

Supplementary Material

Please note: All of the instruments and materials in the supplementary material were handed out to participants in their native language. For this supplementary material, all instruments and materials that were developed or adapted by the authors were translated into English. The translations were not validated, but were approved by a native speaker.

1 Coding Manual for the Preliminary Questionnaire

Conceptualization of the final version of the preliminary questionnaire

On the first day of the study, the preliminary questionnaire was handed out and considers three areas that are relevant for this study: ‘prior knowledge in biology’, ‘familiarity with concept mapping’ and ‘demographics’. Items of the ‘prior knowledge in biology’ part in the preliminary questionnaire refer to two fundamental biological topics (genetics and microbiology).

1.1 Prior Knowledge in Cell Biology

We suggest that prior knowledge in biology items students leave blank (missing code = 99) are scored 0. Furthermore, we suggest calculating a sum score of all items for each participant, which represents the student’s prior knowledge in cell biology in a single score.

The work assignment for all questions in this part of the questionnaire was given first and reads as follows:

Work assignment: Please answer all questions. If you want to change your first answer in the selection questions, please make a circle around the wrong answer.

PriorKnowledgeInCellBiology_01_01¹ (adapted from Großschedl et al., 2018; see also Kleickmann et al., 2014)

DNA is the carrier of genetic information. Its structure was decoded by Watson and Crick in 1953.

¹ All headings can be used as variable names in an SPSS data set. The variable named “PriorKnowledgeInCellBiology” represents the participant’s overall score in the test. The score was calculated with 15 items (without items 06, 10, and 13, due to insufficient internal consistency).

COMPREHENSION-ORIENTED LEARNING OF CELL BIOLOGY

Four bases (adenine, cytosine, guanine, thymine) are involved in the structure of DNA, of which two specific bases are always paired with each other.

Mark the two bases that are paired together in the DNA. (2 answers are correct)

- | | |
|---|---|
| <input type="radio"/> Adenine with Cytosine | <input type="radio"/> Cytosine with Guanine |
| <input type="radio"/> Adenine with Guanine | <input type="radio"/> Cytosine with Thymine |
| <input type="radio"/> Adenine with Thymine | <input type="radio"/> Guanine with Thymine |

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none">• Adenine with Thymine
0	A different answer was marked.
99	Item was left blank.

PriorKnowledgeInCellBiology_01_02 (adapted from Großschedl et al., 2018; see also Kleickmann et al., 2014)

DNA is the carrier of genetic information. Its structure was decoded by Watson and Crick in 1953. Four bases (adenine, cytosine, guanine, thymine) are involved in the structure of DNA, of which two specific bases are always paired with each other.

Mark the two bases that are paired together in the DNA. (2 answers are correct)

- | | |
|---|---|
| <input type="radio"/> Adenine with Cytosine | <input type="radio"/> Cytosine with Guanine |
| <input type="radio"/> Adenine with Guanine | <input type="radio"/> Cytosine with Thymine |
| <input type="radio"/> Adenine with Thymine | <input type="radio"/> Guanine with Thymine |

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Cytosine with Guanine
0	A different answer was marked.
99	Item was left blank.

PriorKnowledgeInCellBiology_02 (adapted from Großschedl et al., 2018; see also Kleickmann et al., 2014)

Like RNA, DNA belongs to the group of nucleic acids.

Mark the statement that accurately describes the differences between the two molecules. (1 answer is correct)

- DNA has the same sugar molecule as RNA, but is double-stranded.
- DNA is double-stranded and has a different phosphate molecule than RNA.
- RNA is double-stranded and contains Uracil instead of Guanine.
- RNA is single-stranded and has Uracil instead of Thymine.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • RNA is single-stranded and has Uracil instead of Thymine
0	A different answer was marked.
99	Item was left blank.

PriorKnowledgeInCellBiology_03 (adapted from Großschedl et al., 2018; see also Kleickmann et al., 2014)

Complete the following sentence by marking the correct answer with a cross (1 answer is correct):

The most important cell components involved in translation are...

- ☐ Cell nucleus and ribosomes.
- ☐ Cell nucleus and mitochondria.
- ☐ Ribosomes, tRNA and mRNA.
- ☐ Cell nucleus, centriole and nucleolus.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Ribosomes, tRNA and mRNA
0	A different answer was marked.
99	Item was left blank.

PriorKnowledgeInCellBiology_04 (adapted from Großschedl et al., 2018; see also Kleickmann et al., 2014)

Mark the substance classes that build the plasma membrane of all cells. (1 answer is correct)

- ☐ Only lipids
- ☐ Only proteins
- ☐ Lipids and carbohydrates
- ☐ Lipids, carbohydrates and proteins

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Lipids, carbohydrates and proteins
0	A different answer was marked.
99	Item was left blank.

PriorKnowledgeInCellBiology_05 (adapted from Champagne Queloz et al., 2017).

Complete the following sentence by marking the correct answer with a cross
(1 answer is correct):

Membrane lipids form bilayers because...

- the hydrophobic tails of the lipids can form a strong bond with water molecules.
- they cannot interact with other molecules.
- they can bind strongly to other lipid molecules – this is why membranes are rigid.
- parts of the phospholipid molecules can interact with water and others cannot.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • parts of the phospholipid molecules can interact with water and others cannot.
0	A different answer was marked.
99	Item was left blank.

PriorKnowledgeInCellBiology_06 (adapted from Großschedl et al., 2018; see also Kleickmann et al., 2014)

Mutations are random changes in the genetic material. Some mutations can have adverse effects on organisms.

Mark the following mutation with a cross that is most likely to have an adverse effect on the organism carrying it. (1 answer is correct)

- ☐ A deletion (removal) of three bases in the middle of a coding sequence
- ☐ A single base deletion in the middle of a non-coding sequence
- ☐ A single base insertion (addition) at the beginning of a coding sequence
- ☐ A single base deletion at the end of a coding sequence

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • A single base insertion (addition) at the beginning of a coding sequence
0	A different answer was marked.
99	Item was left blank.

PriorKnowledgeInCellBiology_07

Complete the following sentence by marking the correct answer with a cross (1 answer is correct):

The anticodon of a specific t-RNA is ...

- ☐ complementary to the corresponding codon of an mRNA.
- ☐ complementary to the corresponding codon of a tRNA.
- ☐ the part of a tRNA that binds a specific amino acid side chain (R group).
- ☐ variable depending on the amino acid side chain (R group) bound to the tRNA.

COMPREHENSION-ORIENTED LEARNING OF CELL BIOLOGY

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> complementary to the corresponding codon of an mRNA.
0	A different answer was marked.
99	Item was left blank.

PriorKnowledgeInCellBiology_08_01

Assign the cellular processes in the left column (1 – 2)
to the correct location in the eukaryotic cell in the right column (a – e).

(From each process, draw a line to a location in the cell. You draw 2 lines in total. As an example, the connection between Photosynthesis and Chloroplasts is shown.)

Cellular process	Location in the eukaryotic cell
<p>Example:</p> <p>Photosynthesis</p> <p>1) Transcription</p> <p>2) Translation</p>	<p>a. Cell wall</p> <p>b. Cytoplasm</p> <p>c. Lysosomes</p> <p>d. Nucleus (core of the cell)</p> <p>e. Smooth endoplasmic reticulum</p> <p>f. Chloroplasts</p>

Coding Schema

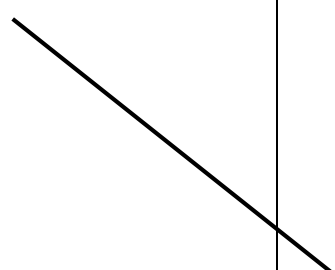
Score	Criteria
1	The correct answer was given: <ul style="list-style-type: none"> Transcription was connected to Nucleus (core of the cell)
0	A different answer was marked.
99	Item was left blank.

PriorKnowledgeInCellBiology_08_02

**Assign the cellular processes in the left column (1 – 2)
to the correct location in the eukaryotic cell in the right column (a – e).**

(From each process, draw a line to a location in the cell. You draw 2 lines in total. As an example, the connection between Photosynthesis and Chloroplasts is shown.)

Cellular process	Location in the eukaryotic cell
Example: Photosynthesis 1) Transcription 2) Translation	a. Cell wall b. Cytoplasm c. Lysosomes d. Nucleus (core of the cell) e. Smooth endoplasmic reticulum f. Chloroplasts



Coding Schema

Score	Criteria
1	The correct answer was given: <ul style="list-style-type: none"> • Translation was connected to Cytoplasm
0	A different answer was marked.
99	Item was left blank.

PriorKnowledgeInCellBiology_09_01

Assign the cellular processes in the left column (1 – 4)

to the cell organell in the right column (a – d), in which it takes place.

(From each process you draw only one line to one organelle in the cell. You draw a total of 4 lines.)

Cellular process	Cell organelle
1) Modification of (protein-bound) sugar molecules	a) Smooth endoplasmic reticulum
2) Synthesis of phospholipids	b) Rough endoplasmic reticulum
3) Synthesis of r-RNA units (ribosome subunits)	c) Golgi apparatus
4) Synthesis of membrane proteins	d) Nucleus (specifically: Nucleolus)

Coding Schema

Score	Criteria
1	The correct answer was given: <ul style="list-style-type: none"> Modification of (protein-bound) sugar molecules was connected to c) Golgi apparatus
0	A different answer was marked.
99	Item was left blank.

PriorKnowledgeInCellBiology_09_02

Assign the cellular processes in the left column (1 – 4)

to the cell organell in the right column (a – d), in which it takes place.

(From each process you draw only one line to one organelle in the cell. You draw a total of 4 lines.)

Cellular process	Cell organelle
1) Modification of (protein-bound) sugar molecules	a) Smooth endoplasmic reticulum
2) Synthesis of phospholipids	b) Rough endoplasmic reticulum
3) Synthesis of r-RNA units (ribosome subunits)	c) Golgi apparatus
4) Synthesis of membrane proteins	d) Nucleus (specifically: Nucleolus)

Coding Schema

Score	Criteria
1	The correct answer was given: <ul style="list-style-type: none"> • Synthesis of phospholipids was connected to a) Smooth endoplasmic reticulum
0	A different answer was marked.
99	Item was left blank.

PriorKnowledgeInCellBiology_09_03

Assign the cellular processes in the left column (1 – 4)

to the cell organell in the right column (a – d), in which it takes place.

(From each process you draw only one line to one organelle in the cell. You draw a total of 4 lines.)

Cellular process	Cell organelle
1) Modification of (protein-bound) sugar molecules	a) Smooth endoplasmic reticulum
2) Synthesis of phospholipids	b) Rough endoplasmic reticulum
3) Synthesis of r-RNA units (ribosome subunits)	c) Golgi apparatus
4) Synthesis of membrane proteins	d) Nucleus (specifically: Nucleolus)

Coding Schema

Score	Criteria
1	The correct answer was given: <ul style="list-style-type: none"> Synthesis of r-RNA units (ribosome subunits) was connected to d) Nucleus (specifically: Nucleolus)
0	A different answer was marked.
99	Item was left blank.

PriorKnowledgeInCellBiology_09_04

Assign the cellular processes in the left column (1 – 4)

to the cell organell in the right column (a – d), in which it takes place.

(From each process you draw only one line to one organelle in the cell. You draw a total of 4 lines.)

Cellular process	Cell organelle
1) Modification of (protein-bound) sugar molecules	a) Smooth endoplasmic reticulum
2) Synthesis of phospholipids	b) Rough endoplasmic reticulum
3) Synthesis of r-RNA units (ribosome subunits)	c) Golgi apparatus
4) Synthesis of membrane proteins	d) Nucleus (specifically: Nucleolus)

Coding Schema

Score	Criteria
1	The correct answer was given: <ul style="list-style-type: none"> • Synthesis of membrane proteins was connected to b) Rough endoplasmic reticulum
0	A different answer was marked.
99	Item was left blank.

PriorKnowledgeInCellBiology_10

Mark with a cross what transcription and translation have in common.

(1 answer is correct)

- ☐ In the initiation phase the ribosome binds.
- ☐ Transcription and translation are divided into the three phases initiation, elongation and termination.
- ☐ Both processes take place in animals, but not in plants.
- ☐ Transcription and translation have nothing in common.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> Transcription and translation are divided into the three phases initiation, elongation and termination.
0	A different answer was marked.
99	Item was left blank.

PriorKnowledgeInCellBiology_11

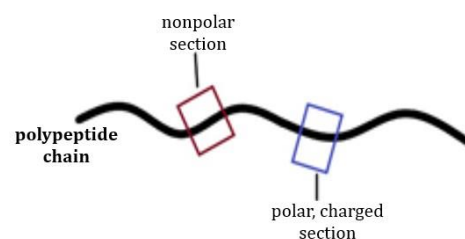
Question on the best representation of the process of transcription (adapted from Shi et al., 2010).

PriorKnowledgeInCellBiology_12

Question on the best representation of the structure that is most likely to form when phospholipids are mixed with water (adapted from Shi et al., 2010).

PriorKnowledgeInCellBiology_13 (adapted from Shi et al., 2010)

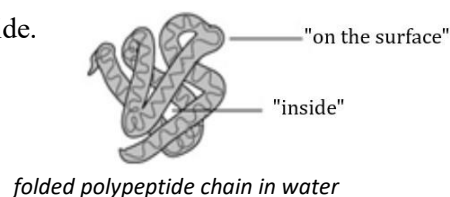
Imagine a long amino acid chain (polypeptide chain) (see figure on the right) in which there is a short polar, charged section and a short nonpolar, uncharged section.



Complete the following sentence by marking the correct answer with a cross (1 answer is correct):

When this polypeptide chain is immersed in water, the most likely way it will fold up so that...

- ☐ the non-polar section is on the surface and the polar section inside.
- ☐ the polar section is on the surface and the nonpolar section inside.
- ☐ both the nonpolar and the polar section are on the surface.
- ☐ both the nonpolar and the polar section are inside.



Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none">• the polar section is on the surface and the nonpolar section inside.
0	A different answer was marked.
99	Item was left blank.

1.2 Familiarity with Concept Maps

We suggest that familiarity with concept maps items students leave blank (missing code = 99) are treated as missing values and not part of further calculations. Furthermore, we suggest calculating a mean score for each student that represents his/her overall familiarity with concept maps. The original items can be found in the respective publication of McClure et al. (1999). The adaptations which were made in our study can be found in the in the respective section of our manuscript.

The work assignment for all questions in this part of the questionnaire was given first and reads as follows:

With the help of the following questions we want to find out if, and if so, how you use **concept maps**. A concept map is a net-shaped "map of thoughts" that helps to illustrate facts and figures. It consists of concepts and describes how they are related to each other. In the figure below you can see a concept map on the topic "acacias".

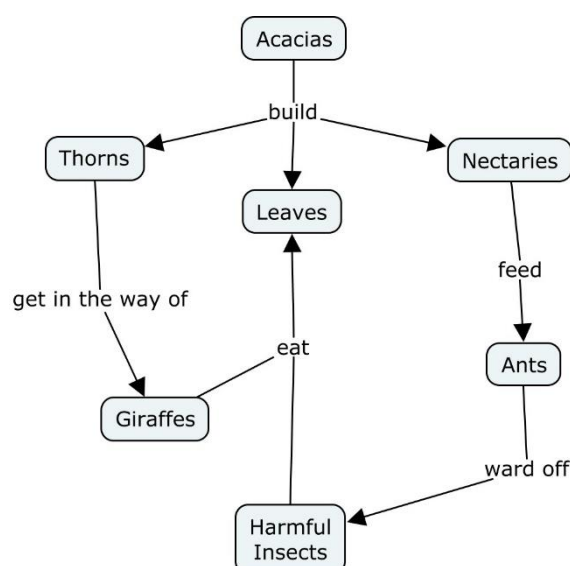


Figure 1: Concept map about the topic "Acacias".

Please judge how well the following statements apply to you personally. There are no right or wrong answers. There are five possible answers available to you. Check only **one box** per line and answer all questions. If you want to change your first answer, please make a circle around the incorrect answer.

All questions below regarding the familiarity with concept maps (FamiliarityWithConceptMaps_01 – FamiliarityWithConceptMaps_07) are entered according to the following coding schema:

Coding Schema

Score	1	2	3	4	5
Meaning	never/ very rarely	rarely	occasionally	often	very often/ always

FamiliarityWithConceptMaps_01²

I used concept mapping at school.

