13 THE APPLICATION OF CONCEPT MAPS IN TEACHING INVERTEBRATE ZOOLOGY

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Abstract

In this paper a comparison is made between the level of efficiency obtained when using concept maps vs. the conventional expository teaching approach in the framework of the zoology curriculum in course of Anatomy and morphology of invertebrates for the undergraduate students at the University of Belgrade – Faculty of Biology. In order to accomplish the tasks of this paper, a model of a pedagogical experiment with parallel groups [experimental (E) and control (C)] was applied, involving 160 students.

The aim was to identify and measure the differences, and compare the efficiencies of these two approaches of teaching.

The E group was presented the course content through teaching instruction which included the elaboration of concept maps. The students from E group, after brief oral presentation by teacher, had to fill-out concept maps, which were related to the five characteristics of the Annelids. The C group was presented the same zoology content through conventional expository instruction-the traditional lecturing model, which is consisted of classical teaching methods: oral presentations, illustrations and demonstrations.

Using this experimental design, we determined that the application of concept maps was more efficient in terms of quantity and quality of knowledge acquired by students in tested teaching field.

1. Introduction

Teaching biology is characterized by a wide range of instructional approaches, methods and teaching tools, in accordance with the program content, the teaching objectives and tasks.

Concept mapping is one of the numerous teaching tools, which can be used in teaching biology (Kinchin, 2000). It is a process of constructing learning maps based on the theories of constructivist (Duffy, Lowyck, & Jonassen, 1992; Richardson, 1997) and meaningful students' learning (Novak & Canas, 2007).

Concept maps are composed of concepts linked by certain correlations in a hierarchical structure. The most important concepts usually are linked by highly informative linking statements which are settled on the labelled lines (Kinchin, 2011). Linking statements need to be valid and to relate concepts in some meaningful way (Buntting, Coll, & Campell, 2006).

Concept mapping is very effective strategy and helps students to learn meaningfully by making explicit the links between scientific concepts (Fisher, Wandersee, & Moody, 2000).

Qualitative approach to concept map analysis can be used for improving teaching process in sense of more effective learning and helping students to integrate their knowledge and build upon their existing naive concepts (Kinchin, Hay, & Adams, 2000). They prevent the existence of gaps in knowledge and misunderstandings (Willson & Williams, 1996), and generally have positive effects on students attitudes and achievements (Horton et al., 1993).

Concept maps can be used as an "expressed model" to investigate students' mental models regarding to the teaching content (Chang, 2007). Mental models are learners' internal conceptual frameworks, and concept maps are external and visual structures. Based upon these similarities, there is evidence for the acceptance of concept maps as an expressed model in order to examine students' mental models (Chang, 2007). It was pointed out that the use of analogies and mental models can enhance student understanding of complex and abstract scientific conceptions (Coll, France, & Taylor, 2005).

Concept maps are very effective for improving knowledge and critical thinking (Kinchin, Streatfield, & Hay, 2010). They are often applied in teaching science and widely described as a tool that can support and enhance students' learning in science classrooms (Kinchin, 2001). Also, they can be used in curriculum planning (Edmondson, 1995; Loertscher, 2011) and for presenting materials to students (Kinchin & Cabot, 2007; Kinchin et al., 2000). They can be tools for measuring and validation (evaluation) of students' knowledge (Herl, Baker, & Niemi, 1996; Kinchin, 2000a; Hay & Kinchin, 2006), or some combination for instruction and evaluation (Peters & Beson, 2010).

Concept mapping has been reported to aid collaborative learning (Sizmur & Osborne, 1997) and to improve students' problem solving (Okebukola, 1992; Buntting et al.., 2006).

Some studies evaluated their application in tertiary biology courses (Smith & Dwyer, 1995; Roberts, 1999; Yarden, Marcbach-Ad, & Gershani, 2004; Buntting et al. 2006; Amundsen, Weston, & Mc Alpine, 2008; Hay, Kinchin, & Lygo-Baker 2008). Results of those studies shown that it is the effective teaching and learning strategy in tertiary tutorial classes.

