Comparison of teaching orientations of an experienced and beginner lecturer in first year Biology

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Hester A Kriel

Student number: 89152532

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Contents

Abstract

First year students at tertiary institutions find themselves in an environment that is both exciting and intimidating. This study explores the dynamics of the classroom where biology students meet an experienced and a beginner lecturer teaching arguably the most difficult topic in the syllabus, photosynthesis. The study investigated the difference in their teaching orientations, which was expected to influence the way in which they plan and present the lessons, the experiences of the students in class, with the emphasis on sections that were explained well and on problems that students may still encounter at the end of the lecture. Interview and classroom observation data were analysed to probe the beliefs, goals and topic specific pedagogical content knowledge of the lecturers in order to generate a qualitative description of the difference in their teaching orientations. The data suggests that the difference in the disciplinary background of the two lecturers influenced their teaching orientations and their time allocation to different sections of the content. It was evident from an inductive analysis of journal entries that first year students respond positively to lecturers that are enthusiastic, well prepared and committed to deliver to the best of their abilities. The study concludes that the poor performance of students in this topic cannot be ascribed to the difference in the teaching orientations of the two lecturers.

Declaration

I declare that this thesis is my own work. It is being submitted to the degree of Master of Science Education at the University of Pretoria. It has not been submitted before for any degree at any University.

(Electronic signature of candidate)

17th day of April 2017

Dedication

To my two lovely daughters who walked the journey with me without complaints and with love. To my late parents for always believing in me and my family and friends, for all their words of encouragement.

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Abbreviations

ATP	Adenosine triphosphate
BL	Beginner Lecturer
CO_2	Carbon dioxide
EL	Experienced Lecturer
FAD	Flavin adenine dinucleotide (oxidized)
FET	Further education and learning
HIMs	High impact modules
MLB 111	Molecular and Cellular Biology
$NADP^+$	Nicotinamide adenine dinucleotide phosphate (oxidized)
NADPH	Nicotinamide adenine dinucleotide phosphate (reduced)
O_2	Oxygen
PCK	Pedagogical content knowledge
PhD	Doctor of Philosophy
TSPCK	Topic specific pedagogical content knowledge
UP	University of Pretoria

CHAPTER 1: INTRODUCTION TO THE STUDY

1.1 Introduction

First year students at tertiary institutions find themselves in an environment that is both exciting and intimidating. It comes as no surprise that the first year in this new environment is associated with the highest attrition rates at tertiary level. First year students have to face many challenges on a personal level as they adjust to this new environment. They also have to adjust to the large volume of work and the big variation in the teaching styles of lecturers. The lecturers are accomplished researchers but few have had any formal training in teaching. This study explores the dynamics of the classroom where biology students meet two very different lecturers teaching arguably the most difficult topic in the syllabus, photosynthesis. The background and context of the study, the rationale, the aim and the research questions which frame the study are discussed in this chapter. The chapter concludes with a preview of the sequence followed in this research report.

1.2 Background and context of the study

Molecular and Cell Biology (MLB 111) is a first year module which is presented during the first semester at the University of Pretoria (UP). MLB 111 is a high impact module (HIM):, a group of courses with a significant impact on student success due to large enrolment numbers and/or strategic placement in multiple programmes.

MLB 111 is the foundation course of all subsequent courses in Biological Sciences. The significance and aim of MLB 111 is explained in the study guide (*Molecular and Cell Biology Study guide* 2013):

> *'All living organisms are composed of cells. A thorough knowledge and understanding of the structural, biochemical and genetic nature of the cell is therefore the foundation for all the different branches of the life sciences. Throughout the module, emphasis is placed on what is common to all cells. The student should, however, at the end of the module come to appreciate the wide variety of cells in different living kingdoms and their specialisations within a single organism, as well as be able to apply the knowledge in areas such as human genetics and biotechnology. This specialisation forms the basis*

> *of all biological disciplines such as Plant Science, Zoology, Entomology, Genetics, Biochemistry, Microbiology and Physiology as well as medical and veterinary sciences encountered in the second semester or in the following years.'*

Countrywide there is a renewed urgency to improve student performance in Mathematics and Science with the aim to reduce the average time to complete first degrees (Department of Arts & Technology, 1996; Education, 2001). There is thus a need to address the possibility that students might not be successful by devising interventions to prevent the extra time to finish their degree. Together with other first year, first semester courses, MLB 111 constitutes the students' first experience of tertiary education. The students' academic experiences during these courses has a more profound influence on their academic self-concepts and expectations of future successes, than later in their academic careers when they have had more successes on which to fall back. The in-depth analysis of factors influencing student success in MLB 111 has become a matter of priority due to the large enrolment numbers (minimum of 1250 students) and their pass rates consistently falling below 70% over the last five years.

1.3 Problem statement

First year MLB 111 students at the University of Pretoria (UP) tend to struggle to understand and explain photosynthesis and therefore perform poorly on this topic. Photosynthesis is the ninth theme in MLB 111 and is covered in five lectures. Owing to the large enrolment for the course, students are divided into three lecture groups which are taught in parallel by a team of two lecturers: the one teaches the Afrikaans group and the other one teaches the two English groups. The reasons for the challenges that the students experience with this topic are poorly understood. There is a debate among the course lecturers whether the students are not committed to studying or if the section is inherently difficult. The two lecturers, one a beginner and the other experienced, have different views on this matter which may influence their teaching orientations.

1.4 The rationale for the study

In the MLB 111 study guide photosynthesis is defined as follows (*Molecular and Cell Biology Study guide* 2013):

> *'Living organisms require a continuous source of energy. Plants and algae, for instance, convert sunlight energy by photosynthesis into chemical energy such as sugars, which in turn,*

> *are used as food sources for animals. Photosynthesis is the primary process for providing food to living organisms and for the replenishment of oxygen in the atmosphere. '*

The question arises whether the process of photosynthesis itself is conceptually more challenging than other topics in the course or whether understanding is hampered by factors unique to each of the lecturers. This study was designed to focus on factors unique to the two lecturers and will investigate the situation from two different angles. The first angle is the difference in teaching orientations of the lecturers which is expected to influence the way in which they plan and present the lessons. The second angle is the experience of the students in class with the emphasis on sections that are explained well and on problems that students may still encounter at the end of the lecture. This approach is expected to provide insights into ways in which the teaching and learning of the topic can be improved in future, in order to improve student performance in MLB 111.

The teaching orientations of lecturers are not the only possible reasons for students to underperform on the topic of photosynthesis. According to literature, learning is also hampered by misconceptions that can be formed as early as primary school (Hershey, 1995; Ray & Beardsley, 2008; Wandersee, 1986; Yip, 1998). These misconceptions do not necessarily have to be about photosynthesis, they could be associated with the physical or chemical principles that are applied in photosynthesis. Misconceptions are often caused by lecturers and teachers that use wrong terminology in an attempt to make the concept easier for the students to understand(Yip, 1998).

The role of misconceptions in student mastery of photosynthesis is well researched and was not pursued in this study. On the other hand, teaching orientations have not been researched in depth. The lecturers' teaching orientations in their classroom practices and they therefore influence student learning. Information regarding the relationship between the teaching orientations of lecturers and the students' experience of a class is limited. After reviewing the literature on teaching orientations, a definition for this construct was formulated as follows: *The teaching orientation of a lecturer is his/her beliefs about the topic and content, the goals that the lecturer set for him/herself and their students and their topic specific pedagogical content knowledge (Friederichsen, Van Driel, & Abell, 2011; Friederichsen et al., 2009).* Each one of the components of the construct can be divided into subcategories as is discussed in depth in the next chapter.

1.5 Research questions

Theos study attempts to answer the following two research questions with particular reference to the topic of photosynthesis in MLB 111:

1. *How does the teaching orientation of a beginner lecturer differ from that of an experienced lecturer?*

2. *How do students experience the teaching of each lecturer?*

1.6 The researcher and her position in the study

At the beginning of the study I was an employee of UP. I have a BSc degree in chemistry and biochemistry and a BSc Honours degree in biochemistry from the North-West University of South Africa. I also obtained a National Certificate in Education from the University of South Africa. Being a qualified Physical Sciences teacher I have experience in teaching at high school level and in adult education. I also have experience in teaching large classes with a minimum of 300 students in them. As an educator I have my own teaching orientation and as a trainer of teachers I often need to evaluate the classroom practice of other teachers and give them advice. My expertise is a strength in a study like this but it is also a concern because of the bias that could potentially be introduced by my preferences and personal style. This possible bias was carefully managed by the choice of data collection methods, frequent discussions with my study leaders and the validation of the data and the findings throughout the analysis.

I personally know both the beginner and the experienced lecturer personally because of my employment at UP. There was a possibility that this personal relationship could induce bias in terms of either exposing or covering up perceived weaknesses. In recognition of this fact, the methodology was designed specifically to prevent bias as is explained further in chapter 3.

1.7 Sequence of the research report

In the first chapter, the background and context of the study, the problem statement, rationale and the position of the researcher was discussed. In the second chapter, the relevant literature is reviewed and the theoretical framework is outlined. In the third chapter, the methodological approach, case studies, ethical considerations and considerations of trustworthiness and transferability are discussed. The sample setting, data collection methods and analytical approach are also described. The fourth chapter presents the analyses of the data and discussion of the results. Chapter five presents the findings and conclusions of the study, as well as their implications for teaching in a cluster of biological science departments, areas for further research, the limitations of the study and lastly the reflections of the researcher.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In this chapter the concepts and teaching aspects of photosynthesis, teaching orientations and the definitions of experienced and beginner lecturers are discussed.

2.2 The teaching of photosynthesis

Photosynthesis is one of the processes that sustains life on our planet because it supports nearly all ecosystems and it releases oxygen into the atmosphere. Sunlight energy is used during photosynthesis to convert carbon dioxide (CO_2) from the atmosphere to organic compounds and in the process oxygen (O_2) is released into the atmosphere. The topic of photosynthesis helps students understand how photosynthesis is the bridge between the living and non-living world and explains the relationships between different organisms in an ecosystem (Talaat & Lucas, 1992). Photosynthesis is one of the most studied plant processes from a primary school level up to a tertiary level. At tertiary level it is at molecular level and consists of chemical processes and terminologies (Vila & Sanz, 2012).