FamiliarityWithConceptMaps_02 (adapted from McClure et al., 1999)

I use concept mapping as a study strategy for university.

FamiliarityWithConceptMaps_03

Question on using concept mapping as a study strategy from McClure et al. (1999).

FamiliarityWithConceptMaps_04

Question on using concept mapping for exam and quizz preparation from McClure et al. (1999).

FamiliarityWithConceptMaps_05 (adapted from McClure et al., 1999)

I use concept maps to help me understand texts (or textbooks) better.

FamiliarityWithConceptMaps_06 (adapted from McClure et al., 1999)

I use concept maps as “notes” in class.

FamiliarityWithConceptMaps_07 (adapted from McClure et al., 1999)

I use concept maps for tasks or problems to get a better overview and to solve the problem better.

² All headings can be used as variable names in an SPSS data set. The variable named “FamiliarityWithConceptMaps” in our SPSS data set represents the participant’s mean score in the test.

1.3 Demographics

We suggest that demographics items students leave blank (missing code = 99) are treated as missing values and not part of further calculations.

The work assignment for all questions in this part of the questionnaire was given first and reads as follows:

Personal Details

Finally, we would like to know something about you:

Gender³

I am or feel most associated with the following

Gender:

☐ female

☐ male

Coding Schema

Score	Meaning
0	female
1	male
99	Item was left blank.

³ All headings from this part of the test are used as variable names in the SPSS data set. The variable named "UniversityStudyProgramGrouping" in the SPSS data set represents the suggested recoding result.

Age

Coding Schema

UniversityStudyProgram

Subject combination 1. _____ 2. _____
(for teachers) 3. _____

Coding Schema

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Suggested Recoding

	According to coding schema	Suggested recoding
Score	1	1
	2	
	3	
	4	0
	5	1
	6	
	7	0
	8	
	9	1
	10	0
	99	99

Semester

Semester: _____

Coding Schema

Score	Action
Individual score	Number is entered as the number of semesters the participant has studied at the university.
99	Item was left blank by the participant. 99 is entered to indicate that the number of semesters the participant has studied at the university is unknown.

FinalSchoolExamGrade

Final school grade (overall average): _____

Coding Schema

Score	Action
Individual score	Number is entered as the participant's school graduation grade, meaning the overall average (in German: <i>Abiturdurchschnitt</i>).
99	Item was left blank by the participant. 99 is entered to indicate that the participant's school graduation grade is unknown.

EducationalLevelInBiology

Did you take biology in the last two years of high school?

☐ yes ☐ no

If so, did you take biology as a basic or advanced course?

☐ basic ☐ advanced

Coding Schema

Score	Criteria
2	The following answers were given: <ul style="list-style-type: none"> • yes • advanced
1	The following answers were given: <ul style="list-style-type: none"> • yes • basic
0	The following answer was given: <ul style="list-style-type: none"> • no
99	Item was left blank.

2 Scaffolds, Prompts, and Feedback for Group T++

Conceptualization of the final versions of the scaffolds and prompts

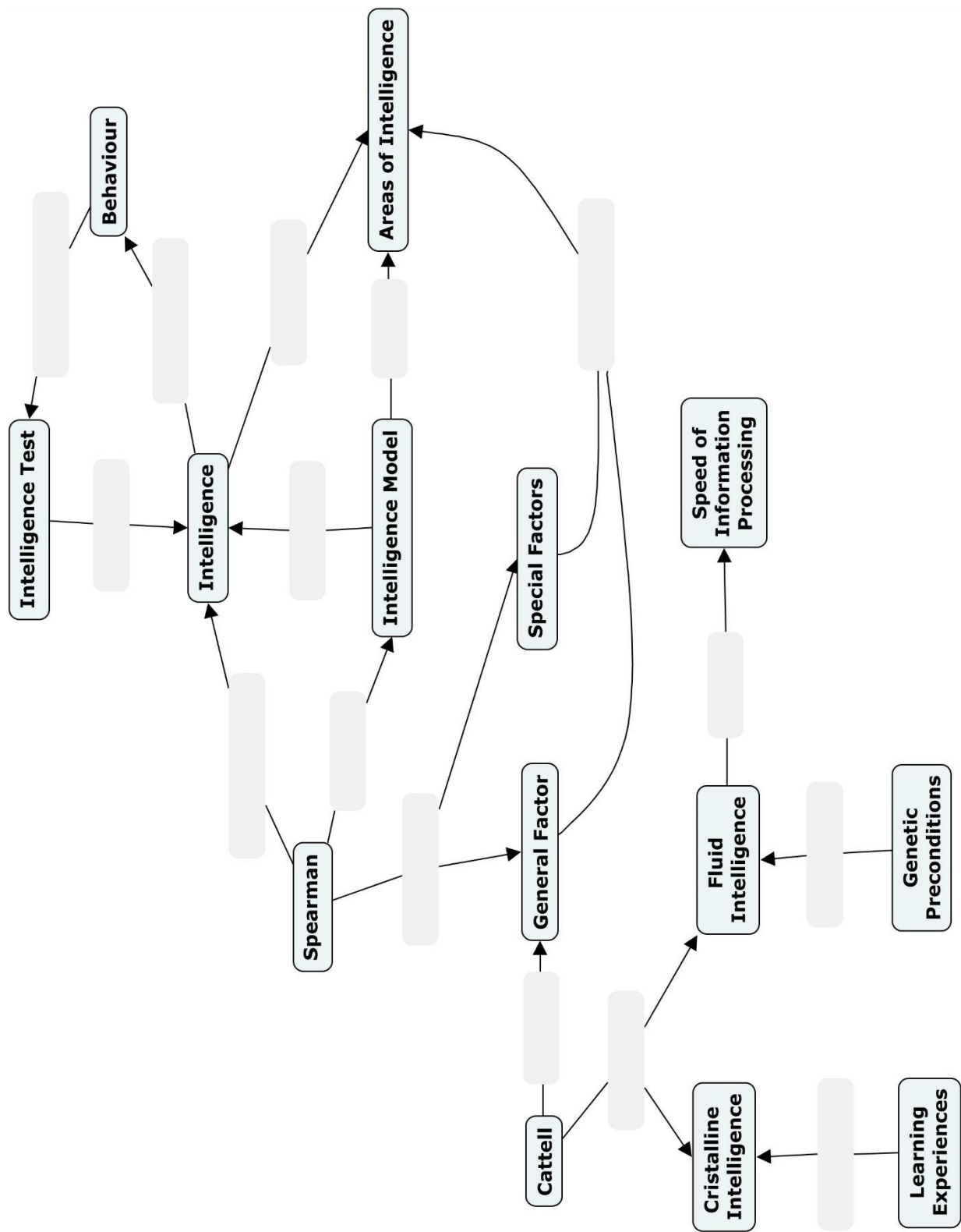
Group T++ received scaffolds as well as prompts and feedback. In week 1, a skeleton map allowed participants to focus entirely on the main concepts and linking words and prevent the construction of simplistic propositions. In week 2, a given set of the 12 main concepts taken from the learning material allowed the participants to create and define links between these concepts under reduced cognitive load conditions. Finally, in week 3, T++-participants were able to construct concept maps by themselves.

The lists of metacognitive prompts were handed out for the individual work phases to induce the use of relevant learning strategies. Prompts from the regulatory checklist of Großschedl and Harms (2018) were used and reduced in the case of group T++ over the course of the training phase (fading). The number of prompts was reduced after the second week, however, as participants had a skeleton map in the first week.

After each work phase, one of the participants' completed maps was transferred to the blackboard and then discussed. Finally, an expert map was presented and discussed, so participants were able to compare it to their own. Additionally, all participants received individual verbal as well as written feedback on their constructed concept maps. Considering previous findings, we decided on a knowledge of correct results- (KCR-) feedback approach but limited the feedback to marking CM mistakes and pointing out any resulting misconceptions. In addition, a list of the most common CM mistakes was available.

Group T– did not receive a CM training but used different learning strategies. This group received scaffolds and prompts that were specific to the training day's learning method: group discussions in week 1, writing a summary in week 2 and carousel workshops in week 3. During the individual work phases, participants worked on the learning material and had the opportunity to discuss their results afterwards and compare them to an expert solution.

2.1 Scaffold (Training Day 1; Group T++): Skeleton Map



2.2 Scaffold (Training Day 2; Group T++): Set of 12 Main Concepts

Bonus

David Wechsler

Intelligence

Intelligence Age (IA)

Basic Intelligence Age (GA)

Intelligence Quotient (IQ)

IQ Test

Age

Mean value (M)

Dispersion (s)

Comparison Group

William Stern

2.3 Metacognitive Prompts (Training Days 1 and 2; Group T++)**Tips for the construction of concept maps**

A concept map is a "map of thoughts" in the form of a net. With it you can illustrate the concepts and their connections for yourself and others. When creating concept maps, it can be helpful to have a plan for creating the concept map beforehand, to monitor its progress during its creation, and to check its results after the concept map has been created. These questions are designed to help you perform these steps and create a concept map that is effective for learning.

	Planning
Prepare	Planning prompt 1
	Planning prompt 2
	Planning prompt 3
	Monitoring
Connect	Monitoring prompt 1
	Monitoring prompt 2
	Monitoring prompt 3
	Monitoring prompt 4
	Evaluation
Assess	Evaluation prompt 1
	Evaluation prompt 2
	Evaluation prompt 3
	Evaluation prompt 4
	Evaluation prompt 5

Annotation. Prompts are from the regulatory checklist of Großschedl and Harms (2018).

2.4 Metacognitive Prompts (Training Day 3; Group T++)**Tips for the construction of concept maps**


A concept map is a "map of thoughts" in the form of a net. With it you can illustrate the concepts and their connections for yourself and others. When creating concept maps, it can be helpful to have a plan for creating the concept map beforehand, to monitor its progress during its creation, and to check its results after the concept map has been created. These questions are designed to help you perform these steps and create a concept map that is effective for learning.

	Planning
Prepare	Planning prompt 1
	Planning prompt 2
	Monitoring
Connect	Monitoring prompt 1
	Monitoring prompt 2
	Monitoring prompt 3
	Evaluation
Assess	Evaluation prompt 1
	Evaluation prompt 2

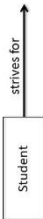
Annotation. The original list of prompts is from the regulatory checklist of Großschedl and Harms (2018).

2.5 Scaffold (Training Days 1, 2 and 3; Group T++): Catalogue of Common Mistakes – Concept Maps (page 1 of 2)


Mistake category I
„Unconnected concept“

Example:



Mistake category II
„Missing second concept“

Example:



Mistake category III
„Connection without arrow head“

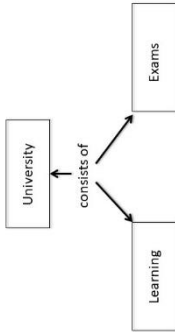
Example:


Mistake category IV
„Connection without arrow label“


Example:



Mistake category V
„Connection with multiple reading directions“


Example:


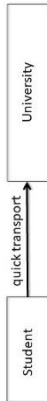
Example II:


Mistake category VI
„Arrow label without verb“

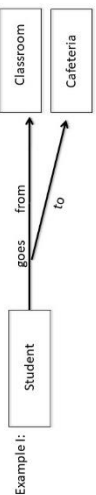
1. Only Noun
Example:


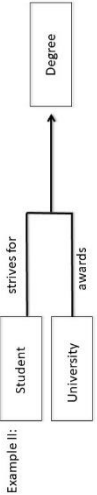
2. Only preposition
Example:


3. Only adjective
Example:


4. Noun and adjective
Example:


Mistake category VII
„Arrow has more than one label“

Example I:


Example II:


Catalogue of Common Mistakes

Concept Maps

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2.6 Scaffold (Training Days 1, 2 and 3; Group T++): Catalogue of Common Mistakes – Concept Maps (page 2 of 2)

Mistake category VIII

„Misplaced arrow label“

Example I:

```
graph LR; Father -- supports --> Student; Mother;
```

Example II:

```
graph LR; University -- offers --> Lectures; University -- offers --> Seminars;
```

Mistake category IX

„Misplaced arrow head“

Example I:

```
graph LR; Student -- strives for --> B1[Bachelor's Degree]; Student -- strives for --> M1[Master's Degree]; B1 -- support --> Parents; M1 -- support --> Parents;
```

Example II:

```
graph LR; Student -- strives for --> Abschluss;
```

Example III:

```
graph LR; S1[Student*in] -- strives for --> B2[Bachelor's Degree]; S1 -- strives for --> M2[Master's Degree]; B2 -- support --> Parents; M2 -- support --> Parents;
```

Mistake category X

„label with pronouns“

Example:

```
graph LR; Parents -- support her in --> US[University Studies];
```

Mistake category XI

„label in infinitive“

Example:

```
graph LR; Student -- taking part in --> C[Class(es)];
```

Mistake category XI

„Arrow label with an entire sentence“

Example:

```
graph LR; Student -- lives generally with other persons in a --> SF[Shared Flat];
```

Mistake category XII

„Double line after proposition“

Example:

```
graph LR; Bus -- transport --> Student; Train -- transport --> Student;
```

Mistake category XIII

„Incorrect Concept“

Example:

```
graph LR; N1[Nutrients from food/ Nutrients in food]; N2[Markus + Emma]; N3[Leaves, Stem, Roots];
```

Connections to and from those concepts are invalid and are not considered for rating!

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3 Scaffolds and Prompts for Group T–

3.1 Scaffold and Prompts (Training Day 1; Group T–): Tips and Tasks for the Small Group Discussion

Tips and tasks for the small group discussion

<u>Before the discussion:</u>	
Gain an overview	Read the task assignment carefully. What previous knowledge do you have from schooldays/other sources? Sift through distributed and own material.
Find the heading	Write down the heading: _____
Plan the approach	Which subtopics should be considered in your discussion? What do you start/continue/stop with? (consider the time frame) Write down your plan in bullet points:
<u>During reading and discussion:</u>	
Check understanding	Where do you still have problems understanding? <i>For example, what was the difference between the intelligence models?</i>
Use information material	Try to solve the problems of understanding with the information material available to you.
Check approach	Are you really going ahead as planned? What did you change in your plan? <i>I'm going to add Guilford's model of the cube.</i> <i>What the connection between intelligence and behaviour is, I have yet to understand.</i>
<u>Towards the end of the reading and discussion:</u>	
Final check	Compare planned procedure and own discussion. Is everything correct in your opinion? What have you learned? <i>For example, I have learned how the intelligence models differ.</i> What do you still not understand despite using the information material?

3.2 Scaffold and Prompts (Training Day 2; Group T–): Tips and Tasks for Writing a Summary

Tips and tasks for writing a summary

<p><u>Before reading:</u></p> <p>Gain an overview</p> <p>Find the heading</p> <p>Plan the approach</p>	<p>Read the task assignment carefully. What previous knowledge do you have from schooldays/other sources? Sift through distributed and own material.</p> <p>Write down the heading:</p> <hr/> <p>Which subtopics should be considered in your summary? What do you start/continue/stop with? (consider the time frame)</p> <p>Write down your plan in bullet points:</p>
<p><u>During writing process:</u></p> <p>Check understanding</p> <p>Use information material</p> <p>Check approach</p>	<p>Where do you still have problems understanding? <i>For example, what do the calculations have in common and how do they differ?</i></p> <p>Try to solve the problems of understanding with the information material available to you.</p> <p>Are you really going ahead as planned? What did you change in your plan? <i>I will also add the individual components of the deviation IQ.</i></p>
<p><u>Towards the end of the writing process:</u></p> <p>Final check</p>	<p>Compare planned procedure and own summary. Is everything correct in your opinion? What have you learned? <i>For example, I have learned how the calculation models are related and how they are constructed.</i></p> <p>What do you still not understand despite using the information material?</p>

3.3 Scaffold and Prompts (Training Day 3; Group T–): Tips and Tasks for the Carousel Workshops

Tips and tasks for the carousel workshops

<p><u>Before reading:</u></p> <p>Gain an overview</p> <p>Find the heading</p> <p>Plan the approach</p>	<p>Read the task assignment carefully. What previous knowledge do you have from schooldays/other sources? Sift through distributed and own material.</p> <p>Write down the heading:</p> <hr/> <p>Which subtopics should be considered in your summary? What do you start/continue/stop with? (consider the time frame)</p> <p>Write down your plan in bullet points:</p>
<p><u>During the carousel workshops:</u></p> <p>Check understanding</p> <p>Use information material</p> <p>Check approach</p>	<p>Where do you still have problems understanding? <i>For example, what do the normal distribution and the IQ scale have in common and how do they differ?</i></p> <p>Try to solve the problems of understanding with the information material available to you.</p> <p>Are you really going ahead as planned? What did you change in your plan? <i>I also add the individual scale ranges and intelligence characteristics.</i></p>
<p><u>Towards the end of the carousel workshops:</u></p> <p>Final check</p>	<p>Compare planned procedure and own summary. Is everything correct in your opinion? What have you learned? <i>For example, I have learned what explanations are used for the Flynn effect.</i></p> <p>What do you still not understand despite using the information material?</p>

4 Coding Manual for the Treatment Check After the Training Phase

Intelligence Quiz

The “intelligence quiz” served as a treatment check after students had completed the training phase in week 3 on the topic intelligence. The test was filled out by students on the third day of the study (week 3).

