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The Chemistry of Remembering: Integration of a Learning Video into an Inquiry-Based Chemistry Unit Based on the Topic of Alzheimer's Disease

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Abstract

During the 21st century mankind will be facing new challenges, including demographic change and the resulting risk of widespread diseases such as Alzheimer's and their socio-economic costs. The German Alzheimer's Association e.V. states that currently 1.7 million people are affected by dementia in Germany, most of them with Alzheimer's disease, with rising tendencies [1]. Correspondingly, fundamental chemical research focuses its research questions on the elucidation of such diseases, so that therapeutic options can be used to accelerate the sustainable relief of society.

To sensitize and prepare future generations for such current research topics, they should be integrated into chemistry education for a contemporary and future-oriented teaching [2]. As recent studies showed, such lessons should include topics such as "chemistry & medicine" as well as "current topics in chemistry" in order to effectively arouse students' interest [3].

Based on Alzheimer's disease, the presented teaching unit examines how remembering works from a chemical point of view. By means of an inquiry-based method and with the aid of a learning video, processes at biomembranes on a molecular level as well as the regulation of ion channels are explained (e.g. diffusion, chemical gradients, etc.). Since acetylcholine, as a neurotransmitter, is relevant both for the process of remembering as well as for research on Alzheimer's disease, its synthesis and degradation is shown. As a result, the substance group of esters is emphasized and serious effects of the misregulation of the synthesis and degradation explained. Finally, references are made to current research on Alzheimer's disease so that students can put their newly acquired knowledge about important basic chemical concepts directly into an application-oriented context. Additionally, the students will work on a supportive worksheet focusing on the ester group, allowing the learning concept to be used either as an elaboration or as a repetition.

Keywords: *Chemistry & Medicine, Alzheimer´s Disease, Teaching Unit, Ester;*

1. Introduction

In recent years, scientific-educational research has dealt intensively with the role of the natural sciences in formal and non-formal educational contexts. Thus, large-scale studies such as `The Relevance of Science Education´ (ROSE) and `Programs for International Student Assessment´(PISA) already focus on the mutual relationship between science teaching and students' interest in science [2, 4]. Accordingly, the research consensus can be derived that science education should be reoriented. Furthermore, Schiepe-Tiska et al. (2015) suggest that, in addition to an increase in knowledge and competence, a motivational orientation and an improved self-image of the pupils must be promoted in order to meet challenges of the 21st century (*e.g.* demographic change) [4]. In addition, Merzyn (2008) points out that chemistry teaching should be oriented primarily towards the basic structures of the scientific disciplines. Focal points such as areas of application or interdisciplinary research questions are only given minor consideration. But exactly these contents are of special interest for the students [5]. Complementarily, a pilot study was used to substantiate the fact that pupils show a particular interest in the subject areas "Chemistry & Medicine" and "Current Topics in Chemistry" [3].

As a result, Alzheimer's disease was selected as a topic for the presented teaching unit. While on the one hand, this disease lies within the students' fields of interest, on the other hand it reveals specific areas of application as well as medical research questions with respect to chemistry.

2. Scientific Principles

In 2018, 50 million people worldwide were affected by Alzheimer's disease and it is predicted that 152 million people will be affected in 2050 [6]. It's apparent, how demographic change is being exacerbated by such widespread diseases and is creating additional demand for both treatment and care.
According to current knowledge, the neurotransmitter acetylcholine plays an important role for learning processes and remembering. Acetylcholine is synthesized from acetyl coenzyme A and choline (see Figure 1), which is a transesterification.

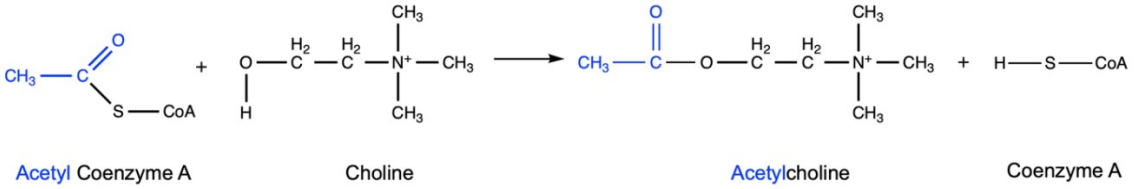

Figure 1: Synthesis of acetylcholine from acetyl coenzyme A and choline.