2.2.1 Possible misconceptions

Several misconceptions on the topic of photosynthesis have been experienced by students and are documented in literature (Ahopelto, Mikkilä-Erdmann, Anto, & Penttinen, 2011; Cañal, 1999; Hershey, 1995; Meir, Perry, Stal, Maruca, & Klopfer, 2005). The earliest misconceptions are formed in primary school; students think that plants get their ready made food from the soil, water is as important to plants as food is to animals and plants breathe in a different way to humans.

In later years new misconceptions form as the work is explained in more detail. Students with conceptual difficulties in chemistry and physics carry this problem over to molecular biology. One of the explanations for such conceptual problems is that reactions happen on a molecular level and students cannot observe them. Limited knowledge of chemistry complicates photosynthesis for students and results in them failing to see photosynthesis as a complex chemical reaction (Hazel & Prosser, 1994; Ross, Tronson, & Ritchie, 2005). Linking other chemical and physical processes such as water uptake and respiration to photosynthesis is also problematic. Many students think that photosynthesis only takes place in sunlight while respiration only takes place at night, not realising that the processes happen simultaneously.

Traditionally high school and first year students struggle with redox reactions causing them to have difficulty in identifying the redox reactions in photosynthesis (Gilbert, de Jong, Justi, Treagust, & Van Driel, 2002). Although most students understand the ecological aspect of photosynthesis only a few understand the processes in which energy change takes place (Talaat & Lucas, 1992). According to Gaspar (2013) there are a few misconceptions which she has identified over the years while lecturing photosynthesis. The first misconception involves the NAD reaction where the hydrogen ion (H^+) comes from the glucose molecule and not the hydrogen gradient, the second major problem is the reactions of $NADP^+$, ATP, NADPH and FAD in the energy transfer reactions; the students confuse which reactions happen where and when.

Beginner teachers tend to use terminology incorrectly in their attempts to help students understand certain concepts, which can lead to misconceptions (Yip, 1998). Knowledge about photosynthesis does not mean that there may not be possible misconceptions on the lecturer's side as well (Ahopelto et al., 2011). These misconceptions can be transferred to students without the lecturer realising it.

2.2.2 Big ideas

Big ideas are key ideas in a certain topic that can be used to focus sections to make them more understandable for students (Charles & Carmel, 2005; Davidowitz & Rollnick, 2011; Harlen & Holroyd, 1997; Wiggins & McTighe, 2005). In this study big ideas are used by lecturers to divide the topic into smaller parts with the aim of making the studying and understanding easier for students. Four big ideas were formulated by the researcher for the topic of photosynthesis in MLB 111. The textbook and study guide were used for this purpose and the big ideas were validated by the co-supervisor who has many years of experience in teaching this topic and this course (Gaspar, 2013) These big ideas are:

1. Photosynthesis converts light energy to chemical energy
2. The light reactions convert solar energy to the chemical energy of ATP and NADPH
3. The Calvin cycle uses chemical energy of ATP and NADPH to reduce CO_2 to sugar
4. An alternative mechanism of carbon fixation has evolved in hot arid climates

2.3 Teaching Orientation

Teaching orientations are, for the purpose of this study, defined as the beliefs of the lecturers, their learning goals and their topic specific pedagogical content knowledge (TSPCK) (Friedrichsen et al., 2009). Science teachers' orientations focus on beliefs about the role of the teacher, the role of the student, views about science and goals or purposes for teaching science (Friedrichsen, Van Driel, & Abell, 2011). The teaching orientation of a teacher is formed by his/her own experiences as a student and will most likely not change (Brown, Friedrichsen, & Abell, 2013). Trigwell, Prosser, and Taylor (1994) believe that teaching orientations can only be divided into two categories: Learning goals (what is focused on) and on how it is being focused. The third component of teaching orientations in our study builds on the work of Rollnick, Bennett, Rhemtula, Dharsey, and Ndlovu (2008) that was used together with the research done by Trigwell et al. (1994) to form a new definition for teaching orientations.

The lecturers' knowledge of and beliefs about the purpose and the reasons for teaching a specific section influences their teaching orientations which includes goals related to subject matter and classroom context. Classroom context refers to the lecturers' beliefs about students' abilities, classroom size, the number of students and the lecturer's professional development.

2.3.1 Lecturer's beliefs

The beliefs that shape teaching orientations include a teacher's or lecturer's beliefs about the purpose for teaching science at a particular grade level (Magnussen, Krajcik, & Borko, 1999). It also includes the lecturer's personal belief as to why the topic should be covered in the module. A lecturer's beliefs includes those regarding their confidence about their personal ability to be a lecturer and their belief in the student's ability to learn the content (Settlage, 2000). The context in which teaching takes place influences the beliefs and the classroom practices of the lecturers. The context includes the classroom size, the number of students, the condition in the classes, and the type of students (Gwimbi & Monk, 2003). These beliefs all influence the lecturers' teaching orientations.

2.3.2 Learning goals

According to Kember and Gow (1994) the learning goals that the teachers set for themselves and their students influence student learning. Lecturers see their role as creating a learning environment for the students in which they understand why they should study specific content. Some lecturers feel that in an ideal academic world they would know the students and understand their problems and assist them in correcting them. The lecturers also see it as their role to instruct the students in such a manner that allows the students' full understanding and ownership of the content. One of the main teaching goals of lecturers is to assist students in developing critical thinking skills (Kreber, 2003). Some lecturers still tend to think that knowledge is received in the same way it is delivered, where students are regarded as passive receivers (Kember & Gow, 1994; D. Kember, 1997). Gess-Newsome, Cardenas, and Austin (2011) claimed that a teacher's characteristics, knowledge and classroom practice is linked with student performance which may have an influence on the goals set by the lecturer for the performance of the students. Teaching goals are set by lecturers and curriculum developers to ensure that students learn certain content. The general teaching goals for photosynthesis were decided on when the theme was originally planned.

2.3.3 Topic Specific Pedagogical Content Knowledge

Shulman (1986) is seen as the founder of the construct of pedagogical content knowledge. He posited that teachers do not only need to know the content but they also need to know the subject matter knowledge for teaching. He also stated that teachers should have more than one strategy to explain the same content and that they should know why the specific content is taught. Pedagogical content knowledge (PCK) blends content and pedagogy into a way to present topics and problems to accommodate diverse interests and abilities of learners (Shulman, 1987). According to Halim and Meerah (2002), if lecturers fail to take the students' way of thinking into consideration the lecturers have problems in teaching content, irrespective of their knowledge and experience. A lack of content knowledge also results in unawareness of misconceptions. Geddis, Onslow, Beynon, and Oesch (1993) viewed PCK as *'knowledge that plays a role in transforming subject matter into forms that are more accessible to students.* TSPCK is a reflection of the specificity of a topic with the emphasis on the quality of teaching; not only learning how to teach, but to learn how to teach a specific topic. It is important to be a good teacher in specific topics and not just be a good teacher (Mavhunga & Rollnick 2013). Rollnick and Mavhunga (2016) divided TSPCK into five main categories: student prior knowledge, curricular saliency, what makes the topic difficult, representations and teaching strategies. Each of these categories will be discussed in more detail below.

According to Abd-El-Khalick (2006) teachers' TSPCK can be developed by training. The best way to develop TSPCK is with teaching experience and expertise gained over time. There is a difference between teaching expertise and teaching experience. Teaching expertise is gained with self-evaluation and the quality of teaching experiences. It does not necessarily correlate with the years of teaching experience. Teaching expertise is the best way to gain TSPCK (Abd-El-Khalick, 2006; Gess-Newsome & Lederman, 1995). The problem with this is that experienced lecturers can still be unaware of certain TSPCK aspects (Shulman, 1987).

2.3.3.1 Student prior knowledge:

Student prior knowledge is the knowledge of photosynthesis that students have before they the section. This is also the knowledge that they use again in this section. Prior knowledge does not only have to be about photosynthesis, it includes all of the knowledge the students have before the topic is retaught, including possible misconceptions.

Photosynthesis is covered by all students in Natural Sciences in primary school. Even if students did not choose Life Sciences as a subject they still have limited general knowledge on this topic. Redox reactions are explained in full detail on school level in Physical Sciences which is a prerequisite for MLB 111. Students also study redox reactions in respiration which is the theme prior to photosynthesis, as well as in the first year chemistry module. During the respiration process *an electron transport chain* and *proton gradient* similarly to the proton gradient and electron transport chain formed in photosynthesis.

2.3.3.2 Curricular saliency:

Curricular saliency in short describes the lecturer's knowledge on the topic and the sequencing and scaffolding of topics and concepts. It is the knowledge of what comes before and after the topic (Rollnick et al., 2008). It can be divided into macro and micro saliency. According to Ahopelto et al. (2011) lecturers can be aware of the importance of photosynthesis without understanding how and where it fits into the bigger global picture.

The question arises as to why the photosynthesis topic is included in the Molecular Cell Biology Course (Mavhunga & Rollnick 2013).

Macro Saliency defines where photosynthesis fits into the bigger picture of MLB 111 (Davidowitz & Rollnick, 2011; Kind, 2009; Nkuna, 2013). Photosynthesis is important because a description of life cannot be imagined without defining the origin of the food chain for all living organisms. This origin is the organic nutrient material that originates from all photosynthetic organisms, mainly plants, and sources energy from the sun. Another learning opportunity stemming from the topic of photosynthesis is the comparison of the different mechanisms used by different life forms to flourish as living organisms, including how closely interdependent all living organisms are to survive. An appreciation of the importance of conservation of all life forms of nature is nurtured in this way, which orientates students towards taking responsibility for looking after the planet that we inhabit. In MLB 111 all of the different cells are looked at and because photosynthesis is the beginning of life it has to be included in the syllabus of an introductory biology course (Geddis et al., 1993). Photosynthesis provides the energy for all living organisms to survive. Students learn that it does not matter which type of cell you are looking at (animal, plant or bacteria) the same type of building blocks and reactions define life. It also shows students that energy conversion on earth (first law of thermodynamics) occurs in an open system that sources its energy from the sun.