We suggest that intelligence quiz items students leave blank (missing code = 99) are scored 0. Furthermore, we suggest calculating a sum score for all items, which represents the students’s declarative knowledge in a single score.

The work assignment for all questions in this part of the questionnaire was given first and reads as follows:

Work assignment: Below you will find 20 tasks. Each of these tasks consists of a task definition, five content statements and five answer alternatives. First, read each task definition and the associated statements in full. Then solve the task by considering for each of the five statements whether it is correct or not. The five answer alternatives below specify which of the five statements or which combination of the five statements could be correct.

Please read through all five answer alternatives and then decide which answer alternative is correct. Of the five answer alternatives, only **one** is always correct; there are **no** tasks where none or more than one answer is correct. Please mark your answer with a cross.

Note: The task is always worded in plural for each task (e.g. "Which of the following statements are correct?"), even if only one of the statements mentioned should be correct.

- Example: Many animals can fly.

Which of the following statements are correct?

1. Pigeons can fly.
2. Antilopes can fly.
3. Crocodiles can fly.
4. Rhinoceroses can fly.
5. Zebras can fly.

- ☐ Only statement 1 is correct.
- ☐ Statements 1 and 3 are correct.
- ☐ Statements 1 and 2 are correct.
- ☐ Statements 2, 3 and 4 are correct.
- ☐ Statements 1, 3 and 5 are correct.

TreatmentCheckAfterTraining_01⁴

Intelligence is an object of research, which various researchers are and have been working on.

Which statements about the construct "intelligence" in general are correct?

1. Intelligence is one of the best studied psychological constructs ever.
2. The universal definition of intelligence is "general cognitive ability".
3. Intelligence is best assessed through interviewing, by letting respondents assess how intelligent they are.
4. Intelligence is associated with success in various educational and professional areas of life.
5. Persons with a high intelligence level are usually viewed negatively in our society.

- ☐ Only statement 4 is correct.
- ☐ Only statement 3 is correct.
- ☐ Statements 2 and 3 are correct.
- ☐ Statements 1 and 4 are correct.
- ☐ Statements 2, 3 and 5 are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Statements 1 and 4 are correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_02

However, the construct "intelligence" still poses questions.

What are the difficulties in capturing intelligence?

1. With the existing tests, intelligence cannot be measured objectively.
2. Intelligence as a theoretical construct cannot be observed directly, but can only be estimated by inference after observing appropriate performance behaviour.
3. The intelligence performance of individuals is often overestimated, as they can fake good test results.
4. Science has not yet been able to develop tests to measure intelligence because researchers have not yet been able to agree on a uniform definition of the construct.
5. A valid assessment of intelligence performance is only possible from adulthood onwards, as intelligence performance in childhood is subject to strong fluctuations.

⁴ All headings can be used as variable names in an SPSS data set. The variable named "TreatmentCheckAfterTraining" in the SPSS data set represents the participant's overall score in the test.

- ☐ Only statement 2 is correct.
- ☐ Statements 3 and 4 are correct.
- ☐ Statements 1 and 5 are correct.
- ☐ Statements 2, 3 and 4 are correct.
- ☐ Statements 3, 4 and 5 are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only statement 2 is correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_03

Edwin Boring was one of the researchers who worked on the construct "intelligence".

Which statements are correct regarding Edwin Boring's operational definition:

"Intelligence is what an intelligence test measures"?

1. The definition states that the results from different intelligence tests cannot be compared to one another.
2. In the definition Boring expresses his view that there is no such thing as "intelligence".
3. The definition is a minimum consensus, which became necessary after all previous attempts to define intelligence in terms of content in a generally valid way failed.
4. The definition states that intelligence can be measured with different tests and that the meaning of intelligence as a construct can probably vary from test to test.
5. Boring's operational definition is no longer used today, as science has a uniform definition of "intelligence" in terms of content.

- ☐ Only statement 2 is correct.
- ☐ Only statement 5 is correct.
- ☐ Statements 1 and 5 are correct.
- ☐ Statements 3 and 4 are correct.
- ☐ Statements 1, 2 and 3 are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> Statements 3 and 4 are correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_04

Alfred Binet and Theodor Simon developed the first scientific intelligence test.

What were the measuring characteristics of the Binet-Simon test?

- The test was used to (1.) measure intelligence and (2.) use the measurement result to recommend concrete educational measures to the parents of the tested children.
- With the test (1.) intelligence could be measured and (2.) the result could be checked for validity with the help of the self-reported learning history of the children.
- With the test (1.) intelligence could be measured and (2.) the measurement result could be quantified as a standardised intelligence quotient.
- With the test (1.) intelligence could be measured and (2.) the distance to children of normal intellectual capacity could be quantified.
- In the course of test validation, it turned out that the test was not suitable for measuring intelligence, so it had to be discarded and was therefore not used.

- ☐ Only statement 4 is correct.
- ☐ Statements 1 and 5 are correct.
- ☐ Statements 2 and 5 are correct.
- ☐ Statements 1, 3 and 5 are correct.
- ☐ None of the statements is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> Only statement 4 is correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_05

Until the 20th century, intelligence was considered a uniform, homogeneous construct. Charles Spearman then pleaded for a distinction between a general factor (g-factor) and additional special factors (s-factors) of intelligence.

Which statements are correct in this respect?

1. Humans generally perform exactly identically in all areas relevant to intelligence, which is why Spearman's plea for a distinction of factors is obsolete.
2. The intelligence performance of humans in different relevant areas is on a quite similar level, but in most cases they are a little bit more efficient in some areas and a little bit less in others.
3. Highly gifted individuals are characterized by the fact that they perform far above average in a few areas relevant to intelligence, but far below average in all other areas, which is why a differentiation of factors seems to make sense.
4. With increasing age, more and more areas become apparent in which people can show intelligent behavior, which is why a differentiation of factors seems to make sense.
5. By comparing the intelligence performance of gorillas and toddlers, Spearman was able to experimentally prove the different factors, which in turn led him to argue in favor of such a differentiation.

- ☐ Only statement 5 is correct.
- ☐ Only statement 2 is correct.
- ☐ Statements 1 and 5 are correct.
- ☐ Statements 2, 3 and 4 are correct.
- ☐ Statements 1, 2 and 4 are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only statement 2 is correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_06

Raymond Cattell assumed that Spearman's g-factor could be further broken down into two independent components: fluid and crystalline intelligence.

Which statements are correct in this respect?

1. Fluid intelligence is understood as the brain's physiological efficiency.
2. Crystalline intelligence is understood as a sediment of individual learning experiences.
3. The development of fluid intelligence is – in contrast to that of crystalline intelligence – strongly dependent on socialization.

4. Crystalline intelligence is expressed, for example, in verbal understanding or the routine implementation of effective problem-solving strategies, whereas fluid intelligence is expressed more in the general speed of information processing.
5. While crystalline intelligence is subject to age-related degradation processes, fluid intelligence can be increased up to old age.

- ☐ Only statement 3 is correct.
- ☐ Statements 1 and 4 are correct.
- ☐ Statements 1 and 2 are correct.
- ☐ Statements 2, 3 and 5 are correct.
- ☐ Statements 1, 2 and 4 are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Statements 1, 2 and 4 are correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_07

The existing intelligence structure models have differences and similarities.

Which statements are true regarding these differences and similarities?

1. There is only one single intelligence structure model, so that there can be no differences.
2. In all existing models the same hierarchical basic structure is assumed: a superordinate g-factor with several subordinate s-factors.
3. In all models, "social intelligence" is subsumed under the dimension of so-called "practical everyday intelligence".
4. The same number of factors is postulated in all models, but they differ in their specification of content.
5. None of the models distinguishes between the intellectual operations as such and the visible products of intelligent behavior as an expression of the competent use of these intellectual operations.

- ☐ Only statement 2 is correct.
- ☐ Statements 3 and 5 are correct.
- ☐ Statements 2 and 4 are correct.
- ☐ Statements 1, 3 and 5 are correct.
- ☐ None of the statements is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • None of the statements is correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_08

Intelligence research deals with intelligence structural models and their applicability in practice.

What applies to the practical approach in intelligence research?

1. In 2014, U.S. researchers developed a generally valid, temporally stable psychometric model of intelligence, which has since been the basis for current research questions.
2. The selection of an intelligence model necessary for the processing of a research question should be based on the respective research goal/interest in knowledge.
3. Models, in which different independent intelligence dimensions are postulated, are not suitable for a differentiated intelligence diagnosis.
4. Depending on which intelligence model a research question is based on, a specific selection of test instruments is available.
5. If one wants to learn about general cognitive performance, it is best to choose a model in which different independent intelligence dimensions are postulated.

- ☐ Only statement 4 is correct.
- ☐ Statements 3 and 5 are correct.
- ☐ Statements 2 and 4 are correct.
- ☐ Statements 1, 4 and 5 are correct.
- ☐ All statements are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Statements 2 and 4 are correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_09

Alfred Binet and Theodor Simon developed the first scientific intelligence test. However, the test they developed contained serious problems.

What serious problems did the classic Binet-Simon test contain?

1. The test users felt overwhelmed by the complicated application and calculation rules.
2. The included tasks only differentiated satisfactorily for younger age groups.
3. The intelligence tasks of the test proved to be unsolvable in 36.7% of the cases.
4. The difference in intelligence had to be interpreted differently depending on the age range.
5. The duration of the test was too long, which led to considerable motivation and thus also performance impairments of the tested children.

- ☐ Only statement 2 is correct.
- ☐ Statements 2 and 4 are correct.
- ☐ Statements 1 and 5 are correct.
- ☐ Statements 1, 2 and 3 are correct.
- ☐ Statements 2, 3 and 4 are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Statements 2 and 4 are correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_10

In 1912, the German psychologist William Stern found a solution to previous problems of intelligence measurement by proposing a new calculation rule, the so-called intelligence quotient (IQ).

Which statements apply to Stern's IQ formula??

1. The intelligence age determined by intelligence tests is relativized by the age of a person.
 2. The age of intelligence determined by intelligence tests is relativized by the empirical dispersion of the next higher age group.
 3. Stern's IQ formula only works appropriately in adulthood, but not in children and adolescents.
 4. The mathematical structure of Stern's formula implies that IQ – despite constant intelligence performance – decreases with increasing age.
 5. Since intelligence only increases rapidly in adulthood, but is relatively stable in childhood, Stern's formula has the least distortions in the age range of children and adolescents.
- ☐ Only statement 2 is correct.
 - ☐ Only statement 3 is correct.

- ☐ Statements 1 and 5 are correct.
- ☐ Statements 1 and 4 are correct.
- ☐ Statements 2, 3 and 4 are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Statements 1 and 4 are correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_11

In 1936 David Wechsler published his formula of the so-called Deviation-IQ, which is still used for IQ-calculation today.

Which statements are correct?

1. The individual test value of a person is relativized by the social conceptions of average intelligence performance determined by questioning.
2. The individual test value of a person is relativized by the average intelligence performance of middle-aged persons (30-45 years).
3. The individual test value of a person is relativized by the average intelligence performance of primates.
4. The individual test score of a person is relativized by the results within the respective age group.
5. A person's individual test score is used to calculate the likelihood of that person showing abnormal behaviour over the next 15 years.

- ☐ Only statement 5 is correct.
- ☐ Only statement 4 is correct.
- ☐ Statements 1 and 2 are correct.
- ☐ Statements 2, 3 and 5 are correct.
- ☐ Statements 1, 3 and 5 are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only statement 4 is correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_12

Which of the following arguments can be used to make the necessity of a test-result normalization plausible?

1. Test subjects from different cultural backgrounds (e.g. Oriental vs. Occidental) do not usually have the same intellectual level, so a differentiation according to cultural affiliation seems to make sense.
2. Test subjects from different age groups (e.g., children vs. adolescents vs. adults) usually do not have the same intellectual level, so a differentiation by age seems reasonable.
3. Test subjects from different types of schools (e.g., German Hauptschule vs. German Gymnasium) usually do not have the same intellectual level, so a differentiation by type of school seems reasonable.
4. Test subjects with different native language groups (e.g. Romansh vs. Slavic) do not usually have the same intellectual level, so a differentiation according to native language group seems reasonable.
5. Test subjects from different geographical regions (e.g., near the equator vs. far away from the equator) usually do not have the same intellectual level, so a differentiation by residential region seems reasonable.

- ☐ Only statement 1 is correct.
- ☐ Only statement 3 is correct.
- ☐ Statements 2 and 3 are correct.
- ☐ Statements 1, 4 and 5 are correct.
- ☐ Statements 2, 3 and 5 are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> Statements 2 and 3 are correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_13

The "mean value" and the "dispersion" are mathematical-statistical concepts.

Which statements apply to the determination of the mathematical-statistical concepts of "mean value" and "dispersion" in a population (e.g. a comparison group)?

- Mean value and dispersion can usually be estimated sufficiently reliably on the basis of testing large samples of several thousand subjects.
- The mean value of a population can be estimated by adding the scores of all participants in the sample and dividing by the number of participants.
- The dispersion ratios in a population can be estimated by calculating how far the individual measured characteristic values of each participant from a sample deviate on average from the calculated mean value.
- To date, there is no reliable method for validly estimating mean and dispersion, so it is essential to collect the characteristics of interest from each individual member of a population.
- The average deviation of each measured value from the calculated population mean for a population is also called "deviation standard".

- ☐ Only statement 4 is correct.
- ☐ Statements 1 and 2 are correct.
- ☐ Statements 3 and 4 are correct.
- ☐ Statements 2, 3 and 5 are correct.
- ☐ Statements 1, 2 and 3 are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> Statements 1, 2 and 3 are correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_14

Mathematical-statistical concepts or expressions are used to determine the deviation IQ.

Which concepts or expressions are not part of the formula used today?

1. variance s^2 in the comparison group
2. Test value X of a person
3. Mean value M of the comparison group
4. Dispersion s in the comparison group
5. Standard deviation ($= 15$) of the IQ distribution

- ☐ Only statement 1 is correct.
- ☐ Only statement 4 is correct.
- ☐ Statements 1 and 2 are correct.
- ☐ Statements 2 and 5 are correct.
- ☐ All statements are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only statement 1 is correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_15

The normal distribution is a mathematical-statistical concept.

Which statements apply to a normal distribution?

1. Most biological, psychological and social characteristics and traits in a population are normally distributed.
2. The form of a normal distribution can generally be described as asymmetrical and polymodal.
3. The shape of a normal distribution usually resembles a "bell shape".
4. The population mean μ is located below the lowest point of the curve.
5. The population mean μ is located below the highest point of the curve.

- ☐ Only statement 1 is correct.
- ☐ Statements 2 and 4 are correct.
- ☐ Statements 1, 3 and 5 are correct.
- ☐ Statements 1, 2 and 5 are correct.
- ☐ None of the statements is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> Statements 1, 3 and 5 are correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_16

Various statements can be derived from the IQ distribution.

Which statements are correct?

1. The IQ as a characteristic is normally distributed in the population.
2. The mean value μ of the IQ in the population is 100.
3. The standard deviation σ of the IQ in the population is 15.
4. About 2/3 of the population has an average expression of the IQ.
5. About 2.3 % of the population has a far above average IQ.