It has been proven that concept mapping gives the students an opportunity to participate in a far more comprehensive learning process, which is very relevant to the professional practice requirements (Akinsanya & Williams, 2004).

Particularly, it is important, that students in mastering the biology content, continuously and timely gain the information about successfulness of their mastering this content. According to this, various types of feedback information for students have been developed. The effects of feedback were tested with the help of concept mappings.

The efficient application of concept maps in Biomedical Sciences and education is evident (González, Palencia, Umaña, Galindo, & Villafrade, 2008; Moni, Beswick, & Moni, 2005; Sandee, 2005). The effectiveness of concept maps produced by students using paper and pencil was specifically examined (Chang, Sung, & Chen, 2001).

Science courses generally have hierarchical structure of important concepts (Donald, 2002; Kinchin, 2011). This is in correlation with the hierarchical and integrated characteristics of concept maps (Novak, 2010).

Particular consideration of the structure of the zoology courses contents together with the above-mentioned findings concerning the use of concept maps, show the suitability for applying the elaboration of concept maps, like learning tools to externalise knowledge and critical thinking in the Anatomy and morphology of invertebrate course.

2. Research design and method

2.1 Aims and objectives

The main task of this research is to experimentally verify the effectiveness of applying concept maps in accomplishing the zoology curriculum in course of Anatomy and morphology of invertebrates for undergraduate students at the University of Belgrade – Faculty of Biology. Research question is: “Does the application of concept maps contribute to the better acquisition of knowledge?”

The basic-null hypothesis is that there is no statistically significant difference in accomplishing the teaching goals (resulting in students gained knowledge) between the experimental and control groups after introducing the experimental factor (application of concept maps, considered as independent variable) in the experimental group.

The alternative hypothesis is that there is a statistically significant difference in acquired knowledge between the experimental and control groups, after introducing the experimental factor in experimental group. It is expected that the difference in the quality and quantity of the acquired knowledge between the experimental and control groups will favour the experimental group. The aim is to identify and measure this difference, as well as compare the efficiency of these two models of teaching.

2.2 Material and methods

The study included in total 160 undergraduate students from University of Belgrade – Faculty of Biology. To achieve the aims of this research, model of pedagogical experiment with parallel groups [experimental (E) and control (C)] was applied (Appendix 1).

Students were grouped into one E and one C group (Killermann, 1998). Before the introduction of the experimental factor, the groups were made uniform in number of students, gender, and general knowledge of invertebrate zoology as determined by distributing a pre-test of knowledge.

The pre-test was composed of nine tasks in total, which were classified into three broad categories of cognitive domain: knowledge (recall of data or information) (Rank I), comprehension (understanding of meaning) (Rank II) and application (application of that which has been learnt) (Rank III) (Bloom, 1956). Test tasks covered all invertebrate zoology content that had been taught before the topic Annelids (phylum Annelidae).

After equalizing the E and C groups, group E began covering the prepared zoology content (the Annelids) by applying the concept maps. Namely, after brief oral presentation by teacher (PowerPoint presentation: topic Annelids), they get unfilled concept maps (one sample in Appendix 2), which was related to the five characteristics of the annelids (body segmentation, body shell, digestive system, nervous system, genital system). They had to fill-out those concept maps (to write adequate concepts into blank fields), in one instruction period (one week). Each student from E group (after teacher's presentation: topic Annelids), used textbook (to process the text: topic Annelids), pictures and pencil to fill-out those concept maps.

Students in the C group were exposed to the traditional teaching approach (classical model of instruction) for the same teaching contents. Teacher used PowerPoint presentation (topic Annelids) and presented this content through teaching methods: oral presentation, illustrations and demonstrations (during all instructional period). Teacher did not ask the questions about this content. There was no discussion. Only activities for this group of students were listening and watching to what the teacher was saying and showing.

The E and C group were completely separate from each other beyond the classroom setting. They underwent this teaching period simultaneously in different classrooms. In order to prevent any contamination of the design, the students of the E group had no contact with the concept maps outside of the planned period (Kember, 2003).