Micro Saliency looks at the knowledge of the lecturer on photosynthesis itself, where does the topic fits into the MLB 111 syllabus and why. It also refers to the knowledge of a lecturer and how much time to spend on each big idea (Toerien, 2013). Photosynthesis is covered directly after respiration because it needs to be compared to respiration. The overall respiration reaction is the reverse reaction of photosynthesis. There are steps and processes that are similar although they happens in different types of cells. The lecturer must also be able to divide the topic into sensible big ideas in order to structure his/her teaching.

2.3.3.3 What makes the topic difficult

Traditional lecturing methods do not assist students in understanding photosynthesis at the molecular level (Ross et al., 2005). According to Wyckoff (2001) the use of only traditional and direct lecturing as a teaching method is one of the reasons for the poor performance of students. Students struggle with energy change in photosynthesis and do not see the interrelationship of photosynthesis with other topics (Talaat & Lucas, 1992), Vila and Sanz (2012), however, postulate that the topic is difficult because students do not see it as a chemical reaction and because students find redox reactions challenging. The difference between chemical and biological redox reactions poses an additional problem to the students (Gaspar, 2013). Gaspar also stated that the way questions are posed in tests and examinations makes it difficult for students to answer. Students can also find photosynthesis difficult due to an information overload. They struggle to compare respiration and photosynthesis and get confused because they do not understand the mechanisms involved. In addition, students often confuse the Calvin and Krebs cycles (Gaspar, 2013; Kritzinger, 2013; Verschoor, 2013).

2.3.3.4 Representation

Representations are the analogies, models and diagrams used to explain different concepts that students may have. These can only be used successfully with adequate content knowledge (Mavhunga & Rollnick 2013). Ross et al. (2005) recommend the use of analogies, model making and role plays to make photosynthesis more understandable for first year students.

2.3.3.5 Teaching strategies

Teaching strategies are reasoned conceptual strategies. In other words, they are the reasons for using specific representations and strategies to address misconceptions. For some lecturers these strategies are based on their own explanations and the textbook, without taking student difficulties and misconceptions into account (Yenilmez & Tekkaya, 2006). According to Vila and Sanz (2012) introductory lessons must incorporate known concepts to ensure that students understand them before continuing to more complex photosynthesis concepts. Furthermore, Yenilmez and Tekkaya (2006) are of the opinion that the possible misconceptions must be listed before each lesson and should be addressed before new concepts are introduced. They also stated that by breaking down a cycle into smaller sections, students are taught the skill to look at every small part of the cycle. As the students' progress they are expected to be able to do it themselves. When diagrams are used, students should be shown the reasons for a specific reaction to prevent rote learning.

2.4. Experienced versus beginner lecturers

A number of studies have been reported in the literature where researchers have compared the characteristics and practice of beginner and experienced lecturers. However, there is some variation in the definitions used for beginner and experienced lecturers. The general consensus is that an experienced lecturer has more than 10 years teaching experience while a beginner lecturer has between three and six years experience (Friedrichsen et al., 2009; Hoz, Tomr, & Tamir, 1990). According to Yip (1998) teaching experience plays a major role in explaining of difficult concepts at a level that learners and students can understand. Beginner teachers have specific ideas on what to teach and the approach they are going to use. Even with well intended advice they are resistant to change their ideas and methods (Koballa, Glynn, & Upson, 2005). Teachers having taught for two years do not show more experience in teaching difficult concepts compared to teachers with no teaching experience (Friedrichsen et al., 2009). These teachers also concentrate on fewer details on a specific topic. Experience gained by teachers and lecturers during teaching and adapting lessons to the needs of students develop their TSPCK. Pedagogical content knowledge (PCK) blends content and pedagogy into a way to present topics and problems to accommodate diverse interests and abilities of learners (Shulman, 1987). According to Abd-El-Khalick (2006) experienced teachers tend not to emphasize details of photosynthesis but view the process as part of larger biological processes and systems. Abd-El-Khalick (2006) research findings indicated that teaching experience plays a role in the developing of teachers' PCK. It is suggested in the literature that experienced lecturers tend to take it for granted that students have very good prior knowledge of certain concepts (Gess-Newsome, 1999). Gess-Newsome and Lederman (1995) insist that experience alone does not develop PCK of teachers. Rather, their conceptual understanding of subject matter is affected by the kind and quality of the experiences and opportunities they encounter during their careers. This plays a bigger role than the number of years they have taught. Most universities in New Orleans LA, use strong academic PhD students to lecture first year courses. These students are not prepared for teaching their course and learn how to teach through experience (Abell, Rogers, Hanuscin, Lee, & Gagnon, 2009; Fagen & Niebur, 2000).

2.5 Conceptual framework

Based on the literature described above a conceptual framework was developed and is shown in figure 2.1

The lecturers’ teaching orientations mediates the transfer of information into their classroom practice. The lecturers’ beliefs, learning goals and TSPCK together give evidence of the teaching orientations of the lecturers. The formulation of the TSPCK construct by Rollnick and Mavhunga (2016) is used in this study which specifies that TSPCK consists of student prior knowledge, what makes the topic difficult, curricular saliency, representation and teaching strategies. Beliefs are divided into four categories: student abilities, own abilities, content, and context as discussed in paragraph 2.3. Learning goals consist of three components: the role of the educator, the content students must know, and the context in which teaching takes place. The lower part of figure 2.1 reflects the teaching orientation of the lecturers impacts on the students’ classroom experience. The students’ experiences of the classroom practices of the lecturers were divided into the students’ experience of the content and their experiences of the teaching orientations of the lecturers.

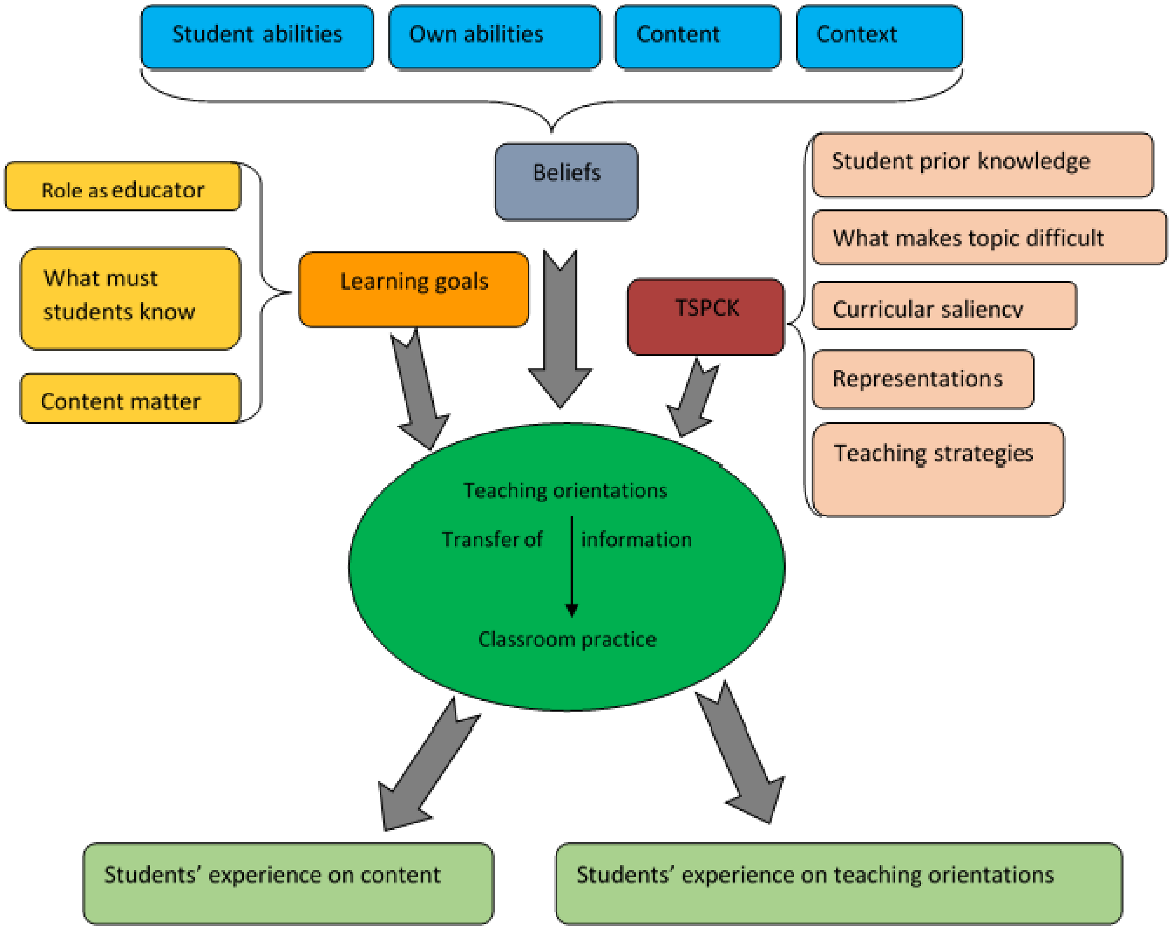


Figure 2.1: Conceptual framework

2.6 Summary

This study focusses on teaching orientation as the central construct. In this chapter the construct was defined based on the literature and a conceptual framework was developed to guide the design of the study and the interpretation of the results. Chapter three discusses in detail the methodology that was followed and describes how the data collection, analysis and interpretation links with the conceptual framework.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

In this chapter the reasons for the type of study conducted and the sample composition are explained. The methodology and the data analyses are discussed in detail. Lastly, ethics and trustworthiness is addressed.

3.1 The aim of the study

The purpose of this study is to describe the similarities and differences between the teaching orientations of an experienced and a beginner lecturer with regard to the photosynthesis theme of MLB 111. A further aim is to explore the students' experience of the teaching of the respective lecturers.

3.2 Methodological approach

This study seeks to address two research questions that were formulated in chapter one.