- ☐ Only statement 3 is correct.
☐ Statements 2 and 4 are correct.
☐ Statements 1 and 5 are correct.
☐ Statements 1, 2 and 5 are correct.
☐ All statements are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> All statements are correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_17

The IQ score ranges have certain scale descriptions.

Which assignments between IQ score ranges and their common interpretation are correct?

1. $< 70 \leftrightarrow$ learning disability
 2. $70-84 \leftrightarrow$ average level of intelligence
 3. $85-114 \leftrightarrow$ average level of intelligence
 4. $115-129 \leftrightarrow$ average level of intelligence
 5. $\geq 130 \leftrightarrow$ high intellectual giftedness
- ☐ Only statement 4 is correct.
 - ☐ Statements 1 and 3 are correct.
 - ☐ Statements 2 and 5 are correct.
 - ☐ Statements 1, 3 and 5 are correct.
 - ☐ Statements 1, 2 and 5 are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Statements 1, 3 and 5 are correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_18

The political scientist James Flynn made a discovery in 1984 that astonished the world and led to many speculations. The effect he observed was named after him.

What is the so-called Flynn effect?

1. The measured average IQ of the total population increases – depending on the respective age group – by about 3 to 7 points every 10 years, but in the group of 10-12 year old children it increases by far the most.
2. The measured average IQ of the total population increases – depending on the performance range considered – by approx. 3 to 7 points every 10 years, especially in the area of mathematical-spatial thinking.
3. The measured average IQ of the total population rises – across all age groups and performance areas – by approx. 3 to 7 points every 10 years (depending on the measurement method).
4. The measured average IQ of the total population decreases – across all age groups and performance areas – by approx. 3 to 7 points every 10 years (depending on the measurement method).

5. The measured average IQ of the total population decreases – across all age groups and performance areas – by approx. 15 points every 10 years (depending on the measurement method)

- ☐ Only statement 3 is correct.
- ☐ Only statement 4 is correct.
- ☐ Statements 1 and 2 are correct.
- ☐ Statements 2 and 3 are correct.
- ☐ None of the statements is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only statement 3 is correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_19

The Flynn Effect, named after the political scientist James Flynn, gave rise to numerous speculations – among other things regarding possible causes for the effect.

Which of the following explanations are plausibly used for the Flynn effect?

1. Longer duration of recreational vacations
2. Higher age of the mother at first pregnancy
3. Greater test familiarity
4. Improved nutrition
5. Improved pharmaceuticals to increase brain efficiency.

- ☐ Only statement 3 is correct.
- ☐ Statements 1 and 4 are correct.
- ☐ Statements 3 and 4 are correct.
- ☐ Statements 2, 3 and 5 are correct.
- ☐ All statements are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> Statements 3 and 4 are correct.
0	A different answer was marked.
99	Item was left blank.

TreatmentCheckAfterTraining_20

Intelligence test results continue to be the subject of much discussion in society and science.

Which statements are correct regarding the validity of intelligence test results?

1. It can be said with certainty that intelligence tests really do measure intelligence.
2. Although it cannot be said with certainty that intelligence tests really do measure intelligence, it can be plausibly assumed on the basis of experience.
3. Meanwhile it could be proven beyond doubt that intelligence tests are not very suitable to measure intelligence, because they actually only measure the willingness to follow instructions and to work on meaningless tasks.
4. The motivation of a test person when solving intelligence test tasks has no influence on his test results per sé.
5. An individual test result may vary due to changed internal (e.g. motivation) and/or external factors (e.g. lighting conditions) in a test situation.

- ☐ Only statement 1 is correct.
- ☐ Statements 2 and 5 are correct.
- ☐ Statements 3 and 4 are correct.
- ☐ Statements 2, 4 and 5 are correct.
- ☐ Statements 3, 4 and 5 are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> Statements 2 and 5 are correct.
0	A different answer was marked.
99	Item was left blank.

5 Coding Manual for the Concept Mapping Self-Efficacy Questionnaire

Concept Mapping Self-Efficacy

The concept mapping self-efficacy questionnaire was filled out by participants on the fourth day of the study (week 4; learning phase) after the introduction to concept mapping. In the test booklet, the self-efficacy test was not labeled as such but as “Questionnaire on familiarity with concept mapping”. After filling out the questionnaire, students completed an error detection task, in which they were given a concept map that included errors. The task was to detect and correct as many errors as possible within four minutes (see CM Familiarity Treatment Check).

We suggest that declarative knowledge items students leave blank (missing code = 99) are scored 0. Furthermore, we suggest calculating a sum score for all items, which represents the declarative knowledge in a single score.

The work assignment for all questions in this part of the questionnaire was given first and reads as follows:

This part of the test is about how you evaluate **working with the concept map**.

In the following statements, you should always tick the answer that best reflects your feelings. Please always try to decide as **spontaneously** and **honestly** as possible.

Remember: There are **no** right or wrong answers.

Work assignment: Rate each statement (1. - 6.) as not at all accurate or very accurate for yourself.

All questions below regarding the concept mapping self-efficacy (CMRelatedSelfEfficacy_01 – CMRelatedSelfEfficacy_07) are entered according to the following coding schema:

Coding Schema

Score	1	2	3	4	5
Meaning	NOT AT ALL				VERY

CMRelatedSelfEfficacy_01⁵

I feel competent in presenting subject-related content in a concept map.

CMRelatedSelfEfficacy_02

I feel competent in selecting the important concepts for my concept map.

CMRelatedSelfEfficacy_03

I feel competent in creating correct connections between the terms in a concept map.

CMRelatedSelfEfficacy_04

I feel competent in correctly labeling the arrows of a concept map.

CMRelatedSelfEfficacy_05

I could explain to a friend WITH WORDS ONLY how to create a concept map so that he could create one himself.

CMRelatedSelfEfficacy_06

I could explain to a friend with words, pen and paper how to create a concept map, so that he could create one himself.

⁵ All headings can be used as variable names in an SPSS data set. The variable named “CMRelatedSelfEfficacy” in the SPSS data set represents the participant’s mean score.

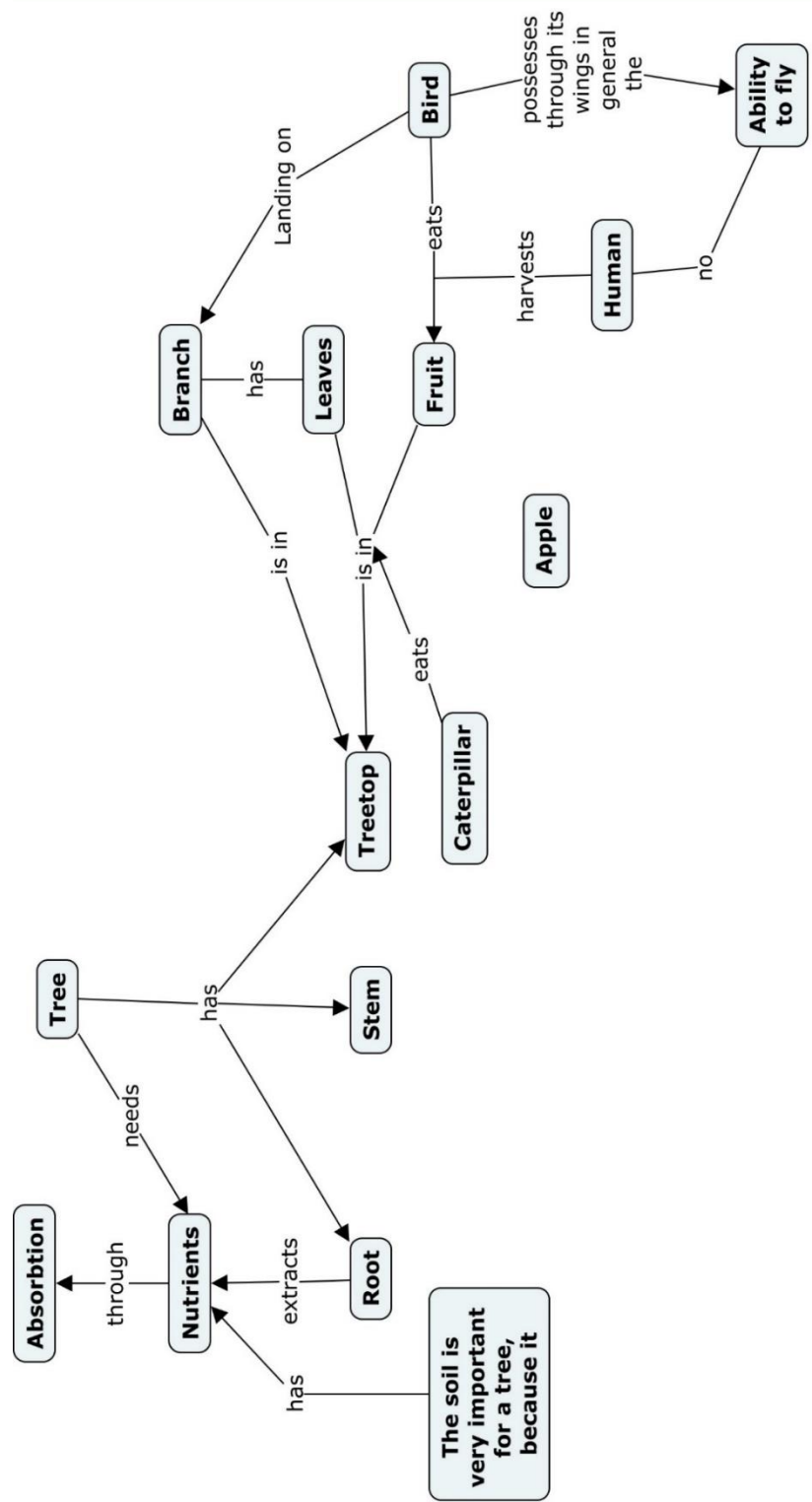
6 CM Familiarity Treatment Check

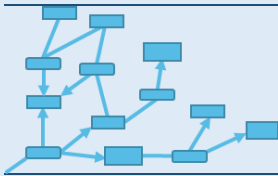
A friend of yours sent you this concept map on the topic "tree" for correction.

In the map below, highlight the **concept map "technique" errors**.

Mark the errors clearly so that your friend knows exactly where the error is. □

Correct the errors in the concept map. □





7 Learning Booklet for the Individual Learning Phase

Intervention day

Learning booklet

Instead of showing figures, this learning booklet will only show the figure's size in parentheses and a description of the figure's content. The front page's figure will serve as an example:
 --- figure (8.9 cm x 7.5 cm) of two combined structures: On the bottom is the lower half of an animal cell, in which all organelles and major cell structures are shown. Out of the cell-half emerges a network of connected, different colored dots. The connected dots first form a channel (the last part of the spinal cord) and then a brain-like structure. ---

Notes

On the pages with the learning text you will find three types of markers:

- Boxes with a blue background structure your learning process.
- *Concepts printed in blue and italics* are of particular importance for the understanding of the text.
- Arrows (→) refer to specific elements (e.g. illustrations) in the learning material. Use them; they serve to improve your understanding of the text and support your learning process.

The structure and function of eukaryotic cells

*Work assignment: Read the following part of the text individually.
For a better understanding, also use illustrations 1, 2, 3a, 3b and 4.*

Metabolism, sensitivity, growth, development, death, reproduction and heredity are characteristics of living things and are made possible by its smallest unit, the *cell*. *Cells* are always created by the division of existing *cells*. All living things are made up of *cells*, but a structural distinction is made between *cells* without a *cell nucleus* (procytes) and *cells* with a *cell nucleus* (eucytes). Creatures that are made up of procytes are called prokaryotes; these include bacteria and protobacteria. In contrast, plants, animals, fungi and unicellular organisms are made up of eucytes and are accordingly called eukaryotes.

Through cell differentiation, eukaryotes develop different cell forms. In unicellular eukaryotes, a single *cell* takes over all functions of life, whereas in multicellular eukaryotes the principle of "division of labor" between different specialized cell groups is characteristic. As the complexity of an organism increases, the number of different cell types also increases, and as an example of a very complex organism, humans possess germ cells for reproduction, white blood cells for immune defence, red blood cells for oxygen transport, nerve cells for signal transmission and much more.

Despite considerable differences in their more specific structures, all eukaryotic *cells* can be traced back to a uniform basic structure: They are enclosed by a *plasma membrane* that separates the *cell* from its environment, and they are filled with a fluid, the *cytoplasm*, in which various cell structures (e.g., cell organelles) are embedded. However, the cell structures of animal and plant cells differ more or less clearly from each other. These differences are functionally significant and are due to the adaptation to different environmental conditions, which is well illustrated by the example of the outer cell shape:

Plants, as firmly rooted living beings, must be made up of *cells* that have a stable structure and ensure that strength is achieved. Plant cells therefore have an elastic *plasma membrane* and a solid cell wall as a further outer boundary.

In contrast, animals are creatures that are in motion a lot. In contrast to plants, they must therefore be made up of *cells* that have a very flexible structure and can adapt to the different body shapes of movement. Animal cells therefore do not have an additional solid cell wall, but are only limited by the elastic *plasma membrane* (→ Fig. 1).

--- figure (5.8 cm x 9.5 cm) of two cells: On the left is an animal cell, in which the nucleus, mitochondria and two other structures are shown. On the right is a plant cell, in which the nucleus, mitochondria and two other structures are shown. The cell is framed by a cell wall. Between them, in the top third of the figures is "elastic plasma membrane" written, with two arrows pointing from the label to the respective plasma membranes of the two cells. On the right of the plant cell is a label "firm cell wall" with an arrow pointing from the label to the thick cell wall. ---

Fig. 1: Simplified overview of the components that are microscopically recognizable in an animal cell (left) and a plant cell (right)

Bacteria also have a solid cell wall as prokaryotes. Since a single *cell* fulfills all vital functions, the solid cell wall serves primarily as a special protection against potentially harmful environmental influences.

However, *cells* must not only be separated from their environment, but must also be able to establish an interaction with their environment in order to exchange energy and matter. The special structure of the *plasma membrane* (as well as the cell wall in plants and bacteria) enables *cells* to establish this interaction. The *plasma membrane* is a so-called biomembrane, i.e. a thin membrane made of organic substances that occurs in living organisms and has a barrier function. Fat molecules (phospholipids) and protein molecules (proteins) are found as components in all *biomembranes*. *Phospholipids* have two different parts: a hydrophilic (= "water-loving") head part and a hydrophobic (= water-repellent) tail part consisting of (saturated or unsaturated) fatty acid chains. The *phospholipids* of the *plasma membrane* are regularly arranged in a viscous double layer: the hydrophilic heads face outwards on both sides, while the hydrophobic tails face each other, thus stabilizing the membrane via interactions (→ Fig. 2).

--- figure (6.8 cm x 9.8 cm) of a phospholipid bilayer section: A three-dimensional array of tightly packed phospholipids is shown. The label on top of the figure reads "Hydrophobic tails of a phospholipid molecule" and two arrows point to the two tails of a phospholipid that point downwards to the middle of the bilayer. The label below the figure reads "Hydrophilic head of a phospholipid molecule" and an arrow points to the head of a phospholipid molecule, whose tails point upwards to the middle of the bilayer. ---

Fig. 2: Schematic representation of the *phospholipid* bilayer

The *phospholipids* of the *plasma membrane* show considerable mobility. This mobility increases at higher temperatures and decreases at lower temperatures, but also depends on the amount of unsaturated fatty acids and cholesterol in a *plasma membrane*, as these substances are the main determinants of its flexibility:

- In saturated fatty acid chains, the atoms are all linked together by single chemical bonds and are therefore strictly ordered and elongated/straight, which promotes dense and rigid packing of the molecules. In unsaturated fatty acid chains, there are also chemical double bonds between the atoms, which cause a “kink” in the fatty acid chain at the site of their occurrence, which prevents a dense molecule-packing and thus promotes the flexibility of a membrane. The higher the proportion of unsaturated fatty acid chains, the more flexible a membrane is (→ Fig. 3a).
- Cholesterol is stored in the *plasma membranes* of animal cells between the *phospholipids*. As a relatively rigid molecule, it reduces the flexibility of the membrane at higher temperatures. At low temperatures, however, it increases the flexibility of the membrane (→ Fig. 3b).

