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MISCONCEPTIONS

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THE "LIGHT" AND "DARK" REACTIONS OF PHOTOSYNTHESIS -
TERMINOLOGY AS A SOURCE OF MISCONCEPTIONS

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The "light" and "dark" reactions of photosynthesis - Terminology as a source of misconceptions
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INTRODUCTION

The division of the process of photosynthesis into a "light phase" and a "dark phase" is a well established presentation of the functioning of the photosynthetic apparatus. This division can be traced to important points in the history of photosynthesis research. Consequently it is also the way the subject is presented in textbooks and taught. From psychological, didactical and scientific points of view this division into "light" and "dark" phases is fully justified: In the light ATP and NADPH₂ are produced and oxygen is released. Subsequently the products of the light phase are utilized to fix carbon dioxide. The light reactions occur in the thylakoid membranes whereas the so called dark reactions proceed in the soluble part of the chloroplast - the Stroma. The light phase can experimentally be separated from the dark phase as shown by Hill (1937).

With the growing awareness of students' difficulties and misconceptions a lot of attention has been directed toward understanding of photosynthesis (see review by Wood-Robinson 1991). The importance of photosynthesis and the complexity of the process have made it an excellent candidate for research on students' conceptions, at all age levels. Recently, the labels "dark phase" or "dark reaction" came under criticism and were designated as a possible source for misconceptions. Storey (1989) in his review of textbook errors writes: "This time-honored name ("dark reaction") is misleading and inaccurate, implying that photosynthesis occurs in the dark in green plants" (Storey, 1989, p. 271). Wivagg in his Editorial "Terminology Revisited" (Wivagg 1988) wonders "how many former (and current) biology students believe that plants fix and reduce carbon at night" (Wivagg 1988, p. 258).

The present study presents some preliminary results which support Storey's claim and Wivagg's fear about the pitfalls of imprecise terminology.

PURPOSE

The purpose of the study is to describe preliminary results pertaining to difficulties and misconceptions stemming from the term "dark reaction" assigned to the carbon fixing phase of photosynthesis.

METHOD

Sample

The sample for the present study consisted of 516 11th or 12th grade students, who participated in a study on improving the understanding of photosynthesis (Amir & Tamir 1992). Participation in the study was voluntary. However since the students came from urban as well as rural schools from all over Israel we are confident that they fairly represent the student population who elect to study high level biology.

Instruments

The students responded to a pretest which was designed to assess prior knowledge. At the completion of the study they took a posttest which was partly identical to the pretest and partly addressed recently learned concepts and ideas. The overall results of both tests are described in Amir & Tamir (1992).

An important feature of both tests was the use of several types of item formats: Multiple choice, multiple choice with justification (Amir, Frankl & Tamir 1987, Tamir 1989) proposition generating tasks (Amir & Tamir 1991) and open ended problems. In this paper we shall describe results pertaining to those items in which difficulties and misconceptions regarding the "dark reaction" of photosynthesis had been uncovered.

The items analyzed in this study are:

ITEM 1

The following scheme describes a chain of two processes:

Light energy ----> A ----> Chemical energy ----> B ----> Heat & anorganic matter

A. Name processes A and B.

(correct answer: Process A is photosynthesis, process B is respiration).

ITEM 2

Fifty disks 1 cm in diameter, were cut from sunflower leaves at 4 am and dried to remove all water from them (group A). The same procedure was applied to 50 disks that were removed at 4 pm (group B) and to fifty disks that were removed at 4 am on the following morning (group C).

A. Which group had the highest dry weight? Explain. (Correct answer: Group B, products of photosynthesis accumulated.)

B. Had group C a higher dry weight than group B? - Explain. (Correct answer: Group B had a higher dry weight. Some of the products of photosynthesis were used up during the night and/or transported out of the leaves).

Item 1 was included in both pre and posttest while Item 2 was part of the posttest only.

Analysis

Students responses to both items were given a mark on a scale of 0 to 4, were 0=wrong and 4=full and complete. Intermediate marks (1 to 3) were given to partially correct responses and to responses that included a specific misconception (These results are not described in this paper). In addition, students' responses were also categorized according to specific contextual categories (see Results section for details).

In an attempt to arrive at an improved understanding of students' misconceptions we cross analyzed their answers to the above mentioned

items, with their responses to items dealing with related topics such as the relationship between photosynthesis and respiration.

RESULTS AND DISCUSSION

In presenting the results we start with the results pertaining to the two items described above and will follow by additional information gained through the cross analysis with other items.

ITEM 1:

The frequency distribution of categories for Item 1 are presented in Table 1. The results in Table 1 show that a small percentage of the students mistakenly identified process A as the "light reaction" and process B as the "dark reaction". From examining the scheme presented in Item 1 it seems that for these students the "dark reaction" is the process which they often misconceive to occur in the dark or only at night namely, respiration. This particular misconception was previously described (e.g. Haslam & Treagust 1987).

Table 1
Item 1: Frequency distribution of categories
(in percentage) (N=516)

Category	Pretest	Posttest
<hr/>		
Process A		
0. No response	21	2
1. "Light reaction"(*)	8	5
2. Incorrect	3	2
3. Partially correct	13	1
4. Photosynthesis (**)	55	91
Process B		
0. No response	32	2
1. "Dark reaction"(*)	13	5
2. Incorrect	4	4
3. Partially correct	26	2
4. Respiration (**)	25	87

* misconception, ** correct response

Although the total number of students who hold the misconception is rather small even in the pretest, the fact that it exists surprised us. Moreover, the item itself did not deal directly with the "light" and "dark" reaction, a fact which points to the importance of dealing with problematic issues in more than one direct approach.