1. *How does the teaching orientation of a beginner lecturer differ from that of an experienced lecturer?*

2. *How do students experience the teaching of each lecturer?*

In this study the experiences of first year students were investigated in their class environment as they were taught by the respective lecturers, while at the same time evidence of the teaching orientations of the lecturers was collected. The teaching orientations of lecturers and how students experience the classes cannot be measured and calculated quantitatively as it can only be explored qualitatively. Qualitative research is defined as a methodology that investigates and describes the behavior and experiences of people in their natural environment. Typically, the sample group is smaller than with quantitative research. The sample is a portion of the population that is studied. The three most commonly used sampling methods are stratified purposive studies (use pre-selected criteria), criterion sampling (based on typical characteristics of the participants), and snowball sampling (participants use social networks to invite more participants) (Maree, 2007). Data is collected by interaction with and observation of participants. The researcher is the research instrument. He/she creates the context for the study, interacts with the participants, getting them to open up and trust the researcher by listening to them. He/she collects all of the data, performs the analyses and interprets it into meaningful findings (Krefting, 1991; Maree, 2007; Poggenpoel & Myburgh, 2003).

3.2.1 Reasons for choosing a case study as a methodology

A case study design is a good choice in qualitative studies because it can explain events and phenomena in the context in which they occur and can generate answers on the questions ‘how’, ‘what’ and ‘why’. It can also give insight into possible undetected problems and the reasons for the problems (Crowe et al., 2011; Yin, 2013). Stake (1995) defined three types of case studies: intrinsic, instrumental and collective case studies. An intrinsic case study investigates a unique occurrence. An instrumental case study uses a specific case to look at a broader incidence and a collective case study looks at more than one case at the same time to get a wider understanding of a specific issue.

Three different epistemological approaches are generally used in case study research (Crowe et al., 2011). The critical approach involves questioning one’s own assumptions and takes the wider environment into account. It is interpreted with limiting conditions in relation to power and control that might influence behavior. The second approach is that of interpretive case studies which build theories by the understanding of contexts and processes from different perspectives. The third case study approach is positivist case studies, where variables are set before the study and then probed to see whether they fit in with the study findings. The epistemological view of the researcher influences the case study approach. When a researcher questions his/her own and others’ assumptions it is called a critical approach. Interpretivists try to understand social meanings whether they are shared or individual. When the researcher focuses on the natural sciences and how it can be generalised it is called a positivist approach (Crowe et al., 2011).

This study is an intrinsic and interpretive case study. It is intrinsic because the specific sample could only be used once and the findings are of interest to a specific faculty (Natural and Agricultural Sciences) and Department of Biochemistry at a specific institute (UP). A specific section of MLB 111 was studied, with a specific group of voluntary participants. This study cannot be repeated. It is interpretive because the study interprets the teaching orientations of the lecturers and the experiences of the students in their classes. These findings describe the experiences of the first year students of the class of 2013 in the photosynthesis theme of MLB 111. It also describes the teaching orientations of the lecturers.

Experiments can be repeated but case studies can usually not be repeated, which is one of the aspects that make this research method less desirable (Maree, 2007). The following potential pitfalls should be addressed. A researcher should keep the procedures systematic to ensure a rigorous study. The researcher should be careful not to be biased and must report findings fairly. As a Physical Sciences teacher I have developed my own teaching orientation and care should be taken that I do not compare the lecturers' teaching orientations with my own. Frequent discussions with my study leaders assisted with this matter.

One of the shortcomings of case study research is that it cannot be generalised. In this study only two lecturers were observed. One cannot assume that these two lecturers are representative of all novice and experienced lecturers. The findings cannot be generalised towards a population but can rather, together with other similar studies, contribute towards a theory about lecturers' orientations and experience. The research must be compact and must not take too long to complete because it can result in bulky reports that are very difficult to read. Qualitative studies do not always have to be an alternative to experiments but can be used as a complimentary method (Yin, 2013). According to Yin (2013) a case study is an inquiry into a real world situation where the boundaries are not clearly defined. The inquiry relies on multiple sources of data, which necessitates the researcher to do triangulation to verify the findings from each data source. Farmer, Robinson, Elliott, and Eyles (2006) stated that triangulation adds to the validity of findings when multiple sources are analysed. This study is a case study.

3.3 Description of the context and sample

In case studies, the boundaries, the context and sample, the type of data collected and how it is analysed should be defined very carefully. The possible risks should be identified before the time so that they can be addressed timeously (Crowe et al., 2011).

3.3.1 Context

MLB 111 is one of the first year modules at UP and is considered as a HIM. HIMs are courses with a significant impact on student success due to large enrolments and/or strategic placement in multiple programmes.

The module is divided into ten themes and photosynthesis is one of the themes that lecturers identify as problematic because students generally struggle with the concept. Photosynthesis is the seventh theme in MLB 111 and five days are allocated to this theme (*Molecular and Cell*

Biology Study guide 2013). This module was presented from 15 to 23 April 2013. Owing to the large enrolment on the course (1614 students), students were divided into three lecture groups one Afrikaans and two English classes. Two venues were allocated for MLB 111. The Roos hall is an old lecturing halls and can accommodate 450 students. Thuto hall is newly built with better technology than the Roos Hall, and can accommodate 500 students. The Afrikaans group and one of the English groups were in the Roos hall and, the second English group was in the Thuto hall.

The theme was presented to all three groups and was divided in 17 study aims in the study guide:

1. Distinguish among autotrophic, heterotrophic, phototrophic and chemotrophic organisms.
2. Give 3 examples of the importance of photosynthesis to living systems.
3. Describe the structure of the chloroplast and explain where the light-dependent and light-independent reactions take place.
4. Describe the relationship between wavelength and energy in the electromagnetic spectrum.
5. Explain why we can be confident that the light absorbed by the chlorophylls contributes extensively to photosynthesis.
6. Describe what can happen to an electron in a biological molecule such as chlorophyll when a photon of light energy is absorbed.
7. Supply alternative names for the light-dependent and light-independent reactions.
8. Explain how the light-independent reactions are dependent on the light-dependant reactions.
9. Explain the structure and function of a photosystem.
10. Describe photosynthesis as a redox process and contrast cyclic and non-cyclic (linear) electron transport ways (chemiosmosis).
11. Explain how a proton (H^+) gradient is established across the thylakoid membrane and how this gradient functions in ATP synthesis.
12. Summarize the three phases of the Calvin cycle and indicate the roles of ATP and NADPH in the process.
13. Explain how the light-dependant reactions are dependent on the light-independent reactions.
14. Explain why the Calvin cycle is also referred to as the C_3 cycle.
    NB: Do not confuse the Calvin cycle with the Krebs cycle.
15. Explain what photorespiration is.
16. Describe how the C_4 pathway and CAM pathway increases the effectiveness of the Calvin cycle in certain types of plants.
17. Explain the differences between C_3, C_4 and CAM plants.

These study aims can be considered learning outcomes for the students on what they need to know for the examination. The students attended four 50 minute academic classes per week, and one three hour session, which was used as a tutorial practical session. One tutorial session was scheduled for photosynthesis. It was a combined tutorial for photosynthesis and respiration and took place in the week 27 February to 9 March 2013, almost a month before the theory classes were presented.

3.3.2 Lecturers sample

Two lecturers volunteered to be part of this study. They are Ms Amy and Prof James. The pseudonyms are used to protect the identity of the lecturers and have been chosen to represent their gender and qualifications. Both lecturers are Afrikaans speaking with excellent proficiency in English. During the study the teaching orientations of the lecturers were studied and compared.

Prof James is the experienced lecturer (EL) and at the time of the study he was 60 years old. He has been a professor in the Department of Biochemistry at UP since 1992 and served as the head of the Department from 2003 - 2011. Over the last 25 years he has been a supervisor for four PhD and 34 MSc students. He is author or co-author of 52 published scientific articles. In his career he has received 12 merit awards related to his research and work as lecturer. Prof James has lectured large first year groups (more than 400 students) for more than 15 years. This participant is a biochemist and photosynthesis is not in his field of expertise.

Ms Amy is the beginner lecturer (BL). She was 33 years old at the time of the study and has obtained an MSc in Plant Sciences and three years' experience in teaching large groups (more than 400 students) in MLB 111 at UP. For most of her career she has lectured smaller classes. She has been responsible for conducting practical training and tutorial sessions associated with these courses. Photosynthesis lies in her field of expertise.

3.3.3 Student sample

The student sample was used to collect data on the students' experiences of the teaching orientations of the lecturers. The sample was taken from the 2013 first year MLB 111 students at UP. The population consisted of 1641 students who enrolled for the course. A stratified sample of 259 students was chosen. Students placed in the Tuesday afternoon practical groups were invited to take part in the study. This group excluded the students enrolled for dental and medical courses but gave a true representation of the number of Afrikaans and English speaking students enrolled in the course. The sample changed into a convenience sample because the participation of the students was voluntarily.

3.4 Data collection

A case study looks at a phenomenon in its real life context (Cohen, Manion, & Morrison, 2007). Subjective and objective data were collected. Multiple sources of data were used to produce a rich description of the specific case. Lecturers' interviews and the video footage were used to answer the first research question, while the student journal entries were used to answer the second research question.

3.4.1 Lecturer interviews

At least three types of interviews are defined in the literature (Maree, 2007). Open ended interviews are usually conducted with free discussions with the participants, where they explore their views. Semi-structured interviews require the participants to answer a set of predetermined questions, allowing for clarification and probing of answers. Owing to the nature of interviews the interviewee can easily be side-tracked by irrelevant information, and the researcher must then guide the participant back to the focus of the interview. In structured interviews the questions are developed in advance, used with larger groups and are frequently repeated to ensure consistency.

The semi-structured interviews used in this study (Appendix 1), were conducted individually with the lecturers after the topic was taught. The same questions were used for the two interviews but extra questions arose during the different interviews that made every interview unique to the lecturer. The interviews determined the nature of the lecturer's teaching orientations by looking at their learning goals, beliefs and TSPCK as discussed in chapter two.

3.4.2 Video material of lectures presented

Technical staff from the Department for Education and Innovation made a video recording of each one of the lectures presented by participating lecturers. Eighteen lectures in total were recorded which included a trial run in every class to introduce the students to the camera team. This helped to ease the students during the recording of the photosynthesis lectures. The videos were used to investigate how lecturers transfer their TSPCK into pracice, as captured in their interviews. In this way data collected about the teaching orientations of lecturers could be triangulated.