The acetyl coenzyme A present in the body belongs to the group of thioesters. Due to the high potential for the transfer of acetyl groups, *i.e.* the transfer of the acetyl group is exergonic, the reaction to the ester can take place in the body without, for example, having to carry out an acid catalyzed esterification [7]. The acid catalyzed ester formation is often discussed in chemistry class, which enables a direct comparison between the two forms of synthesis. Whether the substance group of thioesters should be discussed here can optionally be decided on the basis of the curricular specifications.
Additionally, not only acetylcholine as such should be considered here, but also its release in the body in order to be able to understand a possible dysfunction in Alzheimer's disease. The release of acetylcholine into the synaptic cleft of neurons occurs through the fusion of intracellular vesicles. As soon as the vesicle fuses with the membrane, acetylcholine molecules are released into the synaptic cleft. After the neurotransmitters interact with the postsynaptic receptors, the information is passed on to the following cell. If a reduced number of neurotransmitters is released during the process (*e.g.* because of died off nerve cells), remembering becomes more difficult since the concentration of acetylcholine molecules in the synaptic cleft is no longer sufficient to stimulate the postsynaptic receptors. However, a number of therapy options exist which prevent the breakdown of the released acetylcholine of still active nerve cells. Acetylcholinesterase, for example, can be inhibited which leads to an increase in acetylcholine within the extracellular space. This increase in molecules can, in turn, enhance the stimulation of subsequent cells and regenerate the memory process. [8]

3. The Teaching Concept „The Chemistry of Remembering"

The teaching concepts primary questions are: "How does remembering actually work? And what happens at the molecular level when Alzheimer's patients can't remember?". Based on these questions, the above-mentioned scientific principles will be taken up within the concept in a didactically reduced form. In order to establish a link to the students' everyday life experiences, a general introduction to the disease and its symptoms should precede the scientific principles. Additionally, an emotional connection to the topic should be established in which students can talk about their own experiences with regards to relatives or acquaintances. Once the significance of the topic has been worked out, both chemical and biological basic knowledge should be repeated and acquired. Since the topic is of interdisciplinary nature, the learning prerequisites can be very diverse.
In order to do justice to this heterogeneity, a learning video with subchapters was created, in which the basic knowledge regarding membranes as well as transport routes and stimulus transmission is presented (see 3.1). This enables individualized learning and each student can extract the information he or she needs to acquire a basic understanding of the topic. A supplementary worksheet is used to support the consolidation and the transfer of newly acquired knowledge (see 3.2).
The teaching concept will be implemented by alternating between digital as well as analogue media:

1) Development of research questions: “How does remembering work? And what happens on the molecular level when Alzheimer’s patients can’t remember?
2) Acquisition or activation of knowledge regarding basic chemical concepts of substance transport through biomembranes (required material: learning video and worksheet, see 3.1 and 3.2) Central points are:
    a. Basic chemical concepts such as diffusion or electrochemical gradients, which regulate the transport of substances.
    b. Influence of the concentration on diffusion processes.
3) Learning about the synthesis and degradation of acetylcholine related to Alzheimer’s disease (required material: Learning video and worksheet, see 3.1 and 3.2). Central points are:
    a. Functional groups of the hydroxy-, ester- and acetyl groups.
    b. Ester formation and the underlying reaction mechanism.
    c. Possible dysfunction in Alzheimer’s disease.
4) Discussion of the social relevance of membrane- and Alzheimer’s research, pro- and counter-arguments, concluding statement (required material: worksheet, see 3.2)

3.1 Structure and Content of the Video

The inquiry-based learning video begins with the central question: “How does remembering work?”. Along with a video sequence from everyday life the question should arouse the students’ interest, since the process of remembering affects each individual on a daily basis. The students are guided through the video based on different topics (see Figure 2). This structure is intended to illustrate that several processes build on each other. The structure is also supposed to serve as an orientation for the students to realize what they have already achieved and where they still need to go in order to achieve the overall learning objective.

