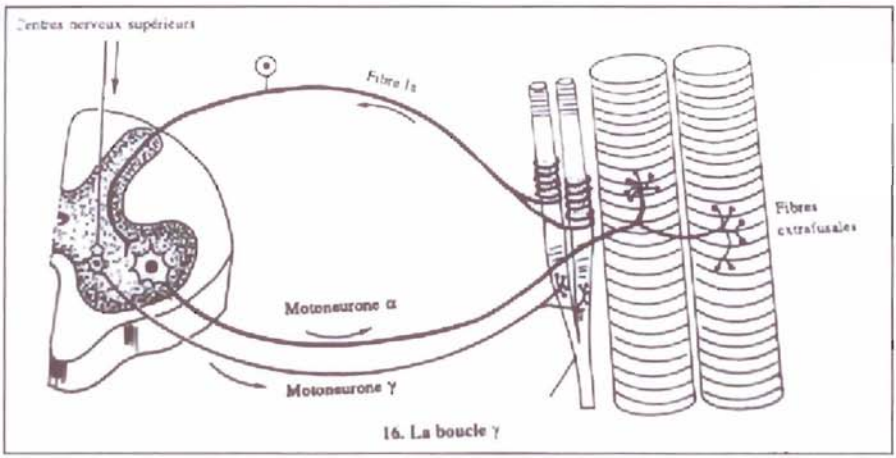

Figure 5. An Exceptional Feedback with the Gamma / Alpha Innervation of Muscular Fibres, but only for the Myotatic Reflex (Tunisian Textbook for 18-years Old Students = Last Year of Secondary School, Sciences "Sciences Naturelles", 4ème Sc. Exp., 2004, Tunis: CNP, p.231).

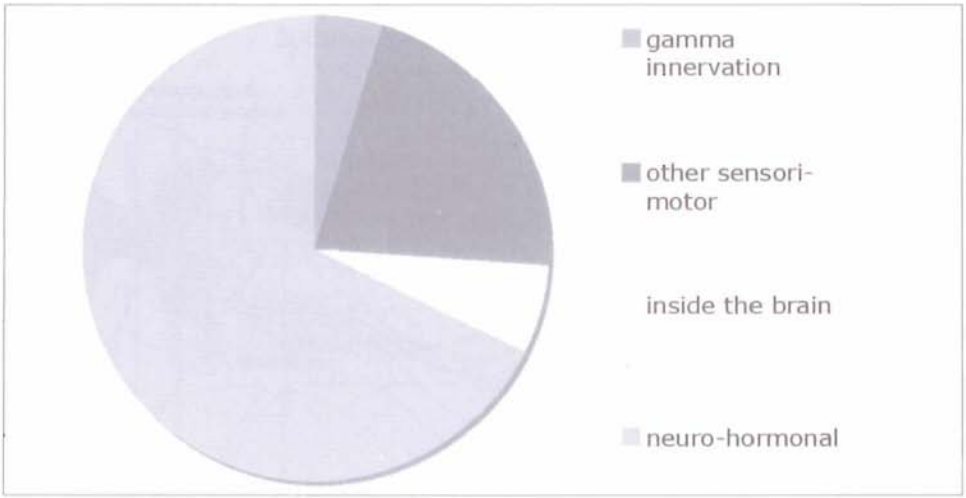

Figure 6. Repartition by topics of the 65 images presenting feedback, in all analysed textbooks (see also the right column of Table 2 for their occurrence by country).

The most frequent illustrations of neuro-hormonal regulations with feedback are found for the control of the sexual women cycle and also the control of men sexual activity. Figures 7 and 8 are illustrations of this kind of feedback, generally occurring at the level of the hypothalamus. It is more an interaction between hormones and central nervous system controlling neurohormones secretion, rather than feedback inside the brain itself.

Nevertheless, even here, we can find in some countries (as in Portugal, or in Cyprus: Figure 9) a still linear control coming from the brain (the hypothalamus) without any retro-control mentioned.

There is here a strong link not only between these taught knowledge and the values of reductionism and behaviourism, but also with important social practices: How to understand the use of feminine contraceptive pills without any knowledge on the neuro-hormonal regulation they are interfering with?

The regulation of the cardiac rhythm is another example of a possible illustration of a neurohormonal retro-control to illustrate feedback. Nevertheless, in several countries (as in Tunisia), they only illustrate this reflex activity with a linear pathway "Receptors → Central Nervous System → Responses." And even when the feedback is drawn in the nervous pathways, the explanation can still be behaviouristic.