3.4.3 Student journals

The students in the sample were asked to complete a daily journal (Appendix 2). The journals were made available electronically and students responded online. This made the sorting of the data easier and ensured the anonymity of the students. Students were reminded every day via sms to complete the journal after every class for the duration of the teaching of photosynthesis (five lectures per lecture group for three lecture groups of ca. 600 students each). Students were asked to comment on the topics that were explained exceptionally well and the topics that were still unclear. They were also asked to give reasons for their answers. The students captured their experiences of the way topics were explained and gave their opinion of the presentation skills and the characteristics of the lecturers although it was not asked of them. The journal posed seven questions. The first three questions were used to categorise the journal entry according to the lecturer, venue and date of the class attended. The rest of the questions asked students to identify topics covered in the lecture, topics they felt were explained exceptionally well and the topics they still found unclear. The students could also give general comments. The total number of entries submitted for the experienced lecturer was 86 and for the beginner lecturer 166.

3.5 Data analysis

3.5.1 Lecturer interviews

Both interviews were transcribed by the researcher. These transcripts are included as Appendix 1 the respective lecturers signed them off as a true version of the interview. The transcriptions were analysed with ATLAS.ti. Evidence of teaching orientations in the answers of the lecturers was grouped together under TSPCK, beliefs and learning goals. One answer could be included in more than one group. Quotations were chosen to substantiate the interpretations. All of the data was tabulated and is presented in chapter four.

3.5.2 Video material of classes

There were two sets of videos for Ms Amy seeing that she taught both of the English lecture groups. After the analysis of the first two lecture group sessions it was concluded that there was no significant difference between the teaching of the two groups and only one set of videos was analysed. Ms Amy’s classes in the Roos hall were chosen because Prof James’ classes were also conducted in the Roos hall. This excluded the possibility that lecturers could get negative reports due to the different technologies available in the Roos and Thuto halls.

Each video was analysed. The textbook was used as a benchmark for the coverage of the content. It was assumed that the choice of the textbook implied that it was used as the primary resource for the course. Deviations from the content and depth of coverage would therefore have to be interrogated in terms of the preferences or individual style of the lecturer. The coverage of the theme in the textbook was used as a guideline for the time that lecturers should theoretically spend on each of the big ideas. The time that each lecturer spent on a specific big idea was recorded. The data was used to compare the time the lecturers spent on each big idea. The coverage of each big idea in the textbook in terms of the space allocated to each idea was also converted to percentages and was part of the comparison drawn. The summary at the end of the chapter was included, but the questions at the end of the chapter were excluded from the calculation. The time spent on each big idea in class was used as a proxy for the depth of the coverage of each big idea. This could only be justified if the lecturers use their time productively. After attending the classes and analysing the videos the researcher is convinced that this was the case and that the assumption is justified. The result of the analysis of time spent and the coverage of each big idea is presented in chapter four.

The video material was also used to find evidence of the lecturer's TSPCK. Every time that evidence was found, it was tabulated with the time to make validation easier. A tabulation of this data in included in Appendix 3 and 4. This evidence was used to confirm that the lecturers transfer the TSPCK that was revealed in the interviews. The learning goals of each lecturer were also confirmed in the video material, but it was not possible to abstract their teaching beliefs from the video footage.

3.5.3 Student journals

The experimental design did not make it possible for students to compare their experience of the teaching of one lecturer with that of the other. This information was inferred from their comments about one lecturer only. It was thus decided to use the ratio of positive and negative responses for a particular lecturer as the statistic for this purpose. There is a possible bias in this approach as the possibility that one group, e.g. the Afrikaans group, may have been more reluctant to express positive opinions than the other group. The journal entries were analysed inductively with ATLAS.ti. The first step was to use the first three questions to divide the students into two groups: beginner lecturer's (BL) and experienced lecturer's (EL) students. The questions prompted the students to report their experience of the way the lecturers taught and the topics that they experienced to be explained exceptionally well and those that they still found unclear. The last question in the journal provided an opportunity for students to make general comments. Some students used this opportunity to express their opinion on the characteristics of the lecturers. A new category thus emerged from the data. The entries for general comments were divided into two categories: responses about the lecturer and responses about the content. Inductive analyses allows new themes to emerge during the analysis of data. Initially the plan was to only look at the students' responses on how they experienced the content explained by the respective lecturers. The students' comments on the last question caused a new theme where the lecturers' characteristics were also divided further into remarks about their lecturing, their personalities and the students' personal experiences in the classroom. These were then further divided as shown in figure 3.1 below. The responses of the students that concerned the characteristics of the lecturers were divided into three groups: remarks about the lecturing, personal characteristics and the students' personal experience.

For each of the lecturers the number of responses for each category in figure 3.1 was counted. These totals were converted to percentages. These percentages were used to provide a differentiated overview of student experiences per lecturer and per content subtopic. The findings on content categories were compared to the time lecturers spent on these big ideas. These findings on lecturers and their teaching were used in the triangulation to answer the second research question.

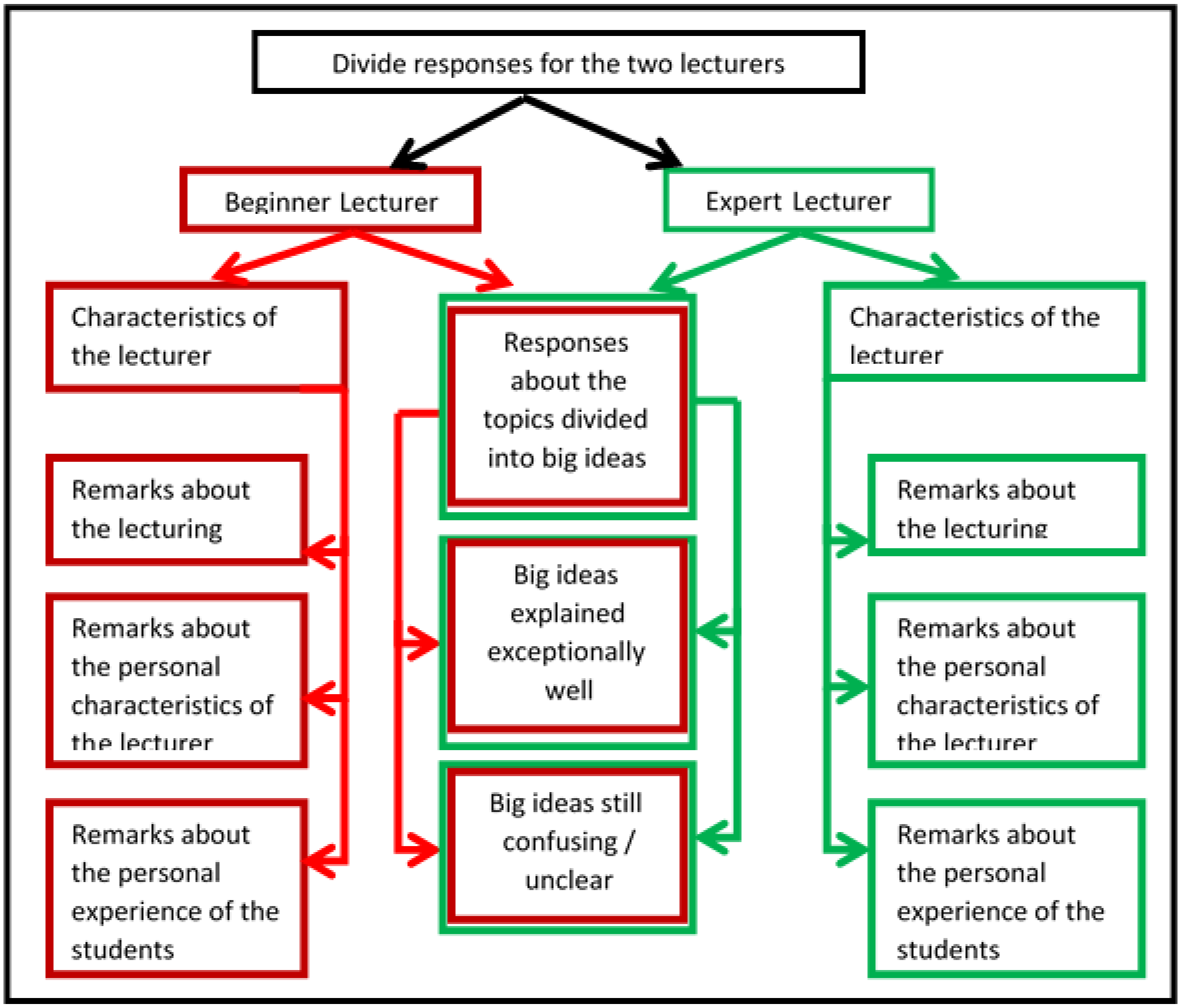


Figure 3.1: Categories that emerged from the journal entries

3.6 Ethics

Ethical issues arise from each step in the investigation. During the planning of the research most of the ethical issues should be addressed. The first step was to ensure that the student sample represented the composition of the class. This meant that the stratified sample had to be a true reflection of the ethnic and language composition of the MLB 111 group. It was important to get the informed consent of the participants. The chosen participants were informed about the reason for the research and they were told what was expected of them. This was done in writing (Appendix 5) and also in an introductory speech. The students signed a consent form if they were willing to participate (Appendix 6). Although the lecturers volunteered to be part of the research the same procedure was followed and consent forms were signed by them too.

The participants should not be harmed in any way thus meaning their human dignity should be protected. Anonymity and careful reporting ensures this protection. Anonymity of the students ensures that their honest replies in the journals cannot be traced back to them and used against them in any way. By default, the computer programme used for the journal entries in this study omitted any data that could be used to trace the students. Pseudonyms were used for the lecturers to ensure that no reports could be used to harm them in any way. The video material of the lecturers was not made available to anybody but the researcher and the supervisor. Careful reporting also ensured that there was no personal information released about the lecturers. Another measure taken was continuous feedback to the lecturers. This ensured that they were fully informed about the progress and the findings. Before the study commenced ethical clearance was applied for (Appendix 7) and it was received in January 2013 (Appendix 8).

3.7 Trustworthiness

Trustworthiness is a measure of the accuracy and the validity of the study. Trustworthiness can be divided into four main categories: credibility, transferability, dependability and conformability (Guba, 1981).