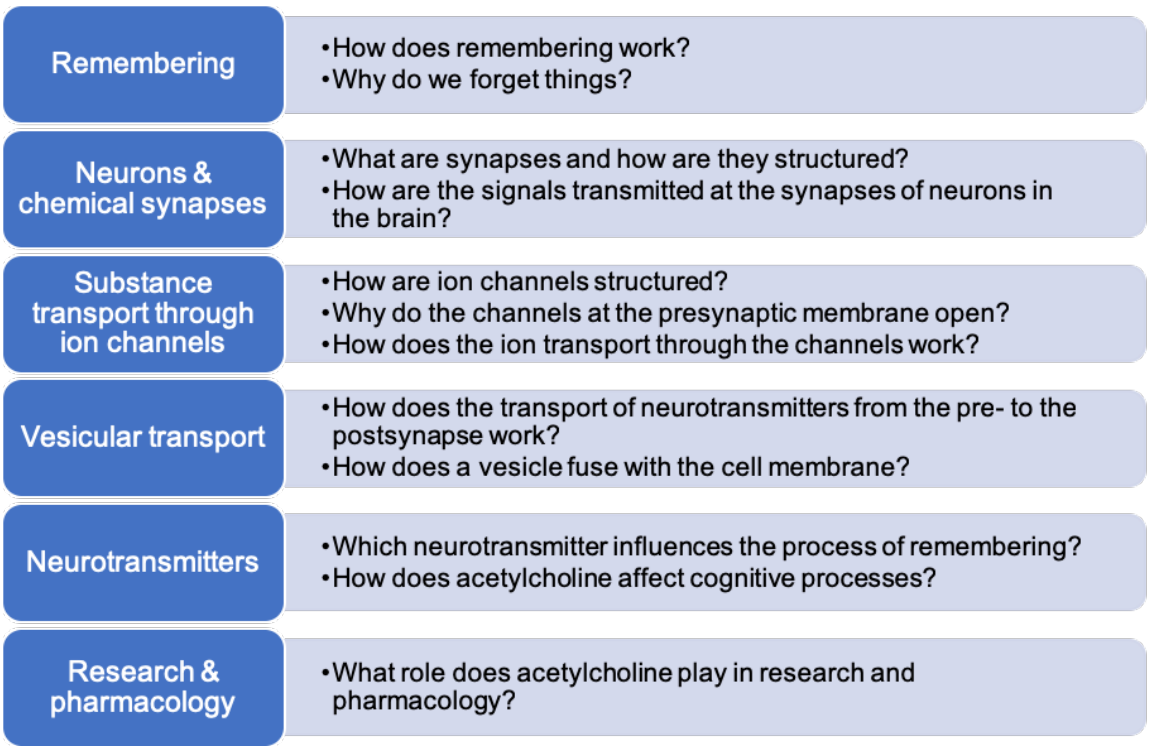

Figure 2: The learning video possesses a superordinate learning structure (left), which is used to clarify more specific questions (right).

Based on the video the following topics need to be discussed:

- Biochemical principles of substance transport through membranes related to human memory (see Figure 3, left).
- Principles of synaptic transfer, substance transport through ion channels and vesicular transport (see Figure 3, right).

- Relevance of basic chemical concepts for the (mis)regulation of biological processes.
- Interdisciplinary nature of the natural sciences.
- Current research on Alzheimer's disease.

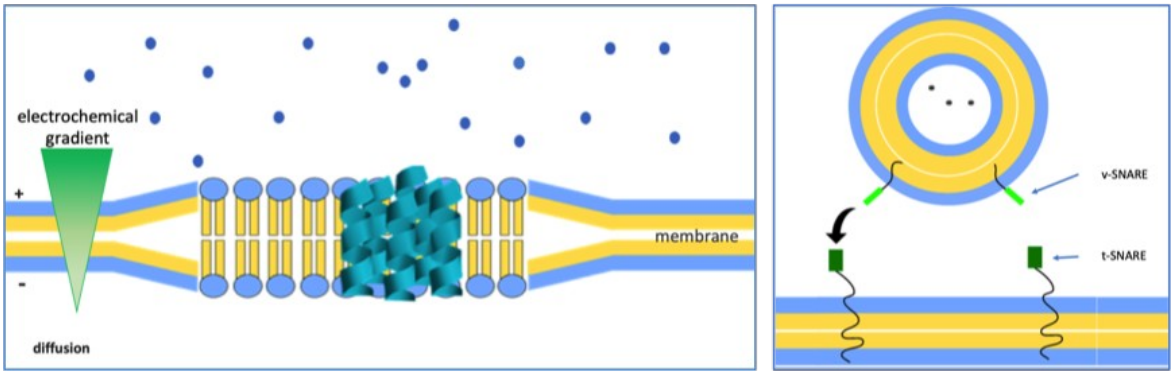

Figure 3: Screenshots taken from the learning video. Left: Schematic of the biomembrane and the electrochemical gradient. Right: Vesical and SNARE-Proteins necessary for the fusion with biomembranes.

Overall, it should be noted that the transport via vesicle is described in more detail, since the process is of particular importance for the understanding of Alzheimer's disease.

3.2 Worksheet

The supplementary worksheet contains various key aspects in order to do the complexity of the topic justice. The following aspects are addressed by the worksheet:

- Basic chemical concepts regulating biological processes (such as substance transport).
- Influence of the concentration on diffusion processes.
- Functional groups of hydroxyl-, ester- and acetyl groups.
- Ester formation and the underlying reaction mechanism.
- Thioesters (optional).
- Possible dysfunction in Alzheimer's disease.
- Social relevance of membrane- and Alzheimer research

4. Implementation into Chemistry Lessons

The occurrence of Alzheimer's disease can't yet be fully explained, which means that the focus in chemistry class is on simplified basic chemical processes (see above). Based on the mentioned chemical principles, the concept is suitable for an upper secondary class and can be used as a supplementary interdisciplinary lesson. The following contexts may allow the embedding of the unit:

- Esters as well as thioesters
  - Synthesis and degradation of acetylcholine
- Biocatalysis
- Simple diffusion, passive and active transport
  - Voltage dependend ion channels
- Electrochemical gradients

5. Conclusion and Outlook

The aim of this unit is to educate students about Alzheimer's disease by linking it to current research and important basic chemical concepts. This will help them to develop a better understanding of the disease and those affected and ultimately prepare them for possible challenges lying ahead. By means of an inquiry-based method, the process of remembering as well as not remembering should be understood by the students. In order to be able to support the learning process, both a learning video and a supplementary worksheet were created.

The teaching concept presented here will be tested with students in the near future. During the evaluation, a particular focus will be placed on the interest in the topic. In addition, it should be investigated whether the learning objectives have been achieved.

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