All these examples illustrate the resistance of most of the biology textbooks to include the processes of regulation, with cycles or even some clear feedback. As if it was too complex for the students (and/or for their teachers…). Nevertheless, the taught knowledge is often rich in new concepts as indicated here in Figures 3 and 4. In contrast, schemas with feedback can be very simple and clear, as in Figure 10 reproduced here from a Hungarian textbook to illustrate somatic and vegetative reflexes related to the spinal cord. In consequence, it is less a question of simplicity vs. complexity than a crucial choice to teach or not the processes of regulations and the concept of feedback, a choice to teach or not that every biological process is regulated, and never a single cause – effect process.

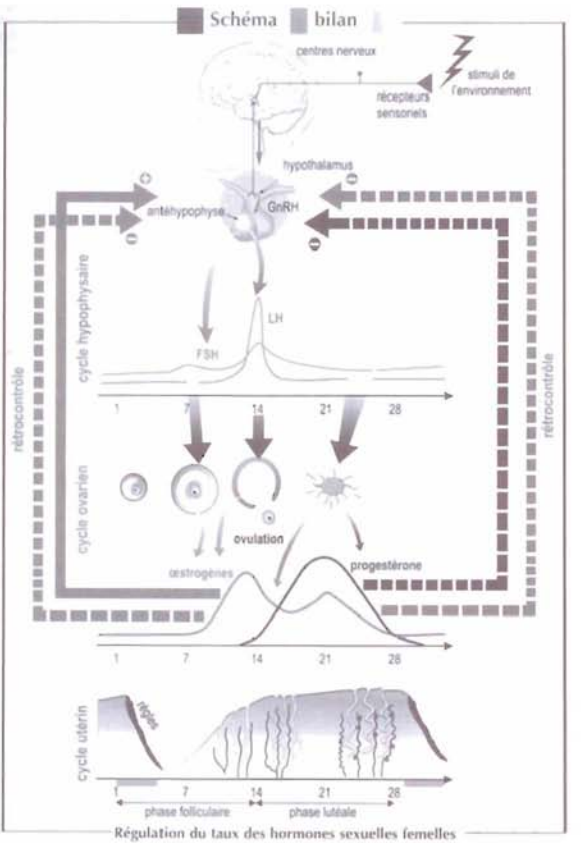

Figure 7. An Example of a Neuro-hormonal Pathway with Positive and Negative Feedbacks at the Level of the Hypothalamus which Controls the Female Hormones (LH and FSH). (Modified from a Lebanese textbook: Sciences de la Vie, 3rd year (16–17 years old students), Chalhoub E. et al., Beyrouth: CRDP, 2002, p.306. The initial image is coloured).

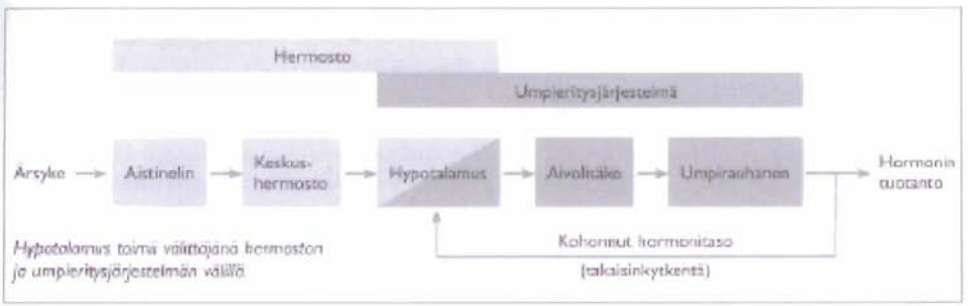

Figure 8. An Other Example of a Neuro-hormonal Pathway with a Feedback. The light grey boxes are the nervous system: from left to right: stimulus → sense organ → central nervous system → hypothalamus. The dark grey boxes are endocrine parts (hypothalamus → pituitary → endocrine gland). The feedback is coming from the "hormone production" to the hypothalamus. (Modified from a Finnish textbook: Bios 4: Human Biology, 16-18 years old students, Happonen et al., Virpi Aalto Wsoy publisher, 2005, p.53. The initial image is coloured)