To determine the knowledge acquired by students using the concept maps and traditional teaching approach, a post-test was applied. It measured the quantity and quality of the students acquired knowledge in the teaching field (the Annelids). The post-test consisted of nine tasks in total (divided into three categories, as was the case in the pre-test) (Appendix 3).

The data and results analyzes were performed using the standard statistical methods/tables-descriptive statistics (sum, percentage frequency, mean, standard deviation, coefficient of variation and Student's t-test for testing differences among the statistics of the same kind). The mean value for individual Ranks is calculated based on the sum of achieved points in the test (the pre- and post-test) divided by the number of students who are doing it. The maximum number of points per Rank was fifth. All these analyses were conducted using the statistical software package Statistica 6 (StatSoft, 2001).

3. Results and discussion

The results of the pre-test are presented in Tables 1, 2.

Table 1. Basic statistical data for the pre-test ($\overline{X}$ - mean of the number of achieved points, S-standard deviation, V - coefficient of variation)

	Rank I			Rank II			Rank III			Total		
Group	$\overline{X}$	S	V	$\overline{X}$	S	V	$\overline{X}$	S	V	$\overline{X}$	S	V
E	3.33	0.77	23.21	1.53	1.15	75.66	2.29	1.52	66.32	7.06	2.81	39.74
C	3.15	0.98	31.24	1.42	1.30	91.59	2.25	1.57	69.95	6.73	3.42	50.87

Table 2. Testing group uniformity in terms of the pre-test, using the t-test (for significance level of $p \leq 0.05$ and a critical value of $t \geq 1.96$*)

Relation	Rank I	Rank II	Rank III	Total
E : C (t value)	1.25	0.51	0.17	0.64

Based on results presented for the pre-test for E and C groups, we can conclude, using Student's t-test for a significant level of $p=0.05$ and a critical value of $t=1.96$, that there is no statistically significant difference in the achieved number of points between the E and C groups in all three levels of tasks and in a test as a whole (Rank I: $t=1.25<1.96$; Rank II: $t=0.51<1.96$; Rank III: $t=0.17<1.96$, a total: $t=0.64<1.96$). These two groups were balanced in terms of general knowledge of zoology before the introduction of the experimental factor.

The results of the post-test are presented in Tables 3, 4.

Table 3. Basic statistical indicators for the post-test ($\overline{X}$ - mean of the number of achieved points, S-standard deviation, V - coefficient of variation)

	Rank I			Rank II			Rank II			Total		
Group	$\overline{X}$	S	V	$\overline{X}$	S	V	$\overline{X}$	S	V	$\overline{X}$	S	V
E	2.85	0.74	26.17	1.28	1.19	93.42	2.21	1.39	62.80	6.34	2.53	39.93
C	2.49	0.77	31.05	0.49	0.78	158.05	1.12	1.29	115.55	4.10	2.37	57.69

Table 4. Testing group uniformity in the post-test, using t-test (for significance level of $p \leq 0.01$ and a critical value of $t \geq 2.58$**)

Relation	Rank I	Rank II	Rank III	Total
E : C (t value)	2.75**	4.61**	4.85**	5.41**

By comparing average values of achieved results, a clear difference can be observed, in terms of levels and in the test as a whole, between E and C groups, favouring the former.

On the basis of the presented result for the post-test of knowledge for E and C groups (Table 3, 4), we can conclude that there are statistically significant differences in the number of points achieved in all three levels of tasks and in the test as a whole, in favour of the E group (Rank I: t=2.75**>2.58; Rank II: t=4.61**>2.58; Rank III: t=4.85**>2.58; a total: t=5.41**>2.58).

The obtained t-coefficient values (marked with an asterisk) are significantly greater than the critical value (by all three ranks and as a whole). Particularly significant are differences in the Rank III test tasks (related to the application of knowledge).

Better results in the post-test of the E group can be explained by differences in the way of teaching the zoology content in the field of Annelids, i.e. by application of the concepts maps in teaching instructions. Students in E group (after brief PowerPoint presentation by the teacher), processed the text (Annelids), from the textbook. It helped them to select and organize relevant information and to filled-out the concept maps. Also, they summarised large amounts of information and integrated their knowledge.