Credibility was ensured by spending time with the students and the lecturers before the sample collection to ensure that they acted naturally. Making notes of all interactions provided proof that the researcher stayed focused during the research. It is very important to have debriefing sessions with peers to provide opportunities for the researcher to test his/her growing insight. Triangulation is a valuable tool to cross-check data. Information that cannot be verified with triangulation must be handled with care so that the researcher does not impose his/her own ideas on the findings. It is important to keep record of all data collected to avoid personal, biased interpretation by the researcher. Structural corroboration prevents internal conflicts that cannot be explained by the researcher. Because of the different data sets, conflicts cannot be avoided. Experts need to test analyses and conclusions made by the researcher, called referential adequacy. Member checking is a continuous process that prevents biased interpretations (Guba, 1981). *Transferability* asks the question whether the findings can be transferred to the wider population. In qualitative research generalisation is not a goal but it is important to report findings in such a way that the reader is able to identify with the findings (Krefting, 1991). *Dependability* means that when triangulation of different data sets is done the findings are strengthened. Overlap methods and an established audit trail enable an external auditor to examine data collection methods, analyses and interpretations. Conformability refers to steps that are taken to ensure that the findings are not the result of personal preferences. Again an audit trail can be used as cross reference for all analyses and interpretations.

In this study, all of the data that was analysed, was validated by another researcher who drew 10% of each data set for confirmation of the analysis. The analysis of the interviews, video data and the student responses were done separately. For each of the data sets the differences in the analysis of the data was less than 10%.

According to Cohen et al. (2007)

> *'One way of controlling for reliability is to have a highly structured interview, with the same format and sequence of words and questions for each respondent.'*

They also stated that we need to recognize that the interview is a shared, negotiated and dynamic social moment. In this case the interview protocol was semi structured with the intention to collect rich data from each lecturer which may have compromised reliability to a limited extent.

3.8 Summary

The analyses of the interviews and the videos were used to answer the first research question: *How does the teaching orientation of a beginner lecturer differ from that of an experienced lecturer?* Triangulation was used to ensure trustworthiness of the findings as is shown in Chapter four. The students' journals were used to answer the second research question: *How do students experience the teaching of each lecturer?* The students' journal entries were used to compare positive and negative comments on the lecturers and the course content. The findings are presented in Chapter four.

CHAPTER 4: RESULTS

4.1 Introduction

This study is aimed at answering the following research questions:

1. *How does the teaching orientation of a beginner lecturer differ from that of an experienced lecturer?*
2. *How do students experience the teaching of each lecturer?*

Teaching orientation as a construct is conceptualised to consist of the beliefs of the lecturers, their learning goals and their pedagogical content knowledge. Different types of data were collected to answer the research questions. As explained in the previous chapter, the data sources for answering research question one were interviews with the lecturers and video capture of lectures. The journal entries of the students were analysed to answer the second research question. The use of multiple data sources facilitated the triangulation of findings to ensure trustworthiness. The types of data that were collected and analysed are shown in Table 4.1 with further specification of the number of units per data sources and the language of communication.

Each of the different components of the teaching orientations (learning goals, beliefs and TSPCK) were looked at in tandem to give a clear comparison of the two lecturers. Two data sets were analysed for evidence of TSPCK. Firstly, the lecturers' views on their own TSPCK were analysed from their respective interviews although the term TSPCK was never mentioned and discussed with the lecturers. TSPCK is tacit knowledge (Kind, 2009) which means that the lecturers are often not aware of the facets of their TSPCK. As the lecturers are not familiar with the pedagogical terminology they probably would not have been able to articulate it clearly. Secondly, their practise was analysed for the manifestation of TSPCK. The time allocation in class per big idea also gave some insight into the teaching orientations of the lecturers.

The journal entries of the students were used to answer the second research question. The big ideas were identified that the students felt were still unclear and the BIs that were explained exceptionally well. The journal entries of the student groups of the two lecturers were analysed separately before a comparison was made.

Table 4.1: Types of data collected

Type of data	**Source**	**Units of data**	**Language of students**
Interviews	Transcribed interview with Prof James	1	English
	Transcribed interview with Ms Amy	1	English
Daily journal entries of the students	Students: Tuesday morning practical group	EL R1: 39 * EL R2: 21 EL R3: 11 EL R4: 6 EL R5: 9 Total: 86	Afrikaans and English
	Students: Tuesday morning practical group	BL R1: 14 BL T1:29 ** BL R2: 33 BL T2: 22 BL R3:29 BL T3: 5 BL R4: 12 BL T4: 4 BL R5:16 BL T5: 2 Total: 166	English and Afrikaans
Daily observations of the classes (Videos)	The lectures	5 DVD's BL and 5 DVD's EL	English and Afrikaans

* R = Roos Hall ** T = Thuto Hall

4.2 Comparison of the teaching orientation of the two lecturers

This section will specifically deal with research question one.

How does the teaching orientation of a beginner lecturer differ from that of an experienced lecturer?

A comparison was drawn between the way that Ms Amy and Prof James introduced and explained photosynthesis. The teaching orientation of each lecturer was analysed under the following three categories: lecturer's learning goals, lecturer beliefs and TSPCK (see paragraph 2.5). During the interviews the lecturers gave an insight into their learning goals and beliefs, both directly and indirectly. This information was verified and supported by the data from the video footage to give evidence of the lecturers' TSPCK. These two sources enabled triangulation of the findings.

4.2.1 Learning goals of the lecturers

The lectures have a common learning goal. Both of them want the students to know and understand the theme by the end of the lectures. Owing to their respective disciplines they may have slightly different learning goals for different themes in photosynthesis. In this study the former indirect evidence for learning goals was obtained from an analysis of the time that they spent in class on each of the big ideas in the topic (see section 4.3).

Learning goals of Ms Amy (BL)

It is evident from the interview with Ms Amy (BL) that she had specific goals in mind on what the students need to know by the end of the photosynthesis section. The group consisted of medical, dental, as well as biological sciences students in the same class. In making decisions about the way to structure her classes she kept in mind that MLB 111 is an entry subject for all biological sciences courses, which means that the basic concepts needed to be taught even though the students may not see the relevance of the topic.

> *'I think because we have to deal with the medical students, and we have to deal with the dentists and we have to deal with the animal science students and they don't necessarily need this, but there is some things expected from us in the other courses, I mean if the other course they want to at least know they have heard about this so we have to do it and we have to test the knowledge.'*

There was evidence of disciplinary bias in the views of the two lecturers, which is evident in their approaches and beliefs about the significance of the Calvin cycle. Ms Amy and Prof James disagreed on the importance of the specifics of certain reactions in the Calvin cycle. Ms Amy felt that the reason for the different emphasis in the same cycle was because the two lecturers were from different disciplines (botany and biochemistry). Ms Amy only explained broad ideas instead of specifics in the Calvin cycle. To Ms Amy the fact that energy is added is important but not how the energy is transferred (the chemical reaction).

> *'Calvin cycle they talk about an aldehyde molecule being reduced to a carboxyl. I mean I don't care, it is just adding energy that's what for me it is what is important you are adding energy to your system. He wants them to know that this is being reduced to that. That is the one thing that I just quickly remembered I have never even said it I said it this year because some students tend to remember it a little bit better if you give them that little extra. But for him it is very important. So I think there is there is a very big difference in approaches between different disciplines if you can say it like that.'*

Contrary to Prof James, Ms Amy did not express any explicit teaching goals that she has formulated for herself during the interview. She mostly concentrated on delivering content which reflects her primary focus as a beginner lecturer.

Learning goals of Prof James (EL).

Prof James valued a structured organisation of the content. His goal was to present complete units in each lecture period rather than to allow units to flow over to the following lecture.

> *'There is a practical element. In there we do it according to the study guide the study guide has got the work divided into study aims. I then go and I prepare the whole thing as a unit and I then hunt according to the study aims I hunt for sensible starts and stops so that we do some things to completion so that we don't take out something of the middle of a study aims so that one study aim is then half way in one lecture and then there is the last half of the same study aim in the next section.'*

Prof James saw the bigger picture on where photosynthesis fits into the biology of life and wanted to share those insights with the students.

> *'I am the bigger picture person so I want them to see the bigger picture always and that is why I did the Calvin Cycle the carbon fixation part I did in a particular way that I have learned what was different from ….. notes.'*

Prof James emphasised the chemical detail of the reactions in the Calvin cycle.

> *'We have compared notes … and me, I lay emphasis on balancing on all those ATP's and carbon's and where they go. I made a big issue of that....'*

Analysis of the video data confirmed that this emphasis on chemical detail was a characteristic of Prof James' lectures but not that of Ms Amy.

The learning goals of the lecturers are compared in Table 4.2. It is evident that there is a distinct difference between the learning goals of the two lecturers. Prof James concentrated on the bigger picture of where photosynthesis fits in, while the specific courses where photosynthesis is needed was important to Ms Amy. When the lecturers taught the theme their emphasis differed. Prof James concentrated on specific chemical reactions in energy transfers, while Ms Amy mainly concentrated on the broad ideas of the transferred energy, which reflects the difference in their disciplinary backgrounds. Prof James insisted that they look at specifics in the Calvin cycle because it is needed by the students in later biochemistry courses. The way in which the two lecturers discussed, negotiated en accommodated the requirements of their respective disciplines showed that they work closely together and that they respect each other's opinions, even though they do not have the same level of teaching experience. It is possible that the outcome of a study like this could be different for lecturers who do not work as closely together as Prof James and Ms Amy (discussed in chapter 3).

Table 4.2: Comparison of the learning goals of the lecturers

Ms Amy	Prof James
Specific goals of what the students need in later courses Concentrate on the broad ideas of energy transfer	Structured organisation of the content Concentrate on the holistic picture Concentrate on specifics of chemical reactions

4.2.2 Beliefs of the lecturers

The interview data was analysed for evidence of the lecturers' beliefs. Borg (2001) formulated a general definition of beliefs: '*a belief is a proposition which may be consciously or unconsciously held, is evaluative in that it is accepted as true by the individual, and is therefore imbued with emotive commitment: further, it serves as a guide to thought and behaviour'* (p. 186). Beliefs can be divided into beliefs about the students, content, context and ways of learning as discussed in chapter 2 paragraph 2.3.1. The beliefs of the lecturers and evidence thereof is reported below for each of these aspects.