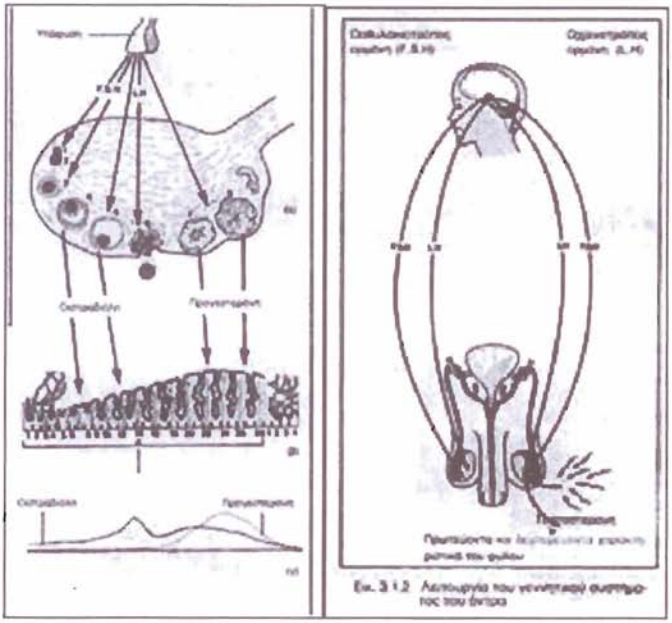

Figure 9. No Feedback in the Control (by the Brain) of the Sexual Activity for Women (at left) and Men (at right): Modified from a Cyprus textbook: Human Biology -Health Eduction, Kousparov A.C. et al, 2nd grade of High School (13-14 years old students), Cyprus: Ministery of Education, 2001, p.23 and p.18.

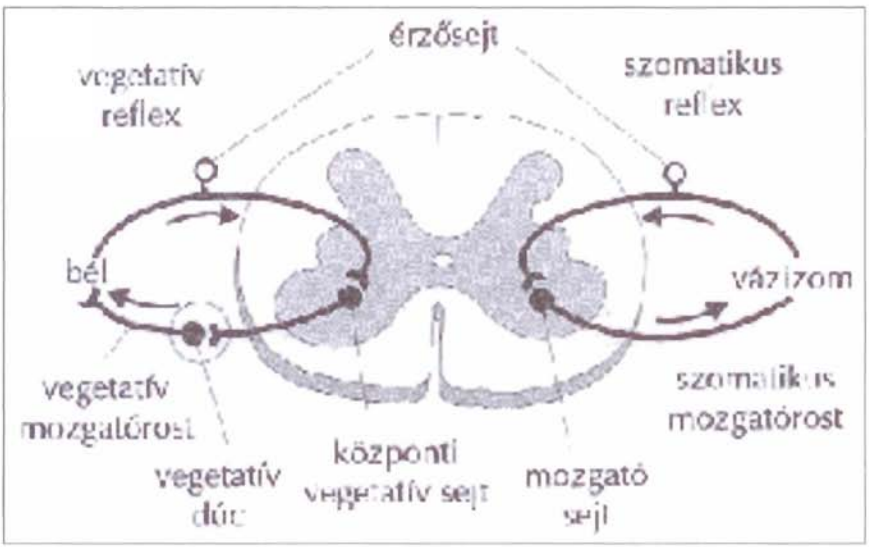

Figure 10. Clear Feedbacks Showing the Somatic and Vegetative Reflexes related to the Spirial Chord (Hungarian textbook for 18 years old students, Biologia IV, Mihaly E et al, Toth Géza publisher, 2003, p. 725).

Are There Illustrations of Cerebral Neuronal Networks in Textbooks?

Very few countries are illustrating neuronal networks in the brain. In the textbooks for the youngest students, there are sometimes areas drawn inside the brain, with linear connections between them, or in few cases, with a network of areas including feedback (e.g., Figure 2). This dominance of anatomy in biology was identified by Canguilhem (1981) as an ideology, and is still prevalent in most of the biology textbooks in the 15 chosen countries.

For older students, some neurons can be drawn inside the brain or inside the spinal cord: with only one of two neurons (Figures 4, 5, and 10), or more as in Figure 11, but still in a linear continuity, without any feedback. These examples (Figures 4, 5, 10, 11) also illustrate that there are generally more images of neuronal pathways in spinal chord rather than in brain. The brain is possibly considered as too complex by teachers and by publishers of textbooks, too complex for themselves and in consequence for their students, as Clément (1996, 1997) showed in France from teachers' interviews. A possible explanation of this complexity can also be the persistence of a spiritualist, or at least dualist, interpretation of the thought (Clément 1994).