Concept mapping provides an interface between students' cognitive frameworks and textual information. Students need to challenge the science text, they read by "struggling" with it (Slotte & Lonka, 1999). It requires students to process text at a deeper level (Amer, 1994; Kinchin, 2000).

Compared with other results, the research on the effectiveness of programmed instruction with the help of concept maps in the implementation of the biological program content (using the post-test for students) showed that it was very efficient teaching approach (Chang et al., 2001). Also, the results related to the implementation of the ecological program content with the help of concept maps indicate that it is the most efficient method (Ifenthaler, 2010).

The above results concerning the application of concept maps in biological content can be compared with the results of study, which investigated the effects of incorporating concept mapping in teaching chemistry. Those results suggest that it is a plausible method for enhancing student learning (Tan, 2000).

There was investigation about concept-mapping as a tool for enhancing teaching quality in higher education. Results of this study shown that it can be used to transform abstract knowledge and understanding into concrete visual representations that are amenable to compare and measure. Also, the quality of teaching can be significantly enhanced by the use of concept mapping. It enables the engagement of teachers and students in the processes of discovery and makes learning visible. Teachers can use it to promote meaningful learning among their students. (Hay et al., 2008).

Research of concept mapping in supporting university academics' analysis of course content shown that the concept mapping process provide an alternate means to rethink course content. The findings from this study shown that concept maps also highlighted relationships among concept and frequently provided the occasion to make explicit the types of thinking required in the course (Amundsen et al., 2008).

Some studies examined the use of concept maps to measure tertiary science students' understanding of fundamental concept in science education. The results confirm that concept maps contribute to the clarification of students' misconceptions and the meaningful learning (Roberts, L.1999). Also, students seemed to consider concept mapping to be a helpful strategy to determine the relations between concepts and conceptual themes. The first year biology students involved in the concept mapping tutorial sessions were generally positive about their experience. They reporting that concept mapping helped them to link concepts together as well as summarize and recall course content. They found the use of concept mapping enjoyable (Buntting et al., 2006).

4. Conclusions

The research was conducted with the same teaching content (the Annelids), by applying concept maps in the E group and traditional teaching approach in the C group. The E and C groups showed uniform knowledge on the pre-test (in terms of general knowledge of zoology of invertebrates) in task levels I, II and III, as well as in the test as a whole. We can therefore conclude that the groups were uniform in their general knowledge of zoology before the introduction of the experimental factor.

After introduction of the experimental factor-concept maps in the E group, this group performed better on the post-test of knowledge than the C group. The high level of the statistically significant difference is especially noticeable between the groups (in favour of the E group) in the Rank III tasks (application of knowledge in the given teaching field).

The null hypothesis, postulating equality of the acquired knowledge in E and C groups (in the field of Annelids), is rejected on the basis of statistically obtained results. The alternative hypothesis, which states that there is a statistically significant difference between the levels of acquired knowledge in favour of the E group following introduction of the experimental factor (application of concept maps), is confirmed.

It can therefore be concluded that the application of concept maps directly contributed to better learning and knowledge acquisition in the teaching of zoology content (phylum Annelids). In other words, the high quality of the students' acquired knowledge in the tested teaching field was especially significant in the Rank III tasks (application of knowledge).

Modern biology teaching process, especially of zoology curricula, should involve the concept maps, which was explicitly proven to be of high efficiency. Based upon the obtained results of this research, concept maps would be implemented in teaching process (course: Anatomy and morphology of invertebrates). The intention is that in future it becomes the usual and standard teaching methodology in menu anatomy and morphology courses. It will stimulate the students' participation in the teaching process.

Acknowledgements

The authors would like to express their gratitude to the Ministry of Education, Science and Technological Development of the Republic of Serbia for the financial support (Projects 173038 and 43001).