Beliefs of Ms Amy (BL).

Students: **The BL admitted that she treated all of the students as if they had no prior knowledge when she started the photosynthesis section of the work.**

> *'because biology is not a prerequisite to get into BSc, so we assume they know nothing and we start from as basic as we can possibly go'*

Content: **Some chemical aspects were not covered by the BL because she believed that they were too difficult for the students to understand and that they were not essential for further learning.**

> *'For me that is not important because that is not something you use in botany that oxidation reduction thing for... I have never asked that (in a test or exam) and I will I must tell you I have never explained it to the students because it confuses them'.*

Ms Amy emphasised different aspects of the content and ascribed that to her disciplinary background as compared to that of the EL.

> *'.....I feel the concepts is important for me in biology and biochemists focus a lot especially the respiration of exactly how much you get out of where and what is reduced and what is oxidised.'*

Context: The BL admitted that the big classes made the teaching and discipline more challenging.

> *'I think the big classes influence the discipline to a great extent because you cannot teach in quiet and when you sit at the back of the class the students cannot hear you if the students in the front of the class are talking'*

Ways in which students learn: There is little evidence that the BL took the different learning styles of students into account in her planning and practice. She was guided by her own preference in her choice of teaching aids and her own learning style rather than by the learning styles of the students.

> *'For me personally I especially with stuff like photosynthesis and respiration it is easier to explain if you can draw it step by step.' and ' I study by drawing so I teach by drawing.'*

Beliefs of the Prof James (EL)

Students: The EL believed that students coming from school are not adequately prepared for university any more. In response to the question 'You mentioned that you know what to use the next time and what works well, the correction that you then do, when do you do it? Immediately or next year?' the EL said:

> *'If you do not like chemistry it is too late and it is usually school preparation and it is not (any) more adequate enough or I find the students' ill prepared in chemistry. They are ill prepared when they come from school to university'*

He also admitted that he often expected more knowledge from students than what they really had. Students did similar chemical reactions in grade 12 physical sciences which should provide the students with a bit of background knowledge. Prof James expected the students to remember what they learned at school, and he considered it then as pre-knowledge. Their lack of knowledge surprised him.

> *'…… to assume students know and that assumption is wrong so I am always surprised with the type of questions the students come up with afterwards that I thought, gee, I thought I was being professional and that I had to go right down to such low levels of explanation"*

Content: The EL viewed the theme in relation to the bigger picture of the biology of life.

> *'For me the important thing of photosynthesis is 50% of what makes life go. You can say the anabolic part of life and then the rest is the catabolic*.'

Context: For the EL discipline in the big classes was not an issue.

> *'This is not a high school so personally I regard freedom at the University very high, so unless it is extremely disturbing if students would get up in the middle of the class to walk out I would do absolutely nothing to stop them, but if it is extremely disturbing and disruptive then I would stop them, but I am hoping that by making the class fun that I get their attention from a positive attitude and that I am not frustrating them to them becoming noisy or that they are disgruntled and talk to one another so but no I am not strict on class discipline........'*

Ways in which students learn: Prof James believed that content should also be covered in an entertaining way. He was asked in the interview about his regular invitation to the students to join him in singing lyrics about the most important facts of biochemical processes which were set to well-known tunes and he explained it as follows:

> *'….but I found it from experience to be very positively received and I thought it was a good way to therefore create positive attitudes and fun in the classroom and the students mentioned also in the students assessment they usually say they recommend and they would like other lecturers also to make the class more fun to attend.'*

The beliefs of the BL and EL are summarised and compared in table 4.3. The beliefs about students differed for the two lecturers. While Ms Amy treated all of the students as if they had no prior knowledge, Prof James expected more prior knowledge from them. Prof James regarded photosynthesis holistically and looked at it in the bigger picture but Ms Amy concentrated on where photosynthesis is needed in another courses. Both lecturers found the Roos hall lacking in technology. Ms Amy admitted that she struggled with discipline in the big class while Prof James stated that he had no discipline problems. Prof James believed that students learn best while having fun while Ms Amy stated that the best way to learn is by drawing the different processes Appendix 1.

Table 4.3: Summary of the beliefs of the lecturers

Beliefs	**Ms Amy**	**Prof James**
Students	Assumed no prior knowledge of photosynthesis.	Students are not prepared for university. They are not in command of the expected pre-concepts.
Content	Tried to meet the requirements of follow on modules in botany. Parts of the content were not covered because it was believed to be too difficult for students (Micro view)	Viewed the content in relation to the bigger picture of the biology of life (Macro view)
Context	Found discipline in the big class challenging	Did not think that discipline in the big class was an issue
Way in which students learn	Some evidence of belief in the benefit of drawings for student learning.	Believed that students learn better if they have fun.

4.2.3 TSPCK of the lecturers

TSPCK has been conceptualised to consist of student prior knowledge, curricular saliency, what makes the topic difficult, representations and teaching strategies, as was discussed in Chapter 2. The interview data as well as the video footage of the classes were analysed for evidence of each of these components. The time allocated per BI by the lecturers in comparison to the coverage of each BI in the textbook was also analysed here to help understand how the lecturers implemented their TSPCK. In this section the findings from the interviews will be presented first followed by that from the video footage and lastly the time allocations per big idea.

4.2.3.1 TSPCK from the interviews

The questions in the interview protocol were formulated to probe specifically for the five components of TSPCK of the lecturers. An example of one of the questions from Appendix 1 is:

> *Does your knowledge of what the students know, don't know and what they struggle with, influence your planning?*

This type of questioning posed a risk that respondents may have been prompted to declare knowledge that they did not possess explicitly. It was thus necessary to also analyse the video footage to substantiate the inferences made from the interview data.

TSPCK of Ms Amy (BL)

Student prior knowledge: The lecturer was aware that prior knowledge may be very limited for many students and made provision for that.

> *'because, , biology is not a prerequisite to get into BSc, so we assume they know nothing and we start from as basic as we can possibly go'*

Although Ms Amy said in the interview that she did not expect any prior knowledge from the students she constantly reminded the students of the sections that they already did at school level in Physical Sciences and in previous themes in MLB 111 as will be shown in the analysis of the video data.

Curricular saliency: From the interview data it is evident that Ms Amy can easily identify the big ideas in the topic. She used this knowledge in her planning. The way she planned the lessons demonstrated the depth of her knowledge of macro saliency. Her planning also showed that she knows where the section fits in the bigger picture of qualifications in biological sciences (macro). She kept in mind what prior knowledge would be required for some of the second year subjects and taught accordingly.

> *'….there is an intro part that where you have to understand the basics of light '*
>
> and
>
> *'…..properties so that is also a section? That is also a section and then you start with the light reactions and chemiosmosis that goes with it, the next one is the Calvin cycle and the other part of it is C4 and CAM but it is supposed to fit in with the Calvin cycle'*

What makes the topic difficult: Based on the assumption of the BL that students have little or no prior knowledge, she was very aware which concepts the students would find difficult or confusing. She listed the following topics: the difference between C4 and CAM, chemiosmosis, the Calvin and Krebs cycles, the difference between respiration and photosynthesis and photosystems.

> *'They seem to struggle to put the concepts together and that is easier to do on a one to one basis'*
>
> and
>
> *'The Calvin cycle; I must admit the Calvin cycle, and just physically getting them to understand how many carbons you have to put in to get something out and how much energy you use doing that. That energy incorporation and then the adaptations to that Calvin cycle that is by far the thing they struggle the most with.'*

Her inclination as a botanist is evident, since she did not count carbons and kept track of the energy transfers as would have been important for biochemists. Her disciplinary bias is also evident in what she as a botanist thought the students will find difficult in the Calvin cycle. From the journal entries of the students she was right, they did find the Calvin cycle difficult. Although she knew that, it seemed as if she did not keep that in mind when considering the time she allocated to the big ideas, as will be seen later in this chapter.

Representation: Representations are the analogies, models and teaching strategies used to explain difficult concepts that students may have. The BL used a special device called a Bamboo pad and a PowerPoint presentation which allowed her to draw on the small screen of the Bamboo pad, and the students could see it projected onto the big screen. This allowed her to develop the concepts visually by means of drawings. She also mentioned that she used animations, but from the responses of the students it can be concluded that the animations did not really have an impact on their experiences. This will be discussed in detail in paragraph 4.3.

Teaching strategies: Teaching strategies are reasoned conceptual strategies, in other words the choice of specific representations is informed by a consideration of students' prior knowledge and misconceptions and an understanding of difficulties with the topic. Ms Amy verbalised in her statement little consideration for the different learning styles and needs of the students, but used animations that she had available. She used her own way of studying as a measure of which representations would be effective.

> *'but there is really no other way to do it; I mean the Krebs cycle is a cycle and you have to do it like that and the Calvin cycle is also a cycle and you have to explain it as a cycle in order for it to work.'*
>
> *'I would sit in front of my computer and look at the different animations that I do have regarding that theme then I would try to incorporate it…..'*

She also admitted that she had lots of ideas on how to present photosynthesis but did not know how to implement them in the big classes.

> *So I have lots of plans but it is very difficult to implement them in the big classes*

Ms Amy also preferred to use the Bamboo pad as a device on which to do her drawings, instead of using the pointer that will only allow her to highlight certain parts of a diagram. When questioned why this was her preference she answered:

> *'For me personally I, especially with stuff like photosynthesis and respiration, it is easier to explain if you can draw it step by step. It's a personal thing, I know of many people do not do it like that. I study by drawing so I teach by drawing.'*

TSPCK of the Prof James

Student prior knowledge: From the report on the beliefs of the EL it was already evident that although Prof James believed that the students were not adequately prepared in grade 12 for university, he still expected more knowledge from them than what they had.

> *'……it is usually school preparation and it is not more adequate enough or I find the students ill prepared in chemistry. They are ill prepared when they come from school to university.'* And *'……assume student know and that assumption is wrong so I am always surprised with the type of questions the students come up with afterwards that I thought, gee, I thought I was being professional and that I had to go right down to such low levels of explanation,….'*

Curricular saliency: The EL put a lot of emphasis on the centrality of photosynthesis to the biology of life (macro).