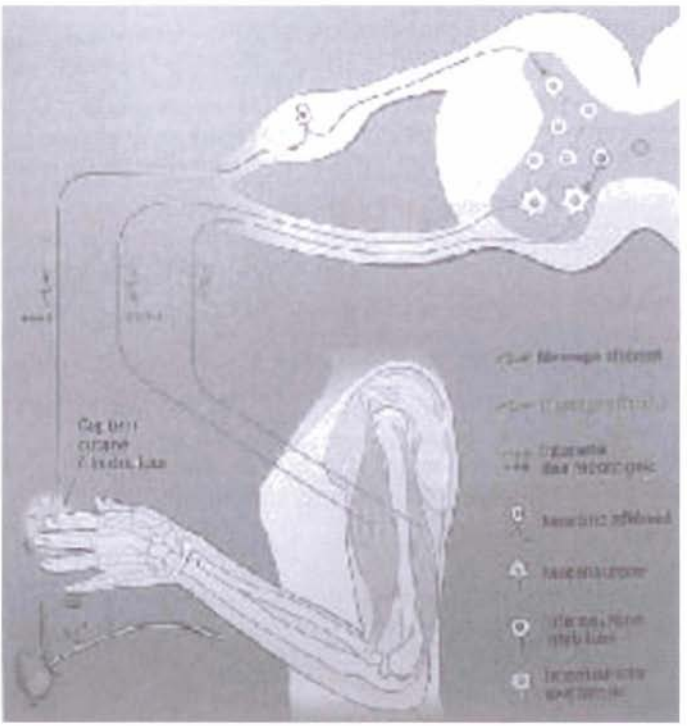

Figure 11. Linear Pathways Involving Several Neurones in the Spirial Chord (reflex) - (Modified from a French textbook 1st S, 16-17 years old students, Hatier publisher, p. 163: the original image is coloured).

In the 55 analysed textbooks, we found only one illustration of cerebral neuronal networks with feedback, in a Senegalese textbook (Figure 12), to illustrate the storage of information in our memory. This image is typical of the knowledge

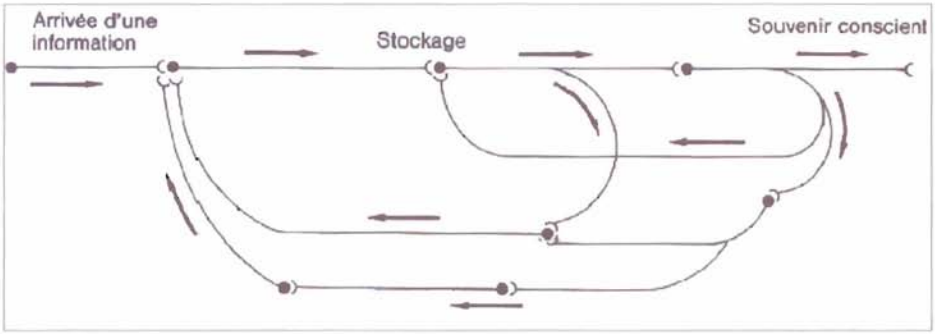

Figure 12. An exceptional image of cerebral neuronal network with feedbacks, showing how they can be the support of memory (modified from the Senegal textbook for 18 years old students, 18-19 years old students, Dion M. & Escalier J., Nathan publ., 1983, p. 266: the original is coloured).

coming from research in neurobiology and cognitive sciences. It is an exception in the analysed biology textbooks, the memory is not a total mystery. The brain is not a black box where the students (and their teachers) often put the soul or the spirit (Clément 1994, 2004), but it is full of neurones and neuronal networks that are the biological support of our thought and memory.

In conclusion, most of the images of neuronal pathways of the 55 analysed textbooks coming from 15 countries show to be still under the influence of:

(1) reductionism, without any feedback or cycles or regulations, with very few exceptions, which are mainly dealing with neuro-hormonal control (and this not in all the15 countries),

(2) behaviourism, with a large prevalence of the schema "Stimulus → Central nervous system (brain or spinal chord) → Response": in 14 of the 15 countries (the 15th is Estonia: there is no image of neuronal pathways in the Estonian textbooks),

(3) innatism (or hereditarianism), only in some countries as Tunisia where the place devoted to innate reflexes is very important;

(4) spiritualism, which is more implicit when the brain is at the origin of the controls, or even when the brain is like an anatomical black box with a strong resistance to explain that our memory and thoughts are located in neuronal networks.

Very few images are related to the constructivism or the cognitive approaches. These results are so strong in all the 15 chosen countries that the few differences observed from one country to another are not relevant, suggesting that the conceptions (interactions KVP, between scientific knowledge, values and social practices) on human brain are less linked to local or national socio-cultural contexts rather than to international dominant ideologies, which to change and to integrate the new scientific findings of research on the human resist to change brain: epigenesis and plasticity of the neuronal networks, which are in our brain the biological support of our thought, learning and memory, and which are organised with a lot of feedback.

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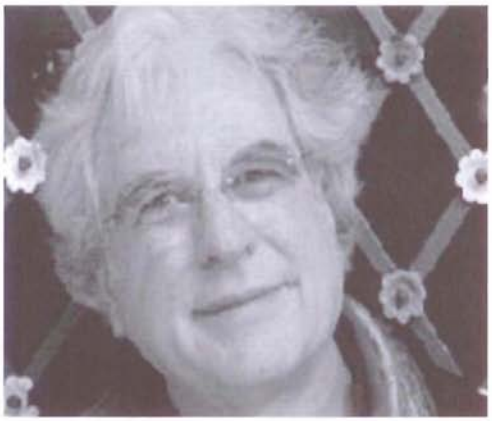

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