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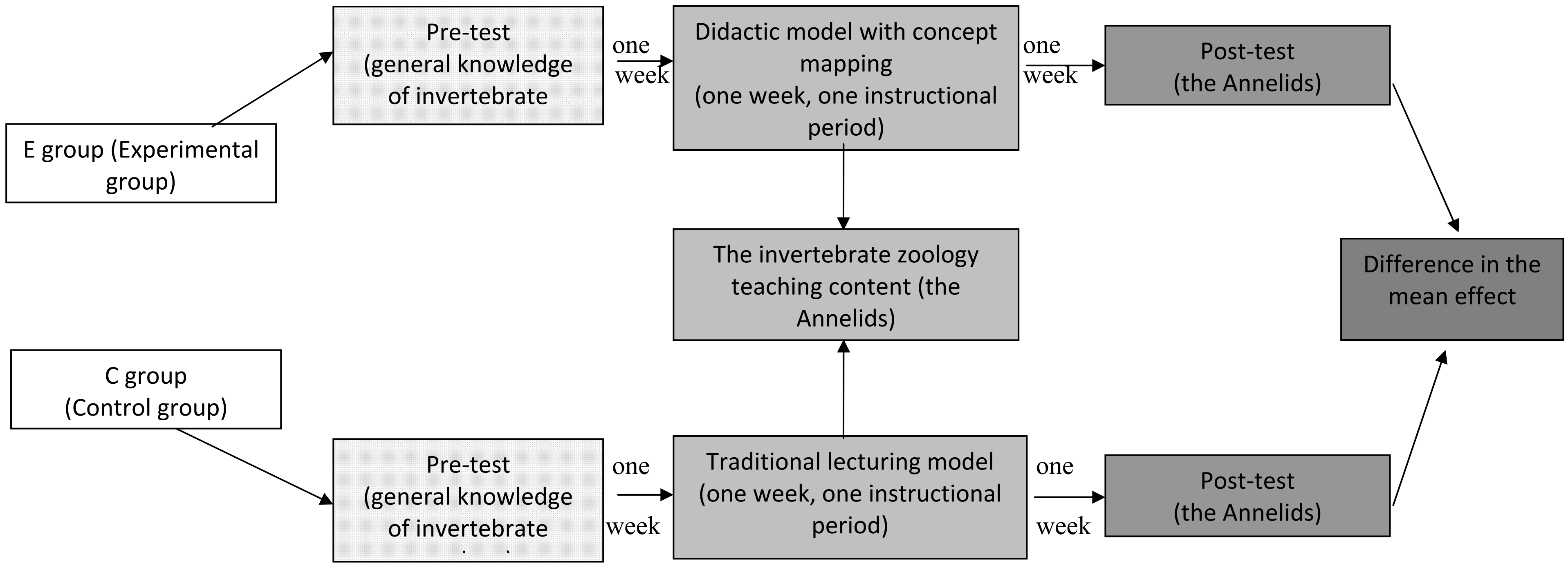
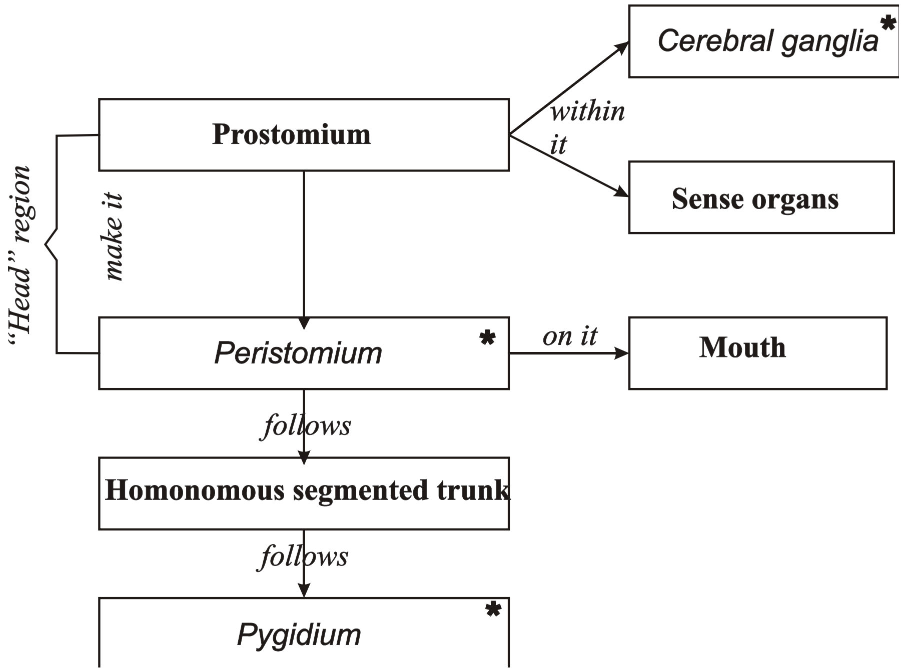
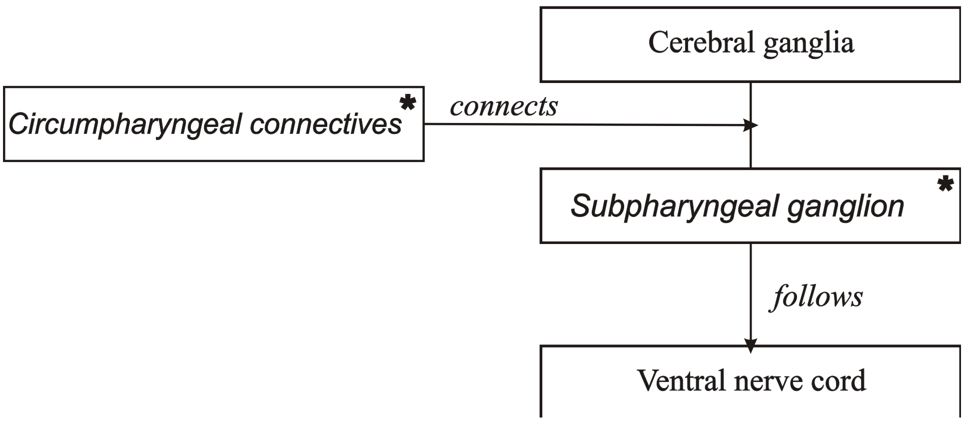
Appendices