--- figure (6.6 cm x 7.1 cm) of two separate rows of tightly packed phospholipid bilayers: On the left is a bilayer, in which the the hydrophobic tails are crooked. Above the bilayer is a label “flexible/mobile”. Below the bilayer is a label “unsaturated fatty acid chains” with two lines pointing to two crooked hydrophobic tails. On the right is a bilayer, in which the the hydrophobic tails are straight. Above the bilayer is a label “inflexible/rigid”. Below the bilayer is a label “saturated fatty acid chains” with two lines pointing to two straight hydrophobic tails.---

*Fig. 3a: Unsaturated fatty acid chains have a kink at those points where double bonds between the atoms occur, which prevents the molecules from moving closer together and thus increases the flexibility of the *plasma membrane*.*

--- figure (4.9 cm x 7.1 cm) of a row of a phospholipid bilayer: Within the top layer, four yellow cholesterol molecules are placed between the phospholipids, with three or four phospholipids between the cholesterol molecules. These molecules prevent the hydrophobic tails from pointing straight to the middle of the bilayer and shove the nearest two to the right. The same is shown for the bottom layer, but there are only three cholesterol molecules and the hydrophobic tails are shoved to the left. A label below the bilayer reads “Cholesterol” with a line to a respective molecule.---

*Fig. 3b: At higher temperatures, cholesterol reduces flexibility by limiting the movement of *phospholipids* in the membrane. At low temperatures, however, it interferes with the regular, dense arrangement of the *phospholipids* and thus prevents the membrane from becoming solid.*

The spatial arrangement of the *phospholipid* molecules to form a bilayer with hydrophilic outer surfaces and a hydrophobic core of fatty acid chains means that water and molecules dissolved in water can reach the outer surface of the *plasma membrane*, but cannot easily pass through, since the hydrophobic fatty acid chains are located inside the bilayer. Therefore, water molecules, for example, can only pass through channels anchored in the membrane to the other side of the membrane. Other molecules dissolved in water can also only enter or leave the *cell* through such channels. The *plasma*

membrane thus helps to control the milieu within the *cell* through this so-called selective permeability. For example, it allows nutrients and oxygen from the environment into the *cell*, while it transports carbon dioxide and other waste products out of the *cell*.

The channels through which water and molecules dissolved in water can pass through the membrane are formed by the second major building block of *plasma membranes*, namely *proteins*. These are irregularly embedded in the *phospholipid* bilayer, but occur characteristically in three different basic positions (→ Fig. 4):

- Peripheral membrane proteins "swim" only on the surface of the phospholipid bilayer.
- Integral membrane proteins immerse themselves completely or partially in the *phospholipid* bilayer.
- Transmembrane proteins penetrate the *phospholipid* bilayer completely and protrude on both sides of the membrane, allowing them to act as channels.

On the outside of the membrane, both *phospholipids* and *proteins* can also carry chains of sugar molecules (carbohydrates). If this is the case, the lipids are called glycolipids and the *proteins* are called glycoproteins; the entirety of *proteins*, lipids and carbohydrate chains is called glycocalyx. The structure of the glycocalyx is genetically determined and specific for each *cell*. *Cells* can recognize each other and communicate with each other via glycocalyx (→ Fig. 4).

--- figure (6.9 cm x 11.2 cm) of a phospholipid bilayer section: The bilayer is shown in a wave, so that the left of the bilayer is shown from below. A hydrophilic head on the bottom layer has a connecting line to the label "Phospholipid" below the bilayer. A yellow oval on the top of the upper layer of the bilayer has a connecting line to the label "Peripheral membrane protein". In the center of the bilayer, a drop-shaped yellow structure is embedded. Both ends of the structure are outside the bilayer. The top of the structure has a connecting line to the label "Transmembrane protein". On the top of the structure, two chains of small, linked hexagonal structures are attached. A branching chain of small, linked hexagonal structures is also attached to the head of a phospholipid molecule. The right side of the bilayer is shown from above and on the far end of the section, another branching chain is attached to the head of a phospholipid molecule. The top of the chain has a connecting line to the label "Glycolipid". On the front of the bilayer section, a ball-shaped yellow structure is embedded within the upper layer of the bilayer. The top of the structure has a connecting line to the label "Integral membrane protein". ---

Fig. 4: Simplified model of a *plasma membrane*. Since the transmembrane protein has additional chains of sugar molecules, it is also a glycoprotein.

In addition to their external demarcation and their involvement in mass transport, *biomembranes* fulfill important functions in so-called cell compartmentation by dividing the cell interior into a multitude of compartments. This division allows different biochemical reactions to take place simultaneously in a *cell* without problems. As a spatial network, the membranes traverse the entire *cytoplasm*, a liquid containing water and other chemical substances. Some of these chemical substances are more likely to be found in the middle of the *cytoplasm*, while other substances are located near the

plasma membrane, i.e. at the edge of the *cytoplasm*. Since *cytoplasm* is liquid, the *cell* can change its shape, comparable to a water-filled bag.

Various cell structures are embedded in the *cytoplasm*. Structures that are enveloped by a *biomembrane* and have a special function are called cell organelles or simply *organelles*. Some *organelles*, such as mitochondria, are involved in extracting energy from the nutrients in food and converting it so that body cells can use it. Other *organelles*, such as the *cell nucleus*, are responsible for storing genetic information that contains a kind of blueprint that distinguishes humans from other animals such as gorillas or hummingbirds. In the following, selected *organelles* of animal cells are presented as an overview.

Start using the terms already marked

*and depict the structure and functions of a cell in a concept map □
as well as structure and functions of a biomembrane. □*

*Afterwards, read the second part of the text and then work on the tasks at the end of the text.
For a better understanding, also use figures 5, 6, 7 and 8.*

Cell nucleus

The cell *nucleus* belongs to the *organelles* and functions as an information center and regulates the activity of the *cell*, for example by signaling when it has to divide or which substances have to be procured or disposed of. The cell *nucleus* is surrounded by a special *biomembrane*, the so-called nuclear envelope, which - just like the plasma membrane - controls which substances are allowed to pass through it. For this purpose, the nuclear membrane is pierced by so-called nuclear pores, which connect the inside of the cell *nucleus* with the *cytoplasm* and enable an exchange of substances. The cell *nucleus* itself is also filled with cytoplasm, which is called nucleoplasm here. Within the karyoplasm, the largest part of the genetic material, the *DNA*, is present in the form of long, thin, pearly threads (chromatin). In addition, the cell *nucleus* contains another structure, the spherical *nucleolus* (→ Fig. 5), which is not surrounded by its own membrane and contains a special part of genetic information that is essential for the formation of so-called *ribosomes* (see below).

--- figure (6.0 cm x 8.3 cm) of the nucleus:
Three quarters of the nucleus are shown, with one quarter cut out on the left upper side so that the inside of the nucleus is visible. The labels "Nuclear pore", "Nucleolus", "Nuclear envelope", "Chromatin" and "Nucleoplasm" are connected via lines with the respective structures that are distinguishable in the figure. ---

Fig. 5: Schematic representation of a *nucleus*

Endoplasmic reticulum

The *endoplasmic reticulum* (ER) belongs to the *organelles* and consists of a number of folded *biomembranes*. As a kind of channel system, it has the task of transporting substances within the *cell*. Almost all *cells* have an ER. At the membrane surfaces of the ER, so-called *ribosomes* (see below) are in some areas located close to each other, which gives the membrane surfaces a rough appearance; other areas of the ER are free of ribosomes (→ Fig. 6). The ER is divided into a *rough ER* (with *ribosomes*) and a *smooth ER* (without *ribosomes*):

- The protein synthesis (= protein production) of the cell takes place at the *ribosomes* of the *rough ER* (see below). In addition, the proteins formed by the cell receive their specific structure here. Furthermore, the *rough ER* is responsible for the production of different membranes, such as the *plasma membrane* or the cell nucleus membrane.
- The *smooth ER* is involved in various metabolic processes, it plays, for example, a role in the calcium supply of muscle cells or detoxification in liver cells.

--- figure (4.2 cm x 11.5 cm) of the rough ER on the left and the smooth ER on the right: The rough ER is shown as a stack of blue amorphous folds, whose exteriors have orange dots. Two of the dots have connecting lines to the label "Ribosome". The smooth ER is shown as interconnected cisternae (tubular structures) that lack ribosomes. ---

Fig. 6: Schematic representation of the *rough* (left) and *smooth ER* (right)

The *ribosomes* of the *rough ER* are not *organelles* in the classical sense, since they are not enclosed by a *biomembrane*. They consist of ribonucleic acid (RNA) and *proteins*. Structurally, they are composed of two subunits, one of which is slightly larger, the other slightly smaller (→ Fig. 7).

--- figure (5.4 cm x 9.7 cm) of the two subunits of a ribosome (side view on the left; front view on the right): In the side view, the two subunits are close together, one subunit of the ribosome is shown in yellow on the left, and one subunit in brown on the right. In the front view, the yellow subunit of the ribosome shown is in front of the subunit in brown. The yellow subunit has a connecting line to the label "Small subunit". The brown subunit has a connecting line to the label "Large subunit". ---

Fig. 7: Schematic representation of *ribosomes*

The *ribosomes* of the *rough ER* are the site of protein synthesis of a *cell*. *Proteins* consist of a long, multiple-folded chain of *amino acids*, but differ in the number and arrangement of these *amino acids*. They are important molecules that enable the *cell* to perform its many tasks. *Proteins* are comparable to tools: as enzymes, they are involved in all chemical conversions and the organization of the energy balance, transport substances in the body to their destination, give *cells* and other structures their shape, fight foreign bodies, are active as muscle proteins, participate in the formation of memory in the brain, and much more.

However, before a *protein* can be produced by the *ribosomes*, the genetic information of the *DNA*, which is the construction manual for the *proteins*, must somehow get from the cell *nucleus* to the *ribosomes*. For this purpose, a copy of this blueprint, the messenger RNA (mRNA), is made in the cell *nucleus* during the so-called *transcription*, which is comparable to a safety measure of nature: the original information on the *DNA* does not leave the well-protected cell nucleus. After the mRNA has left the cell *nucleus* and bound to a *ribosome*, the mRNA undergoes another process, the *translation*, in which the building instruction for protein production is read systematically and piece by piece, so that the *cell* "knows" exactly which *amino acids* it has to string together in which order. Subsequent chemical modifications and folding of the *amino acid* chain produced in this way finally produce a three-dimensional functional *protein*.

Dictyosomes/Golgi apparatus

Dictyosomes are flat cavities (cisterns), which can be stacked and are formed by *biomembranes*. The slightly wider base of the stack is near the cell *nucleus* or the *ER*, while the top of the stack is closer to the *plasma membrane*. The totality of dictyosomes is called the *Golgi apparatus* (→ Fig. 8). The *Golgi apparatus* belongs to the *organelles* and helps to sort the *proteins* assembled at the *rough ER*: the *proteins* are transported from the *rough ER* to the *Golgi apparatus*, where they are either stored, chemically modified and/or packed into membrane vesicles. In vesicles, *proteins* are transported within the *cell* or out of the *cell* (across the *plasma membrane*).

--- figure (5.9 cm x 8.2 cm) of the Golgi apparatus: The Golgi apparatus is shown as a series or a collection of flattened membrane-enclosed disks. The structure has broader disks at the bottom (base) and smaller disks at the top. Many small round structures are at the base and two at the top: one on the left, one on the right. The structure at the top and on the right has a connecting line to the label "Vesicle". The second disc from the bottom has a connecting line to the label "Cistern". ---

Fig. 8: Schematic representation of the *Golgi apparatus*

*Add to your concept map (starting with the use of the terms already marked)
by depicting the structure and functions of the cell organelles □
and other cell components (e.g., ribosomes, proteins). □*

*Once you have used all the terms marked in blue, you should try to add more
terms and connections to your concept map. □*

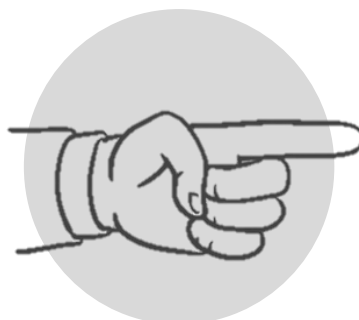
For example, include transcription and translation.



Use the remaining time to occupy yourself intensively with your
concept map. Also think about whether you are satisfied with your
map.

Done?

If so, please enter your *personal
code* on the right and answer the
following questions!



This part of the test is about how you experienced **working with the concept map**. In the following statements, you should always tick the answer that best reflects your feelings. Please always try to decide as **spontaneously** and **honestly** as possible.

Remember: There are **no** right or wrong answers.

		1	2	3	4	5	6	7
1.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.	*** Questions on ICL, GCL and ECL (adapted from Klepsch et al., 2017)***	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

*** meta-
cognitive
prediction

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

8 Coding Manual for the Cognitive Load Questionnaire

Cognitive Load

The Cognitive Load questionnaire was filled out by participants on the fourth day of the study (week 4; learning phase) after the individual learning phase. The original items can be found in the respective publication of Klepsch et al. (2017). The adaptations which were made in our study can be found in the in the respective section of our manuscript.

We suggest that declarative knowledge items students leave blank (missing code = 99) are scored 0. Furthermore, we suggest calculating one mean score for intrinsic cognitive load (ICL) items (LearningPhase_CognitiveLoad_01 & LearningPhase_CognitiveLoad_02), which represents the person's ICL in a single score; one mean score for germane cognitive load (GCL) items (LearningPhase_CognitiveLoad_03 – LearningPhase_CognitiveLoad_04), which represents the person's GCL in a single score; and one mean score for extraneous cognitive load (ECL) items (LearningPhase_CognitiveLoad_05 – LearningPhase_CognitiveLoad_07), which represents the person's ECL in a single score.

The work assignment for all questions in this part of the questionnaire was given first and reads as follows:

This part of the test is about how you experienced **working with the concept map**. In the following statements, you should always tick the answer that best reflects your feelings. Please always try to decide as **spontaneously** and **honestly** as possible.

Remember: There are **no** right or wrong answers.

All questions below regarding the cognitive load (LearningPhase_CognitiveLoad_01 – LearningPhase_CognitiveLoad_07) are entered according to the following coding schema:

Coding Schema							
Score	1	2	3	4	5	6	7
Meaning	I do NOT agree AT ALL					I agree COMPLETELY	

9 Coding Manual for the Structural Knowledge Test

After participants had completed their concept map on the test phase's first day (week 5), the structural knowledge test was handed out to them in German. To capture the cell biology-related structural knowledge of the participants, a similarity judgments test (SJT; adapted from Großschedl & Harms, 2013) was carried out. A total of eleven central cell biological concepts was used, with combinations presented in a balanced manner according to combinatorial considerations. In order to prevent additional confounding sequence effects, two test versions were used, in which the sequence of the 55 given pairs of terms was randomly varied. The interrater reliability in an expert sample of $N = 7$ was $\kappa = .95$, so that a very good agreement and thus content validity of the procedure can be assumed. The mean of these ratings was used as evaluation standard and the deviation of the participants' individual responses was quantified. For this supplementary material, all items were translated into English. The translations were not validated, but were approved by a native speaker.

Structural Knowledge

We suggest that structural knowledge items students leave blank (missing code = 99) are scored as missing. Furthermore, we suggest calculating a correlation score for each student, which represents the correlation of the person's judgements with the experts' and therefore their structural knowledge in a single score.

The work assignment for all questions in this part of the test was given first and reads as follows:

With the following test (Version A/B) we would like to assess your structural knowledge. In this test, 55 pairs of concepts are listed in order. Your task now is to assess the relationship of each pair of concepts.

A STRONG relationship is expressed by high values ("8" or "9"). MINIMAL or NO relationship is expressed by low values ("1" or "2"). Values at the two ends of the scale express more certainty, whereas values in the middle ("4"; "5"; "6") express MEDIUM relationship or INSECURITY ("5") about the relationship.

On the concept of relationship: Two concepts may be related because they share common characteristics or are often associated with each other.

COMPREHENSION-ORIENTED LEARNING OF CELL BIOLOGY

For this test 11 concepts were selected. Please read these concepts carefully.