An interesting question which has arisen is whether the same students repeated in the posttest the mistake they had done in the pretest. Most students did not: Only three out of the 43 students repeated "light reaction" for process A and only five (out of 68) repeated "dark reaction" for process B. This means that the time that had elapsed between pre and posttest - six weeks on the average - was long enough to eliminate an effect on posttest performance. It may also perhaps mean that an even larger proportion of the students confuse the phases of photosynthesis with photosynthesis vs. respiration.

ITEM 2:

Our purpose in item 2 was to evaluate the ability of the students to apply their knowledge of photosynthesis in the context of the whole plant and its energy and material balance. Again, no attempt was made, in this particular item, to address the issue of the phases of photosynthesis.

Five percent of the students claimed that the disks from group B will have the highest dry weight (correct!) because the "light reaction" has taken place (misconception!). For these students carbohydrates are produced during the "light reaction" as can be seen in the following excerpt:

* "The disks in group B will have the highest dry weight because in the light reaction organic material are formed and remain in the plant".

The answers to the question of which group has the higher dry weight, group B or group C, were also helpful in uncovering the misunderstanding caused by the terminology "dark reaction". Here we found that nine percent of the students gave an answer based on the misconception that the "dark reaction" takes place at night long after the "light reaction" has completed its course. The following answers exemplify this misconception:

* "The disks from group C had a higher dry weight than the disks from group B because from 4 pm to 4 am [the following morning] the plant produced the organic materials".

* "The disks from group B were full of energy and NADPH but did not produce sugars yet. The disks from group C already utilized the products to produce sugars".

* "The disks from group C contain the end product of photosynthesis while group B disks contain only intermediate products".

These examples feature the misconception which may be attributed to the terminology: The "dark reaction" does not take place during the light hours but rather during the night. This notion is in absolute contradiction to

the scientific fact that both phases of photosynthesis take place during the light hours.

A similar misconception to that uncovered in Item 1 namely that the "light reaction" is photosynthesis whereas the "dark reaction" is respiration, was uncovered by students who correctly stated that the disks from group B would have a higher dry weight than the disks from group C. An example of an answer:

* "At 4 am the following morning, most materials have been used in the "dark reaction".

The results presented so far point to two misconceptions which can be attributed to the label "dark reaction" or "dark phase":

- (a) The "dark reaction" is a part of photosynthesis but is temporally separated from the "light reaction" and occurs only at night or in the dark.
- (b) The "dark reaction" is respiration.

Misconception (b) is probably a result of another prevalent misconception namely: Plants respire only in the dark (Haslam & Treagust 1987).

An important issue in the research on misconceptions is the consistency in the use of a particular misconception or the use of several related misconceptions by the same student. The data presented in Table 2 compares the responses in Item 1 (pretest only) with those of three additional items (all taken from the pretest). The first of this is a Proposition Generating Task (Amir & Tamir 1991) in which students were required to write a sentence which explains the relationship between photosynthesis and respiration. The sentences were categorized and two of the categories are of interest here : Category A: Lack of distinction between photosynthesis and respiration (e.g "photosynthesis is the respiration of plants" - a misconception) and Category B: Photosynthesis and respiration are complementary processes in the biosphere (correct).

The other two items were multiple choice items. Here we were interested in the students who selected a distractor that represents a misconception e.g "plants do not respire" and "plants give out more CO₂ during 24 hours than O₂".

Table 2
Comparison of responses to item 1 (pretest) with responses to other items (pretest) (in percentages)

Content of item (@)	Process A Category(*)->	Process A		Process B	
		1 N=43	4 N=287	1 N=68	4 N=129
PGT: Category A (misconception)		42	26	41	20
PGT: Category B (correct)	14	22		13	28
Plants do not respire (misconception)		30	20	37	12
Plants give out more CO ₂ during 24 hours (misconception)		40	24	31	26

* category 1=misconception, category 4= correct

@ See text for description of items.

Table 2 shows that the frequency of misconceptions is higher among those students whose responses in Item 1, were categorized as misconception (category 1). Thus 42% of them generated a proposition uncovering their inability to correctly distinguish between photosynthesis and respiration. A lower percentage - 26% - generated such a proposition from amongst the students who gave a correct answer regarding the identity of process A. A similar picture emerges from the results pertaining to the students who mis-identified process B. Higher percentages of students with correct identifications of process B (22% and 28% respectively), generated correct propositions about the complementariness of photosynthesis and respiration in the biosphere.

The misconception "plants do not respire" was selected by a higher proportion of students who made an incorrect identification of processes A and B. The last item dealt with the quantities of oxygen and carbon dioxide that are exchanged during 24 hours by a plant. Selection of the distractor, described above, results from misunderstanding the quantitative relationships between photosynthesis and respiration in plants. A higher proportion of students who mis-identified the processes in Item 1 selected this distractor than students who had made correct identifications. These additional results show that sometimes misconceptions that seem to be different namely: misconceptions regarding the phases of photosynthesis on the one hand, and misconceptions pertaining to the interrelationship of photosynthesis and respiration, on the other hand, are linked in students' mind.

CONCLUSION

The results described in this study are preliminary. However, besides showing the existence of particular misconceptions they provide evidence for the inter-relatedness of misconceptions. It seems that the misunderstandings regarding photosynthesis and respiration in plants are quite complex.

Our attention to the problems arising from the terminology regarding the phases of photosynthesis was attracted through items which were designed with a different goal in mind. The important message from this fact is that misconceptions are sometimes uncovered in unexpected contexts or situations. Uncovering them requires that (a) we give students enough opportunities to express his\her ideas in their own words and not rely solely on multiple choice items and (b) read the responses with an open mind and with awareness of possible pitfalls and misconceptions.

The results also lend support to the recommendation to rename the "dark" phase of photosynthesis as suggested by Storey (Storey 1989).

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