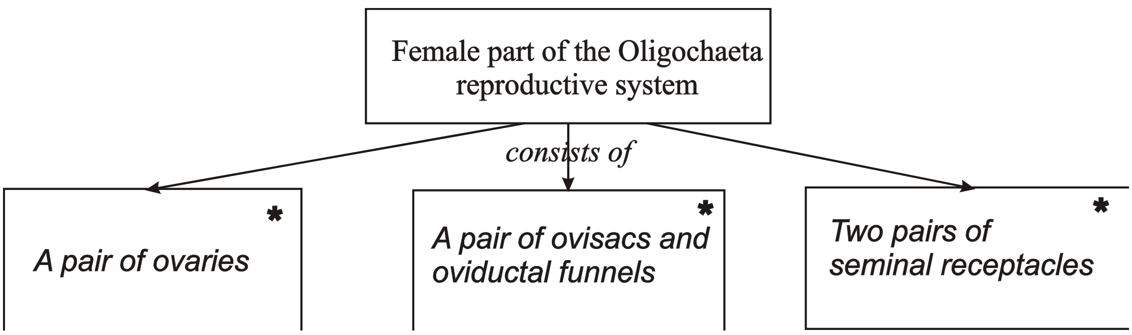
Appendix 1. The model of pedagogical experiment with parallel groups.



Appendix 2. Example of filled-out concept maps on the topic Annelids. The fields assigned with an asterisk were blank at the beginning (the students fill it out during the mastery of the teaching content).







Appendix 3. Example of some tasks used as an indicator of Ranks I, II and III (answers are written in *italic* font style).