1. Biomembrane	7. Plasma membrane
2. DNA	8. Rough ER
3. Golgi apparatus	9. Protein
4. Nucleolus	10. Ribosome
5. Smooth ER	11. Nucleus
6. Phospholipid	

Now decide on two concepts that are strongly related and note them on the line provided:

..... -
(Concept) (Concept)

Now decide on two concepts that are minimally /not at all related to each other and note them down on the line provided:

..... -
(Concept) (Concept)

Please fill out the following test now. Proceed quickly, concentrated and in chronological order. Please make sure that you give all the relationship judgments and check only one answer box per pair of concepts. A missing judgement endangers the evaluation of the data!

Please use the entire scale from "1" to "9" for your judgements!

Note for corrections: If you change your first answer, please make a circle around the "wrong" cross.

We recommend adding a variable in SPSS that gives information on the version of the test (version A or B), so that the individual judgements can be correctly compared to the experts'. All questions below regarding the structural knowledge (StructuralKnowledge_01 – StructuralKnowledge_55) for the respective test versions are entered according to the following coding schema:

Coding Schema

Score	1	2	3	4	5	6	7	8	9
Meaning	Minimally related								Strongly related

Version A	Version B
StructuralKnowledge_01⁶ Nucleus - Biomembrane	StructuralKnowledge_01 Nucleus - Plasma membrane
StructuralKnowledge_02 Protein - Ribosome	StructuralKnowledge_02 DNA - Nucleolus
StructuralKnowledge_03 Smooth ER - Phospholipid	StructuralKnowledge_03 Biomembrane - Golgi apparatus
StructuralKnowledge_04 Golgi apparatus - Nucleolus	StructuralKnowledge_04 Phospholipid - Rough ER
StructuralKnowledge_05 Ribosome - Nucleus	StructuralKnowledge_05 Protein - Smooth ER
StructuralKnowledge_06 Phospholipid - Plasma membrane	StructuralKnowledge_06 Golgi apparatus - Nucleus
StructuralKnowledge_07 Nucleolus - Smooth ER	StructuralKnowledge_07 Ribosome - Biomembrane
StructuralKnowledge_08 Rough ER - Protein	StructuralKnowledge_08 Nucleolus - Phospholipid
StructuralKnowledge_09 Biomembrane - DNA	StructuralKnowledge_09 Smooth ER - DNA
StructuralKnowledge_10 Plasma membrane - Rough ER	StructuralKnowledge_10 Plasma membrane - Protein
StructuralKnowledge_11 DNA - Golgi apparatus	StructuralKnowledge_11 Rough ER - Ribosome
StructuralKnowledge_12 Protein - Nucleus	StructuralKnowledge_12 Protein - DNA

⁶ All headings can be used as variable names in an SPSS data set. The variable named “StructuralKnowledge” in the SPSS data set represents the participant’s overall test score.

StructuralKnowledge_13 DNA - Nucleolus	StructuralKnowledge_13 Smooth ER - Nucleolus
StructuralKnowledge_14 Plasma membrane - Protein	StructuralKnowledge_14 DNA - Phospholipid
StructuralKnowledge_15 Nucleolus - Phospholipid	StructuralKnowledge_15 Nucleolus - Rough ER
StructuralKnowledge_16 Ribosome - Biomembrane	StructuralKnowledge_16 Phospholipid - Ribosome
StructuralKnowledge_17 Smooth ER - Plasma membrane	StructuralKnowledge_17 Rough ER - Biomembrane
StructuralKnowledge_18 Biomembrane - Golgi apparatus	StructuralKnowledge_18 Ribosome - Golgi apparatus
StructuralKnowledge_19 Phospholipid - Rough ER	StructuralKnowledge_19 Biomembrane - Nucleus
StructuralKnowledge_20 Golgi apparatus - Smooth ER	StructuralKnowledge_20 Golgi apparatus - Plasma membrane
StructuralKnowledge_21 Nucleus - DNA	StructuralKnowledge_21 Nucleus - Protein
StructuralKnowledge_22 Rough ER - Ribosome	StructuralKnowledge_22 Plasma membrane - Smooth ER
StructuralKnowledge_23 Golgi apparatus - Phospholipid	StructuralKnowledge_23 Protein - Nucleolus
StructuralKnowledge_24 DNA - Smooth ER	StructuralKnowledge_24 Smooth ER - Phospholipid
StructuralKnowledge_25 Biomembrane - Nucleolus	StructuralKnowledge_25 Biomembrane - Plasma membrane
StructuralKnowledge_26 Rough ER - Nucleus	StructuralKnowledge_26 Nucleolus - Ribosome
StructuralKnowledge_27 Protein - Biomembrane	StructuralKnowledge_27 Phospholipid - Biomembrane
StructuralKnowledge_28	StructuralKnowledge_28

Ribosome - DNA	Rough ER - Golgi apparatus
StructuralKnowledge_29 Smooth ER - Rough ER	StructuralKnowledge_29 Ribosome - Nucleus
StructuralKnowledge_30 Plasma membrane - Ribosome	StructuralKnowledge_30 Golgi apparatus - Protein
StructuralKnowledge_31 Phospholipid - Protein	StructuralKnowledge_31 Plasma membrane - DNA
StructuralKnowledge_32 Nucleus - Golgi apparatus	StructuralKnowledge_32 Nucleus - Smooth ER
StructuralKnowledge_33 Nucleolus - Plasma membrane	StructuralKnowledge_33 DNA - Rough ER
StructuralKnowledge_34 Biomembrane - Smooth ER	StructuralKnowledge_34 Protein - Phospholipid
StructuralKnowledge_35 Nucleolus - Rough ER	StructuralKnowledge_35 Smooth ER - Rough ER
StructuralKnowledge_36 Golgi apparatus - Plasma membrane	StructuralKnowledge_36 DNA - Ribosome
StructuralKnowledge_37 Nucleus - Nucleolus	StructuralKnowledge_37 Nucleolus - Biomembrane
StructuralKnowledge_38 DNA - Phospholipid	StructuralKnowledge_38 Phospholipid - Golgi apparatus
StructuralKnowledge_39 Smooth ER - Protein	StructuralKnowledge_39 Rough ER - Nucleus
StructuralKnowledge_40 Phospholipid - Ribosome	StructuralKnowledge_40 Ribosome - Plasma membrane
StructuralKnowledge_41 Rough ER - Biomembrane	StructuralKnowledge_41 Biomembrane - Protein
StructuralKnowledge_42 Protein - DNA	StructuralKnowledge_42 Golgi apparatus - Smooth ER
StructuralKnowledge_43 Ribosome - Golgi apparatus	StructuralKnowledge_43 Nucleus - DNA

StructuralKnowledge_44 Plasma membrane - Nucleus	StructuralKnowledge_44 Plasmamembrane - Nucleolus
StructuralKnowledge_45 Biomembrane - Phospholipid	StructuralKnowledge_45 Biomembrane - Smooth ER
StructuralKnowledge_46 DNA - Plasma membrane	StructuralKnowledge_46 Protein - Rough ER
StructuralKnowledge_47 Golgi apparatus - Rough ER	StructuralKnowledge_47 Phospholipid - Nucleus
StructuralKnowledge_48 Nucleolus - Protein	StructuralKnowledge_48 Rough ER - Plasma membrane
StructuralKnowledge_49 Smooth ER - Ribosome	StructuralKnowledge_49 Golgi apparatus - DNA
StructuralKnowledge_50 Phospholipid - Nucleus	StructuralKnowledge_50 Plasma membrane - Phospholipid
StructuralKnowledge_51 Plasma membrane - Biomembrane	StructuralKnowledge_51 Nucleolus - Golgi apparatus
StructuralKnowledge_52 Rough ER - DNA	StructuralKnowledge_52 DNA - Biomembrane
StructuralKnowledge_53 Protein - Golgi apparatus	StructuralKnowledge_53 Smooth ER - Ribosome
StructuralKnowledge_54 Ribosome - Nucleolus	StructuralKnowledge_54 Nucleus - Nucleolus
StructuralKnowledge_55 Nucleus - Smooth ER	StructuralKnowledge_55 Ribosome - Protein

10 Coding Manual for the Declarative Knowledge Test

The declarative knowledge test was handed out in German to participants on the test phase's first day (week 5). All items were developed by the authors. For this supplementary material, all items were translated into English. The translations were not validated, but were approved by a native speaker.

Declarative Knowledge

We suggest that declarative knowledge items students leave blank (missing code = 99) are scored 0. Furthermore, we suggest calculating a sum score for all items for each participant, which represents the person's declarative knowledge in a single score.

The work assignment for all questions in this part of the test was given first and reads as follows:

Work assignment: Below you will find 30 tasks. Each of these tasks is made up of a question, five content-related statements and five answer alternatives. First, read each question and the corresponding statements completely. Then solve the task by considering for each of the five statements whether it is correct or not. The five answer alternatives below indicate which of the five statements or which combination of the five statements could be correct.

Please read through all five answer alternatives and then decide which answer alternative is correct. Of the five answer alternatives, only **one** is always correct; there are no tasks where none or more than one answer is correct. Please mark your answer with a cross.

Note: The task is formulated in plural for each task (e.g., "Which of the following statements are correct?"), even if only one of the statements mentioned should be correct.

- Example:

Which of the following statements are correct?

- a) Earthworms have a beak.
- b) Antilopes have wings.
- c) Bugs have a beak.
- d) Rhinoceroses have a beak and wings.
- e) Parrots have a beak and wings.

- ☐ Only e) is correct.
- ☐ Only a) and c) are correct.
- ☐ Only a) and b) are correct.
- ☐ Only b), c) and e) are correct.
- ☐ Only a), c), d) and e) are correct.

DeclarativeKnowledge_01⁷

Which of the following general statements about cells are correct?

- a) Cells are always created by existing cells that divide.
- b) All cells have a cell nucleus.
- c) All living things are made of cells.
- d) A single cell is not viable on its own.
- e) Organisms that are not made up of cells nevertheless perform considerable metabolic processes.

- ☐ Only c) is correct.
- ☐ Only a) and c) are correct.
- ☐ Only a) and e) are correct.
- ☐ Only c), d) and e) are correct.
- ☐ All statements a) to e) are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only a) and c) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_02

Which of the following statements about the distinction between pro- and eukaryotes are correct?

- a) Eukaryotes occur exclusively as multicellular organisms.
- b) Fungi belong to the prokaryotes.
- c) The main criterion for distinguishing between pro- and eukaryotes is the presence or absence of a plasma membrane.
- d) Cells with a cell nucleus are called 'procytes'.
- e) The more complex an organism is, the more similar its cells must be in order to ensure that they function in a coordinated manner.

- ☐ Only b) is correct.
- ☐ Only c) is correct.
- ☐ Only a) and d) are correct.
- ☐ Only a), b), d) und e) are correct.
- ☐ None of the statements a) to e) is correct.

⁷ All headings can be used as variable names in an SPSS data set. The variable named “DeclarativeKnowledge” in our SPSS data set represents the participant’s overall test score (calculated with 28 items; items 01 and 03 were taken out of the equation due to insufficient internal consistency).

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • None of the statements a) to e) is correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_03

Which of the following statements about multicellular organisms are correct?

- Multicellular organisms occur as pro- and eukaryotes.
- Bacteria are prototypical multicellular organisms.
- Multicellular organisms usually have different, specialized cell groups/tissues.
- In multicellular organisms a 'division of labour' between cell groups/tissues with different functions can be observed.
- With increasing complexity of an organism, the number of different cell types increases.

- ☐ Only a) is correct.
☐ Only a) and e) are correct.
☐ Only c), d) and e) are correct.
☐ Only a), c), d) and e) are correct.
☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only c), d) and e) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_04

Which of the following statements about the distinction between animal and plant cells are correct?

- a) Existing differences in the respective cell structures do not play a role in the function of the cell.
- b) Existing differences between animal and plant cells reflect the adaptation to different environmental conditions.
- c) Animal cells have – in contrast to plant cells – a solid cell wall.
- d) Plants must be developed as firmly rooted organisms from particularly stable cells.
- e) Both animal and plant cells are enclosed by a plasma membrane.

- ☐ Only a) is correct.
- ☐ Only b) and c) are correct.
- ☐ Only c) and e) are correct.
- ☐ Only b), d) and e) are correct.
- ☐ All statements a) to e) are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only b), d) and e) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_05

Which of the following statements about the cell wall are correct?

- a) All living things have a cell wall.
- b) Only animals and bacteria have a cell wall, in plants it is missing.
- c) In animals, the cell wall serves primarily to stabilize the cells.
- d) In bacteria, the cell wall serves primarily as special protection against potentially harmful environmental influences.
- e) The most important property of cell walls is their elasticity.

- ☐ Only d) is correct.
- ☐ Only e) is correct.
- ☐ Only b) and d) are correct.
- ☐ Only a, b), c) and d) are correct.
- ☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only d) is correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_06

Which of the following general statements about the plasma membrane are correct?

- a) Only eukaryotic cells have a plasma membrane.
- b) In plant cells, the plasma membrane encloses both the cytoplasm with organelles and the cell wall.
- c) Plasma membranes are constructed as biomembranes from inorganic material.
- d) Biomembranes are found exclusively as outer cell boundaries; if they are found inside a cell, this indicates a cell disease.
- e) On the one hand, plasma membranes delimit cells from their environment, but at the same time enable an interaction/exchange relationship with it.

- ☐ Only e) is correct.
- ☐ Only b) and e) are correct.
- ☐ Only a), b) and c) are correct.
- ☐ Only a), b), c) and e) are correct.
- ☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only e) is correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_07

Which of the following components are not found as building blocks in plasma membranes?

- a) Phospholipids
- b) Proteins
- c) Cholesterol
- d) Polysaccharides
- e) Nitrogen oxides

- ☐ Only a) and c) are correct.
- ☐ Only a) and b) are correct.
- ☐ Only a, b) and c) are correct.
- ☐ Only a), b), c) and d) are correct.
- ☐ All statements a) to e) are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only a, b) and c) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_08

Which of the following statements about the flexibility of plasma membranes are correct?

- a) Unsaturated fatty acids are conducive to a denser molecular packing.
- b) The higher the proportion of saturated fatty acids, the less flexible the plasma membrane.
- c) Temperature has no influence on the flexibility of a plasma membrane.
- d) In plasma membranes of animal cells, cholesterol molecules are embedded between the phospholipids.
- e) At low temperatures, cholesterol molecules interfere with the regular, dense arrangement of phospholipids and thus prevent the membrane from becoming solid.

- ☐ Only c) is correct.
- ☐ Only b) and e) are correct.
- ☐ Only b), d) and e) are correct.
- ☐ Only a), b), c) and d) are correct.
- ☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> Only b), d) and e) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_09

Which of the following statements about the structure and functions of plasma membranes are correct?

- The phospholipids of plasma membranes are arranged in a bilayer with hydrophilic outer surfaces and a hydrophobic core of fatty acid chains.
- The spatial arrangement of the molecules in plasma membranes causes a so-called 'selective permeability'.
- Hydrophilic substances (= water and molecules dissolved in water) cannot easily penetrate plasma membranes.
- Water molecules depend on the passage through channels to reach the cell interior through the plasma membrane.
- The special structure of the plasma membrane is responsible for the fact that nutrients and oxygen are transported into the cell, while carbon dioxide and other waste products are transported out of the cell.

- ☐ Only e) is correct.
☐ Only b) and c) are correct.
☐ Only a), b) and c) are correct.
☐ Only b), c), d) and e) are correct.
☐ All statements a) to e) are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> All statements a) to e) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_10

Which of the following statements about membrane proteins are correct?

- a) Membrane proteins are irregularly embedded in the phospholipid bilayer.
- b) Membrane proteins occur characteristically at five different basic positions.
- c) A distinction is made between peripheral, integral and transmembrane proteins.
- d) Transmembrane proteins usually "swim" only on the surface of the phospholipid bilayer.
- e) Integral proteins penetrate the phospholipid bilayer completely and protrude on both sides of the membrane, allowing them to act as channels.

- ☐ Only a) is correct.
- ☐ Only c) is correct.
- ☐ Only a) and c) are correct.
- ☐ Only a), c) and e) are correct.
- ☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only a) and c) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_11

Which of the following statements about glycocalyx and its building blocks are correct?