Rank I

I Circle the letter of the correct answer:

1. The formation of new segments in the Annelids is done:
a) *in front of pigidium*
b) after pigidium
c) laterally of pigidium
d) on of pigidium

2. Metamerism in Annelids includes:
a) ectoderm and endoderm
b) *ectoderm and mesoderm*
c) ectoderm, mesoderm and endoderm
d) the endoderm

3. Two branched parapodia consist of:
a) two notopodia
b) two neuropodia
c) two ventral branches
d) *notopodium and neuropodium*

4. Nervous system of Annelids consists of:
a) longitudinal nerve cords
b) pairs of ganglia
c) *bilobed cerebral ganglion with ventral nerve cord*
d) nerve net

5. The body surface of Annelids consists of:
a) multilayered epidermis
b) three-layer epidermis
c) two-layer epidermis
d) *single-layer epidermis*

II If the statement is true circle „T", or „F" if the statement is false:

6. Ventral pores connecting the coelom of Annelids with the external environment T *F***.**
7. Calciferous glands of earthworm are situated in the intestine T *F*.
8. In the genus *Lumbricus*, the cerebral ganglion („brain") is situated in the third segment above the pharynx *T* F.
9. Most species of aquatic Oligochaeta have only one pair of testes *T* F.
10. The leeches reproduce asexually T *F*.

Rank II

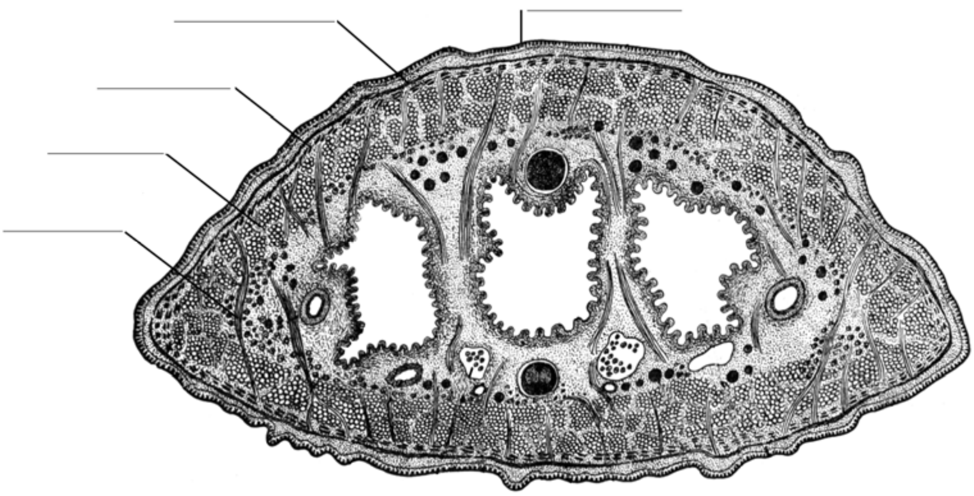
Fill in the table:

Based on the description, determine and name the concept in the table:

Description of concept	Concept
11. It is created from the peritoneum and synthesize glycogen and fat.	*chloragogen tissue*
12. Dorsal longitudinal folds of intestine of the land Oligochaeta with function to increase absorption.	*typhlosole*
13. Glandular epithelium of mature Oligochaeta which secrete mucus that holds the worms together during the copulation.	*clitellum*
14. The third band of perianal cilia of the Annelid trochophore larvae.	*telotroch*
15. Combinations of coelomoduct and nephridium are termed.	*nephromixia*
16. A short canal derived from coelomic tissue, connecting the coelom with the external environment; often combined with nephridium.	*coelomoduct*
17. The body cavity with peritoneal lining; formed in embryonic mesoderm.	*coelom*
18. Thin, non-cellular protective layer produced by and overlying the epidermis, consists mainly of scleroprotein (not chitin).	*cuticle*
19. One of the two fleshy lateral projections from a body segment, usually bearing chaetae.	*parapodia*
20. A stout supportive chaeta found internally in projecting parapodial rami.	*acicula*

Rank III

On the diagram determine and name only those concepts (structural elements) that form body wall of Leeches (Hirudinea), using serial numbers (in front of concept) to be in a series from the outside to the inside of the body.



(*1. epidermis; 2. circular muscles; 3. oblique muscles; 4. longitudinal muscles; 5. dorso-ventral muscle*).