- a) The term 'glycocalyx' refers to the surface structure of the outer surface of the plasma membrane and includes all proteins, lipids and carbohydrate chains.
- b) Phospholipids carrying carbohydrate chains are called glucose.
- c) Proteins carrying carbohydrate chains are called glycoproteins.
- d) The structure of the glycocalyx is genetically determined and specific to each cell.
- e) The glycocalyx is essential for cell recognition and communication.

- ☐ Only d) is correct.
- ☐ Only d) and e) are correct.
- ☐ Only a), b) and c) are correct.
- ☐ Only a), c), d) and e) are correct.
- ☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> Only a), c), d) and e) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_12

Which of the following statements about cell compartmentalization are correct?

- a) Biomembranes traverse the cytoplasm and divide it into (reaction) spaces, the compartments.
- b) A cell comprises a maximum of two cell compartments: one for the nucleus and one for all other cell structures.
- c) In all cell compartments exactly identical conditions prevail, which is why a cell can have several parallel reactions, but at best only in the same direction.
- d) Cell compartmentalization creates different reaction spaces and thus allows different biochemical reactions to run in parallel in one and the same cell.
- e) Cell compartmentalization prevents the spread of pathogens to neighboring cells.

- ☐ Only b) is correct.
- ☐ Only a) and d) are correct.
- ☐ Only a), d) and e) are correct.
- ☐ Only a), b), c) and e) are correct.
- ☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> Only a) and d) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_13

Which of the following statements about the cytoplasm are correct?

- a) The cytoplasm is a solid that serves to prevent deformation of the cell.
- b) The cytoplasm is a fluid that allows the cell to deform.
- c) The cytoplasm contains water and various chemical substances.
- d) The concentration of substances found in the cytoplasm is generally completely uniform in order to maintain the internal cell environment.
- e) The concentration of substances present in the cytoplasm is not the same everywhere: some substances are located more in the middle of the cytoplasm, others more at its edge or near the plasma membrane.

- ☐ Only a) and c) are correct.
- ☐ Only b) and c) are correct.
- ☐ Only c) and d) are correct.
- ☐ Only b), c) and e) are correct.
- ☐ All statements a) to e) are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only b), c) and e) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_14

Which of the following statements about cell organelles are correct?

- a) Cell organelles are found embedded in the cytoplasm.
- b) A cell organelle is a cell structure that is surrounded by at least three biomembranes.
- c) Cell organelles are never surrounded by a biomembrane.
- d) Cell organelles do not perform specific functions but are more relevant for the general cell function.
- e) Examples of cell organelles are the mitochondria or the cell nucleus.

- ☐ Only a) is correct.
- ☐ Only a) and e) are correct.
- ☐ Only b) and e) are correct.
- ☐ Only c), d) and e) are correct.
- ☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only a) and e) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_15

Which of the following statements about the cell nucleus are correct?

- The main task of the cell nucleus is to convert the substances contained in food so that they can be used as energy for the cell.
- The cell nucleus functions as an information center and regulates the activity of the cell.
- The cell nucleus is surrounded by its own nuclear membrane, which - just like the outer plasma membrane - is not freely permeable to all substances.
- The special feature of the cell nucleus is that a material exchange can only ever take place from the cytoplasm into the nucleus, but never vice versa.
- The interior of the cell nucleus is the only area of a cell that is completely free of fluid.

- ☐ Only b) and c) are correct.
☐ Only b) and e) are correct.
☐ Only a), b), and c) are correct.
☐ Only a), b), c) and d) are correct.
☐ All statements a) to e) are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only b) and c) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_16

Which of the following statements about the nucleolus are correct?

- a) The nucleolus is part of the mitochondria.
- b) The nucleolus is surrounded by a double membrane, because the DNA inside needs special protection.
- c) The nucleolus is an evolutionary remnant that no longer performs any function in humans.
- d) The nucleolus has the task of initiating programmed cell death in case of functional disorders or disease.
- e) The nucleolus is essentially involved in the energy production of the cell.

- ☐ Only b) is correct.
- ☐ Only c) is correct.
- ☐ Only a) and e) are correct.
- ☐ Only b) and d) are correct
- ☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • None of the statements a) to e) is correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_17

Which of the following statements about the endoplasmic reticulum are correct?

- a) Almost all cells have an ER.
- b) The ER consists of a series of folded membranes.
- c) As a kind of channel system the ER has the task to transport substances within the cell.
- d) There are two forms of the ER: rough and smooth.
- e) The rough ER has ribosomes on its membrane surfaces, the smooth ER is free of ribosomes.

- ☐ Only d) is correct.
- ☐ Only b) and c) are correct.
- ☐ Only a), d) and e) are correct.
- ☐ Only b), c), d) and e) are correct.
- ☐ All statements a) to e) are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • All statements a) to e) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_18

Which of the following statements about the rough ER are correct?

- a) The rough ER is not a cell organelle in the classical sense, since it is not surrounded by a biomembrane.
- b) The rough ER essentially consists of cisterns arranged in stacks.
- c) The rough ER is essentially involved in the calcium supply of muscle cells.
- d) The rough ER produces, among other things, various membranes, such as the plasma membrane or the cell nuclear membrane.
- e) The rough ER got its name from its surface, which is colonized with bacteria and thus appears roughened.

- ☐ Only a) is correct.
- ☐ Only d) is correct.
- ☐ Only d) and e) are correct.
- ☐ Only b), c) and d) are correct.
- ☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only d) is correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_19

Which of the following statements about the smooth ER are correct?

- a) Always 18 molecules of the smooth ER arrange themselves specifically and thus form the rough ER.
- b) The smooth ER is involved in various metabolic processes.
- c) The smooth ER has antigenic properties and thus plays an important role in the recognition of pathogens.
- d) Important tasks of the smooth ER are the calcium supply of muscle cells or the detoxification in liver cells.
- e) In eukaryotes, the smooth ER is found exclusively in the cells of the germ line (egg cells in women and sperm cells in men).

- ☐ Only b) is correct.
- ☐ Only b) and d) are correct.
- ☐ Only a) and d) are correct.
- ☐ Only b), c) and e) are correct.
- ☐ All statements a) to e) are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only b) and d) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_20

Which of the following statements about ribosomes are correct?

- a) Ribosomes are considered the second most important organelle (after the nucleus).
- b) In contrast to other cell structures, ribosomes themselves possess the genetic information to produce further ribosomes.
- c) The genetic information for the formation of ribosomes is located in the nucleolus of a cell.
- d) The protein synthesis of the cell takes place at the ribosomes of the rough ER.
- e) The presence of ribosomes is not necessary for the protein synthesis of the cell.

- ☐ Only d) is correct.
- ☐ Only c) and d) are correct.
- ☐ Only a), b) and d) are correct.
- ☐ Only a), b), c) and e) are correct.
- ☐ All statements a) to e) are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> Only c) and d) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_21

Which of the following statements about the structure of ribosomes are correct?

- a) Ribosomes consist of DNA and proteins.
- b) RNA is not a component of ribosomes.
- c) Ribosomes are not enclosed by a biomembrane.
- d) The rough surface of ribosomes is created by the coating of cilia.
- e) Ribosomes consist of a total of three subunits: two smaller and one slightly larger.

- ☐ Only c) is correct.
- ☐ Only a) and c) are correct.
- ☐ Only a) and e) are correct.
- ☐ Only b), c) and d) are correct.
- ☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> Only c) is correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_22

Which of the following statements about proteins are correct?

- a) Proteins can be compared to tools that support a variety of vital organismic processes.
- b) Proteins consist of phospholipid molecules arranged in a bilayer, which can carry carbohydrate chains on their surface.
- c) Proteins consist of a long chain of amino acids folded several times.
- d) Different proteins differ in the number and arrangement of their building blocks.
- e) Proteins enable a cell to perform its numerous tasks and are therefore essential for normal cell function.

- ☐ Only b) is correct.
- ☐ Only a) and e) are correct.
- ☐ Only a), d) and e) are correct.
- ☐ Only a), c), d) and e) are correct.
- ☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only a), c), d) and e) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_23

In which of the following tasks are proteins not involved?

- a) Brownian molecular motion for the rearrangement of atoms
- b) Chemical conversion of substances and energy balance
- c) Transfer of substances
- d) Structure formation/shaping
- e) Defense against foreign bodies

- ☐ Only a) is correct.
- ☐ Only e) is correct.
- ☐ Only a) and e) are correct.
- ☐ Only b), c) and e) are correct.
- ☐ All statements a) to e) are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only a) is correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_24

Which of the following statements about protein synthesis are correct?

- a) Protein synthesis essentially consists of two successive processes: translocation and transubstitution.
- b) The 'building instructions' for proteins are found in the genetic information of DNA.
- c) Protein synthesis takes place in the cell nucleus.
- d) The protein synthesis takes place at the dictyosomes.
- e) The final step of protein synthesis consists in a de-spiralization of the linked amino acid chain.

- ☐ Only b) is correct.
- ☐ Only b) and e) are correct.
- ☐ Only a), b) and c) are correct.
- ☐ Only c), d) and e) are correct.
- ☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only b) is correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_25

Which of the following terms are not associated with protein synthesis?

- a) messenger-RNA (mRNA)
- b) Translation
- c) Transcription
- d) Transposition
- e) Energy production

- ☐ Only a) is correct.
- ☐ Only d) is correct.
- ☐ Only d) and e) are correct.
- ☐ Only a), d) and e) are correct.
- ☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only d) and e) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_26

Which of the following statements about the process of transcription are correct?

- a) The "building instructions" for proteins are found in the genetic information of the DNA in the cell nucleus.
- b) During protein synthesis, DNA leaves the nucleus through the nuclear pores to reach the ribosomes of the rough ER.
- c) Since the DNA does not leave the nucleus, a copy of the DNA is made during transcription, which is then transferred as mRNA to the ribosomes of the rough ER.
- d) The process of transcription can be seen as a kind of 'safety measure of nature'.
- e) The transcription can only take place in darkness, because the receptors of the enzymes involved are blocked by light incidence.

- ☐ Only b) is correct.
- ☐ Only a) and c) are correct.
- ☐ Only a), c) and d) are correct.
- ☐ Only b), c), d) and e) are correct.
- ☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only a), c) and d) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_27

Which of the following statements about the process of translation are correct?

- a) The translation takes place at the ribosomes of the rough ER.
- b) The translation only starts after the mRNA has bound to a ribosome.
- c) In prokaryotes there is no independent translation process.
- d) During translation, the building instructions for protein production are read off systematically and piece by piece.
- e) During translation, different amino acids are combined in a specific order to form a chain, which can be converted into a three-dimensional functional protein by subsequent modifications.

- ☐ Only d) is correct.
- ☐ Only d) and e) are correct.
- ☐ Only a), c) and d) are correct.
- ☐ Only a), b), d) and e) are correct.
- ☐ All statements a) to e) are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only a), b), d) and e) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_28

Which of the subsequent processes often still follow the two main processes of protein synthesis?

- a) Folding
- b) Storage
- c) Packaging in vesicles
- d) New linking of the amino acid chain ends
- e) Chemical modification

- ☐ Only a) is correct.
- ☐ Only a) und c) are correct.
- ☐ Only a), b) und e) are correct.
- ☐ Only a), b), c) und e) are correct.
- ☐ All statements a) to e) are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • Only a), b), c) und e) are correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_29

Which of the following general statements about dictyosomes are correct?

- a) Each cell has exactly one single dictyosome.
- b) Dictyosomes are spherical structures about 10 µm in size, which are not surrounded by their own membrane.
- c) The broad base of the dictyosomes lies on the plasma membrane.
- d) Dictyosomes are connected to the glycocalyx by cisterns.
- e) The totality of the dictyosomes is called mega-dictyosome.

- ☐ Only a) is correct.
- ☐ Only c) is correct.
- ☐ Only a) and c) are correct.
- ☐ Only a), c) and e) are correct.
- ☐ None of the statements a) to e) is correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • None of the statements a) to e) is correct.
0	A different answer was marked.
99	Item was left blank.

DeclarativeKnowledge_30

Which of the following statements about the Golgi apparatus are correct?

- The term 'Golgi apparatus' describes the sum of all dictyosomes.
- After proteins have been assembled at the rough ER, they are transported to the Golgi apparatus.
- In general, the Golgi apparatus helps to sort proteins produced by the cell.
- Within the Golgi apparatus, proteins can either be stored, chemically modified and/or packed into vesicles.
- The packaging of proteins in vesicles is important for the transport of proteins within the cell or out of the cell.

- ☐ Only c) is correct.
☐ Only b) and c) are correct.
☐ Only a), b) and d) are correct.
☐ Only a), c), d) and e) are correct.
☐ All statements a) to e) are correct.

Coding Schema

Score	Criteria
1	The correct answer was marked: <ul style="list-style-type: none"> • All statements a) to e) are correct.
0	A different answer was marked.
99	Item was left blank.

11 Coding Manual for the Conceptual Knowledge Test

The conceptual knowledge test was handed out in German to participants on the test phase's second (and last) day (week 6). All items were developed by the authors. For this supplementary material, all items were translated into English. The translations were not validated, but were approved by a native speaker.

Conceptual Knowledge

We suggest that declarative knowledge items students leave blank (missing code = 99) are scored 0. Furthermore, we suggest calculating a sum score for all items for each participant, which represents the person's conceptual knowledge in a single score.

The work assignment for all questions in this part of the test was given first and reads as follows:

Work assignment: Below you will find 15 tasks. Each of these tasks consists of an info text, a task definition and four free lines for your answers.

Please answer all questions **in complete sentences!**

ConceptualKnowledge_01⁸

The most important property of a hormone is its solubility in water, as this determines its diffusion behaviour⁹ (e.g. through plasma membranes). From this point of view, hormones are divided into the classes (1.) lipophilic (= hydrophobic or not water soluble) and (2.) hydrophilic (= lipophobic or water soluble).

How do you explain the fact that lipophilic hormones act inside cells, but hydrophilic hormones act outside cells? Justify your answer by referring to your knowledge of the structure of plasma membranes.

⁸ All headings can be used as variable names in an SPSS data set. The variables named "ConceptualKnowledge" in the SPSS data set represents the participant's overall test score.

⁹ Diffusion is a "migration" of particles to distribute themselves evenly.

Coding Schema

Score	Criteria
2	All following answers are given: - The plasma membrane is hydrophobic inside, ALTERNATIVE: lipophilic. - Hydrophobic, ALTERNATIVE: lipophilic hormones can diffuse through, so they act inside. - Hydrophilic, ALTERNATIVE: lipophobic hormones cannot diffuse through, so they act on the outside.
1	One or two, but not all of the answers above are given.
0	None of the answers above is given.
99	Item was left blank.

ConceptualKnowledge_02

You examine the liver cells of an alcoholic and a perfectly healthy adult under a microscope and compare them in terms of the proportions of smooth endoplasmic reticulum (ER).

Which of the two images shown do you assign to which test person? Justify your answer.

Picture (2A) of a cell and its smooth ER from a healthy person	***Picture (2B) of a cell and its smooth ER from an alcoholic***
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Coding Schema

Score	Criteria
2	All following answers are given: - correct assignment: Fig. 2A belongs to the healthy subject, ALTERNATIVE: Fig. 2B belongs to the alcohol-dependent subject. - Task of the smooth ER: detoxification processes - Justification: Fig. 2A shows less smooth ER, ALTERNATIVE: 2B shows more smooth ER.
1	One or two, but not all of the answers above are given.
0	None of the answers above is given.
99	Item was left blank.

ConceptualKnowledge_03

The enzyme RNA polymerase II, which is responsible for producing an exportable mRNA copy from the information of the DNA in the cell nucleus, is inhibited by taking the poison of the tuber leaf fungus (α -Amanitin).

What further consequences can you expect from this, both for protein synthesis and – as a result – for the cell as a whole? Justify your answer.

Coding Schema

Score	Criteria
2	All the following consequences are mentioned: - The transcription does not take place. - The translation does not take place. - No proteins are produced. - The cell is not viable. The following justification is given: It is a process that builds on each other, ALTERNATIVE: It is a causal chain.
1	One or more, but not all of the answers above are given.
0	None of the answers above is given.
99	Item was left blank.

ConceptualKnowledge_04

One of the main tasks of the blood is to transport oxygen through the red blood cells (erythrocytes). Erythrocytes are formed in the bone marrow from stem cells. During their development into mature erythrocytes, they lose, among other things, their cell nucleus.

Establish – from a functional point of view – a hypothesis (and justify it) regarding the presence or absence of (1.) ER, (2.) ribosomes and (3.) Golgi apparatus in mature erythrocytes.

Coding Schema

Score	Criteria
2	<p>All of the following answers are given:</p> <ul style="list-style-type: none"> - The cell nucleus contains the DNA, ALTERNATIVE: genetic information. - The task of the ER is protein biosynthesis. - Task of the ribosomes is translation. - Task of the Golgi apparatus is protein modification, ALTERNATIVE: protein distribution. - Justification for ER: Protein synthesis is no longer possible due to the absence of DNA. - Justification for ribosomes: Without DNA there is no mRNA which can be read by ribosomes. - Justification for Golgi apparatus: Since no new proteins are synthesized the protein modification is, ALTERNATIVE: protein distribution is no longer possible.
1	One or more, but not all of the answers above are given.
0	None of the answers above is given.
99	Item was left blank.

ConceptualKnowledge_05

As with eukaryotes, prokaryotic ribosomes, like those of bacteria, consist of proteins and RNA. However, they are smaller and less complex than eukaryotic ribosomes and have a slightly different surface structure.

Make a hypothesis (and justify it) about the extent to which medicine uses this fact to treat bacterial infections with relatively few side effects.

Coding Schema

Score	Criteria
2	All of the following answers are given: - The task of ribosomes is translation (protein biosynthesis). - Specific attack on prokaryotic ribosomes, so that no eukaryotic ribosomes are affected.
1	One of the answers above is given.
0	None of the answers above is given.
99	Item was left blank.

ConceptualKnowledge_06

The phospholipids in plasma membranes show considerable mobility, which increases at higher temperatures and decreases at lower temperatures. The flexibility of plasma membranes is an important prerequisite for their function: transport processes and enzyme activities come to a standstill when the membrane solidifies.

It can be observed that organisms whose temperature depends on the ambient temperature (= alternating heat) synthesize more lipids with unsaturated fatty acid chains when exposed to cold.

How do you explain this observation?

Coding Schema

Score	Criteria
2	All of the following answers are given: - The function of the unsaturated fatty acid chains is to ensure the fluidity of the plasma membrane. - More unsaturated fatty acid chains prevent hardening of the plasma membrane when exposed to cold.
1	One of the answers above is given.
0	None of the answers above is given.
99	Item was left blank.

ConceptualKnowledge_07

Peripheral, integral and transmembrane proteins must be anchored in the plasma membrane so that they do not detach and enter the cytoplasm, for example. The analysis of such membrane proteins regularly reveals that they have sections with exclusively hydrophobic amino acids on the one hand and sections with predominantly hydrophilic amino acids on the other.

How do you explain these results?

Coding Schema

Score	Criteria
2	All of the following answers are given: - The plasma membrane is hydrophobic inside, ALTERNATIVE: hydrophilic outside. - Hydrophilic amino acids accumulate on the outside, ALTERNATIVE: Hydrophobic amino acids accumulate on the inside of the plasma membrane.
1	One of the answers above is given.
0	None of the answers above is given.
99	Item was left blank.

ConceptualKnowledge_08

One of the criteria for classifying different cell types is metabolic activity, whereby the more proteins a cell synthesizes per unit of time, the more metabolically active it is. Liver cells are a classic example of highly metabolically active cells: permanently required digestive and detoxification services require the constant re-synthesis of various proteins involved. Many of these highly metabolically active cells contain not only a single nucleus but several and larger nucleoli.

How do you explain this observation? Justify your answer by referring to your knowledge of the function of the nucleolus in the context of protein synthesis.

Coding Schema

Score	Criteria
2	All the following consequences are mentioned: - Function of the nucleolus: contains genetic information for ribosomes. - Function of ribosomes: translation (protein biosynthesis). - The more nucleoli there are, ALTERNATIVE: The larger the nucleoli are, the more proteins can be synthesized.

1	One or two, but not all of the answers above are given.
0	None of the answers above is given.
99	Item was left blank.

ConceptualKnowledge_09

One of the most important tasks of the smooth ER is its participation in detoxification services of the organism'. For example, drugs that are not actually water-soluble are oxidized by the enzyme cytochrome P450 contained in the smooth ER, which makes them water-soluble and allows the body to excrete them with the urine.

If, for example, sedatives (barbiturates) are taken, more smooth ER and thus more cytochrome P450 is formed to break down the water-insoluble barbiturates. The more cytochrome P450 is present, the faster and more efficiently this degradation occurs.

Make a hypothesis (and justify it) as to the extent to which these processes provide a biochemical basis for barbiturate addiction.

Coding Schema

Score	Criteria
2	All the following consequences are mentioned: - Sedative, ALTERNATIVE: Barbiturate intake leads to more smooth ER, ALTERNATIVE: Barbiturate intake leads to more cytochrome P450. - More smooth ER, ALTERNATIVE: more CP450 leads to more efficient breakdown of the sedative, ALTERNATIVE: barbiturates. - To achieve the same effect, more sedative, ALTERNATIVE: barbiturates must be taken.
1	One or two, but not all of the answers above are given.
0	None of the answers above is given.
99	Item was left blank.

ConceptualKnowledge_10

Despite differences in their more specific structures, the plasma membranes of bacteria are basically similar to those of humans: the basic building blocks are fat and protein components, which are arranged in a characteristic double layer with their hydrophilic and hydrophobic sections.

However, many bacterial cells have a special ability: they are able to produce toxins and secrete them into their environment. If this happens in the human body, the secreted toxins can make a person ill and

damage the cells. Some of these bacterial toxins specifically attack the cholesterol in the plasma membrane, for example. It is interesting to note that the plasma membrane of the toxin-forming bacterium is not damaged by this itself, although it is also exposed to the secreted toxin.

What do you conclude from this observation with regard to a significant difference in the specific structure between bacterial and human plasma membranes?

Coding Schema

Score	Criteria
2	All of the following answers are given: - The human membrane has cholesterol. - The bacterial membrane does not have cholesterol.
1	One of the answers above is given.
0	- None of the answers above is given. - If several hypotheses are named, the answer is to be evaluated with zero points, because the elimination of the wrong answer between several given answer options is not the task of the evaluator.
99	Item was left blank.

ConceptualKnowledge_11

Breast milk is produced in the cells of the female mammary glands and consists of water, proteins (milk protein, enzymes, hormones, various immune antibodies, etc.), carbohydrates, lipids as well as vitamins, minerals and trace elements. Various studies have shown that women have a significantly higher proportion of rough ER during the active breastfeeding period than after weaning.

How do you explain this observation? Justify your answer by referring to your knowledge of the function of the rough ER.

Coding Schema

Score	Criteria
2	All of the following answers are given: - Task of the rough ER: protein biosynthesis. - The more rough ER there is, the more proteins can be synthesized.
1	One of the answers above is given.
0	None of the answers above is given.
99	Item was left blank.

ConceptualKnowledge_12

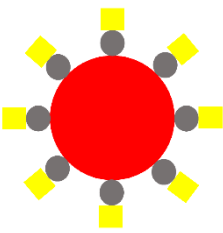
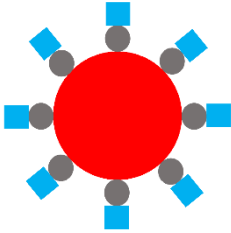
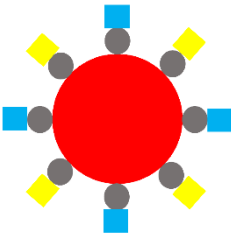

The glycocalyx of the plasma membrane enables the recognition of cells and thus, for example, the differentiation of endogenous from exogenous cells. This is enormously important in medicine, because if, for example, a glycocalyx with different sugar molecules occurs in donor blood during blood transfusions than in the patient (= recipient), this leads to life-threatening clumping of the blood cells.

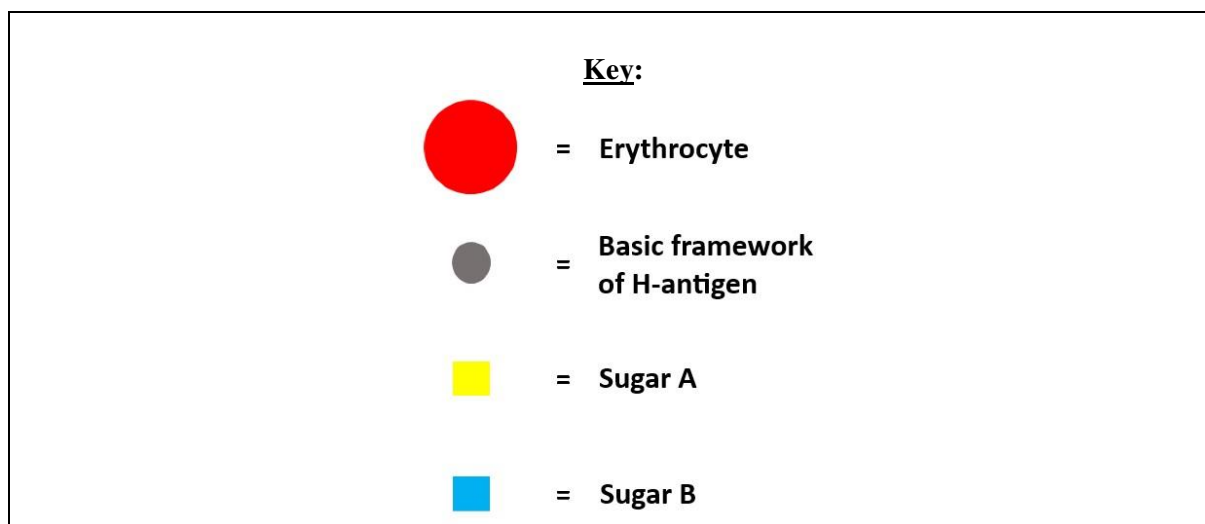
The red blood cells (erythrocytes) therefore have a glycocalyx on their cell surface, which in this particular case forms the basis of the various blood groups A, B, AB and 0. Common to all blood groups is a basic framework, which is called "H-antigen". Various sugar molecules can be bound to this H-antigen. Thus erythrocytes of blood group A carry a different sugar molecule (= sugar A) than erythrocytes of blood group B (= sugar B). Blood group AB erythrocytes carry both sugar A and sugar B.

Make a hypothesis (and justify it) as to what the glycocalyx of the erythrocytes of blood group 0 (see question mark) must look like by considering the compatibility of blood transfusions shown below.

		ACCEPTOR			
		A	B	AB	0
DONOR	A	✓	✗	✓	✗
	B	✗	✓	✓	✗
	AB	✗	✗	✓	✗
	0	✓	✓	✓	✓

A	Can donate to:	A and AB
	Can accept from:	A and 0
B	Can donate to:	B and AB
	Can accept from:	B and 0
AB	Can donate to:	AB
	Can accept from:	A, B, AB and 0
0	Can donate to:	A, B, AB and 0
	Can accept from:	0

			
A	B	AB	0


Coding Schema

Score	Criteria
2	All the following consequences are mentioned: - Erythrocytes have a basic structure of H-antigen. - Blood group 0 has no sugar. - Justification: Blood group 0 has no sugar because they can donate to all blood groups, ALTERNATIVE: can only receive from blood group 0.
1	One or two, but not all of the answers above are given.
0	None of the answers above is given.
99	Item was left blank.

ConceptualKnowledge_13

In the Golgi apparatus, the proteins synthesized in a cell are sorted, stored, chemically modified and/or packaged in vesicles for transport within or out of the cell. Some Golgi vesicles, the so-called lysosomes, contain various digestive enzymes as proteins. Among other things, lysosomes are involved in the degradation of overaged or damaged cell components by absorbing them and breaking them down with the aid of the digestive enzymes. A lysosome is formed by labeling its subsequent digestive proteins, which arrive in the Golgi apparatus from the ER, in a very specific way: a characteristic chemical compound of mannose-6-phosphate is attached to them in order to clearly identify them. The proteins marked in this way are collected and packed into lysosomes, which can then begin their "digestive work".

In the case of the so-called I-cell disease, it can be observed that although lysosomal digestive enzymes are synthesized at the ER to the usual extent and also arrive at the Golgi apparatus, they are later found in large membrane-enclosed accumulations in the cytoplasm instead of in the lysosomes, while the lysosomes themselves are almost functionally inoperative. The prognosis of those affected is very unfavorable: most patients do not reach the age of ten.

Formulate a hypothesis (and justify it) about the exact biochemical cause of the disorder (location in the cell, affected mechanism) and explain why lysosomal digestive enzymes in I-cell disease are located in large membrane-enclosed accumulations in the cytoplasm.

Coding Schema

Score	Criteria
2	All of the following answers are given: - Location: Golgi apparatus/cell nucleus - Affected mechanism: labeling (with mannose-6-phosphate), ALTERNATIVE: protein biosynthesis (transcription, translation) - Justification: because they do not arrive in the lysosomes, ALTERNATIVE: because the lysosomes are non-functional, ALTERNATIVE: because they are in membrane-enclosed accumulations in the cytoplasm. - The digestive enzymes are transported unspecifically in membrane-enclosed accumulations.
1	One or more, but not all of the answers above are given.
0	None of the answers above is given.
99	Item was left blank.

ConceptualKnowledge_14

Proteins are synthesized at the ribosomes. A more differentiated observation of eukaryotic ribosomes shows that these "protein factories" not only occur bound to the membrane of the rough ER, but also freely in the cytoplasm.

In this context the following interesting observation can be made: Since ribosomes can also incorporate amino acids labeled with fluorescent dyes into amino acid chains, it can be traced where these are subsequently transported to. If, for example, the amino acids of ribosomes bound to the rough ER are labeled with a red dye and those of ribosomes occurring freely in the cytosol with a green dye, the following pattern is observed: proteins inside the cell glow green afterwards, while membrane proteins and proteins outside the cell glow red.

Using these study results, formulate a hypothesis (and justify it) about which large classes of proteins are synthesized on (1.) the ribosomes of the rough ER and (2.) the free cytosolic ribosomes. Please keep in mind that a cell always has an own demand for substances.

Coding Schema

Score	Criteria
2	All following answers are given: - Membrane proteins are synthesized on ribosomes of the rough ER. - Justification: Because membrane proteins glow red - Secretory proteins are synthesized on ribosomes of the rough ER. - Justification: Because secretory proteins glow red - Cytosolic/own demand proteins are synthesized on cytosolic ribosomes. - Justification: Because cytosolic proteins glow green.
1	One or more, but not all of the answers above are given.
0	None of the answers above is given.
99	Item was left blank.

ConceptualKnowledge_15

A viral disease occurs – very simply put – at the cellular level as follows: the virus attaches itself to the outer plasma membrane of the host cell and then injects its genetic material (genome) into the cell. This viral genome migrates towards the cell nucleus, where it is incorporated into the host cell's DNA. This is followed by a phase in which viral proteins are synthesized in addition to the 'normal' host proteins, as the inserted viral DNA section is simply transcribed together with the host DNA and then translated. The resulting viral proteins are required for the construction of new viruses. Finally, the individual viral components are assembled and the finished viruses can leave the host cell, for example, by destroying them.

In the course of many decades of research, it has now been possible to identify the section of the genome of many viruses that causes disease. In the meantime, it has become possible to render such pathogenic genome sections harmless by various methods. In addition, modern medicine is currently also able to insert other genome sections into the virus instead, such as those that contain the building instructions for human proteins. These modified viruses can then be administered as part of a gene therapy to patients with certain diseases without them becoming ill as a side effect of the virus.

Make a hypothesis (and justify it) as to which diseases in general the gene therapy strategy described could be suitable for. Describe also which concrete mechanisms of action you expect on the cellular level.

Coding Schema

Score	Criteria
2	<p>All the following consequences are mentioned:</p> <ul style="list-style-type: none"> - Use in diseases where proteins are not properly synthesized due to a genetic defect, ALTERNATIVE: not synthesized at all. - Justification: Because the pathogenic sections can be replaced by the viral DNA. - Justification: Because the intervention allows the protein biosynthesis (transcription/translation) to take place without errors.
1	One or two, but not all of the answers above are given.
0	None of the answers above is given.
99	Item was left blank.

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