> *'For me the important thing of photosynthesis is 50% of what makes life go. You can say the anabolic part of life and then the rest is the catabolic. So the respiration is the catabolic path, the breaking up of whatever that was produced or the extraction of energy in the process of breaking down. That is respiration wherein photosynthesis is the generation of these compounds and also the recovery of gasses like CO_2, oxygen balance, CO_2 being produced by respiration, CO_2 being used and fixated in photosynthesis.'*

He was also aware of where photosynthesis fits into the curriculum of MLB 111 (micro).

> *'so the energy concepts to make all the themes also relating to each other, because the energy concepts are theme five, respiration is theme six and photosynthesis is theme seven*

> *and they all are connected so I go right back to use the concept of theme five, six and seven so that they all integrate'*

However, during the interview Prof James could not identify big ideas and did not demonstrate an awareness of what is required for the follow-up courses. It seems as if he was more strongly guided by the arrangement of his presentations according to the time available for teaching than according to the central big ideas of the topic. He also seemed more focussed on the bigger picture and on the organisation of the topic details into logical chunks that would make the material more accessible to students. It seemed during the interview that he was more removed from the details of photosynthesis than Ms Amy although he concentrated more on the specifics of the reactions in the topic in class. When asked what makes the topic difficult Prof James showed that although he could not explicitly answer direct questions about big ideas, he had a good knowledge of the content and the big ideas. This contradicted his reaction when asked about big ideas.

> ***'We would like you to identify the most important big ideas in this topic. By big idea we mean an excellent conceptual effort that can be phrase in a single sentence of a fragment.***
>
> *For me the important thing of photosynthesis is 50% of what makes life go. You can say the anabolic part of life and then the rest is the catabolic. So the respiration is the catabolic path the braking up of whatever that was produced or the extraction of energy in the process of breaking down that is respiration wherein photosynthesis is the generation of these compounds and also the recovery of gasses like CO2, oxygen balance, CO2 being produced by respiration CO2 being used and fixed in photosynthesis. So I think one of the most important aspects on photosynthesis is to demonstrate the connectedness how it is connected to all the other aspects of life and environment and health.'*

This showed that although he does not realise it, he has a fairly good knowledge of curricular saliency. This tendency, that PCK is often tacit and not articulated clearly by teachers, is described in literature (Loughran, Mulhall, & Berry, 2004)

What makes the topic difficult: Prof James had clear ideas on why the students find the work difficult. He listed the following chemical reactions, that are essential for the understanding of certain concepts, as difficult: Chemiosmosis, the difference between oxidative and substrate phosphorylation, the link of phosphorylation to the formation of ATP, the electron transport chains and the balancing of the energy in and out in the respective systems, C4 and CAM. Apart from these sections that are difficult he also believed that a lack of interest on the students' side makes it difficult for them, which is evident from the following comments:

> *'the moment you come to CAM and C4 it is a specialised topic, so it goes into a corner of specialisation and students may experience at a higher concentration level because it becomes a specialisation ….. you already have to understand the basic concepts of photosynthesis in order to apply the basic concepts of photosynthesis in a higher specialized understanding …..'*

> *'They could be difficult, not difficult…., but because it does not motivate them as strong in their studies let's say 50% or 70% of the class, because 70% of the class is veterinarian, medical doctors and people aspiring to be either of those is 70%, so it could be that the students are not as motivated'.*

Prof James listed specific chemical reactions that he thought students will find difficult while Ms Amy concentrated on specific concepts that students might find difficult rather than on problematic chemical reactions. He focused on the micro level (specific details and reactions) and did not mention specific concepts. His experience as a lecturer and researcher caused him to also look at the content holistically. When looking at the bigger picture, he suspected that the majority of the students are not interested because of perceived irrelevance to their professional goals.

Representation: Representations are the analogies, models and teaching strategies used to explain difficult concepts. Prof James often relied on singing in his class to consolidate the content knowledge.

> *'…on the photosynthesis I sang because that was at the level of 1st years and a number of students actually told me they want the words….. they wanted the words because they say it helped them to learn. They found it fun to learn as well as when they knew they had the words of the song with them.'*

Prof James found a representation that appealed to the students and he was confident enough to use it as a teaching tool.

Teaching strategies: Teaching strategies are reasoned conceptual strategies. The choice of specific representations is informed by a consideration of students' prior knowledge and misconceptions, and an understanding of the difficulties within the topic.

There is more than one reason for the main teaching strategy that Prof James used in his class.

> *'It is always good to get the student in an attitude where they enjoy the class so that is very important to generate a positive attitude from the learners. So if the students would have taken negatively to it if I would have sung my first song,…. but I found it from experience to [be] very positively received and I thought it was a good way to therefore create positive attitudes and fun in the classroom'*

Prof James also prefers to use a pointer to illustrate the reactions on the slides in class unlike Ms Amy, who prefers drawing on the Bamboo pad. When question on why he preferred the pointer to the Bamboo pad he answered:

> *'…so my hand eye co-ordination is simply not good enough for using it. I did try …..and I just couldn't see myself using that thing in class and then losing my confidence when I write off the board or something like that. I couldn't use it, I tried.'*

The evidence of TSPCK for the respective lecturers as deduced from the interviews is summarised and compared in Table 4.4.

Although it was possible to find evidence for all components of TSPCK in the accounts of both lecturers, specific differences were evident. Prof James showed the characteristic of an experienced lecturer, by looking at the bigger picture when asked why students find the topic difficult. He was aware of specific concepts that students would find difficult (micro) but he also realised that the most important reason for why the majority of students in the class found photosynthesis difficult was a lack of interest. Ms Amy focused only on the micro level and identified the specific big ideas that could potentially be difficult for the students. Prof James stated that the atmosphere in the class should be relaxed and fun, while Ms Amy wanted her classes to be quiet in "an atmosphere of learning". Their teaching approach from their representations and teaching strategies are very different although the students found both ways satisfactory as observed later in the chapter. In the following paragraph their responses in the interview will be compared to their practices in the classroom.

Table 4.4: Evidence of the lecturers' TSPCK during interviews

TSPCK	**Ms Amy**	**Prof James**
Student prior knowledge	Expected no prior knowledge from the students because she knows that Life Sciences are not a prerequisite for MLB 111. She knew what the level of prior knowledge would be	Expected more prior knowledge than what students had. He is not in touch with the level of prior knowledge of the students
Curricular saliency (Connectedness)	Emphasis on where knowledge of photosynthesis is required in 2nd year courses.	Emphasis on the connectedness of photosynthesis in the living world and how it fits in with other themes in MLB 111.
What makes the topic difficult	The different concepts in photosynthesis: Instead of listing specifics, she listed broad concepts	Students show a lack of interest because of perceived irrelevance. He also listed specific chemical reactions in the different concepts.
Representation	Drawing structures on PowerPoint slides with the Bamboo pad device and use animations.	Lecturer lead singing of songs to reinforce the content
Teaching strategies	Use the Bamboo pad, because drawing is a way of learning	Sing about the concepts, because it's a fun way to learn

4.2.3.2 TSPCK from the classroom video data

The classroom video footage was analysed for evidence to corroborate the indications of the lecturers' TSPCK that were extracted from the interviews. The video footage was analysed for manifestations of each one of the five components of TSPCK. The type and time of occurrence was captured in order to generate the summaries of occurrences shown in Appendix 6 for Ms Amy and Appendix 7 for Prof James. The comparison of frequencies of occurrences is presented in Table 4.5. Different keywords were used to count the occurrences. To identify when a lecturer would stress difficulty in the topic, phrases like "be careful", "take note", "be aware", "do not confuse or swop" etc. as well as any form of warning would be noted. Two examples are given below from appendices 4 and 5.

> *photosynthesis is extremely complex we only do the tip of the iceberg*

Be aware one uses NADPH not NADH for anabolic reactions

Prof James explained that he would often sing specific songs with the students. Thus songs were counted as a representation and a teaching strategy. A representation was only counted as a teaching strategy if the lecturer explained in class why the specific representation style was used.

Table 4.4 shows that both the lecturers demonstrated TSPCK in their lectures although the concept was unknown to them. At first glance, the number of incidences for the manifestations of the five components of TSPCK for the two lecturers are remarkably similar. However, when the nature of these manifestations is analysed clear differences between them emerge.

Ms Amy and Prof James showed evidence of awareness of student prior knowledge. Both lecturers referred to knowledge gained in previous themes and other subjects. This contradicts what Ms Amy said during the interview. She often referred to work that students should remember from high school and the previous themes opposing what she said during the interview that she expected no prior knowledge. The expectation was that Prof James would refer to prior knowledge gained from school more frequently because he expected more prior knowledge, but that did not happen. Prof James' surprise about the type of questions the students asked implies that he was not in touch with the students' level of prior knowledge and that his expectations were too high.

In terms of curricular saliency the different specialisation backgrounds of the lecturers became evident as both referred to later courses in their respective disciplines where students would need this particular knowledge. Ms Amy referred to third and fourth year Botany classes and Prof James to second year Biochemistry.

Both lecturers made the students aware of the same possible difficulties in the topic. Ms Amy and Prof James would warn students of mistakes that were frequently made by students in the previous years. They also alerted students to possible misconceptions and the similarities and differences between different metabolic cycles.

Both lecturers used the representations that they mentioned in the interviews. They both used slides, pictures and analogies. Ms Amy used the Bamboo pad to make drawings allowing students the time to make notes, and to clarify different reactions, she played relevant videos and showed a cartoon about photosynthesis. Prof James sang a relevant song in every class and he used a pointer to explain the reactions shown on his PowerPoint slides. Ms Amy's teaching strategy gave the students more opportunities to reflect on what she was doing as observed in the next section. Prof James summarised each section with the words in a song.

Table 4.5: Evidence of the TSPCK of the lecturers during interviews

TSPCK	Ms Amy		Prof James	
	Evidence	Incidences	Evidence	Incidences
Student prior knowledge	References to knowledge gained in previous themes, high school physical sciences, physics and chemistry modules	13	References to reactions that have been dealt with in previous themes, no reference to pre-knowledge from school.	13
Curricular saliency (Connectedness)	References to microbiology and 3rd and 4th year Botany	3	References to Calvin cycle in 2nd year Biochemistry	1
What makes the topic difficult	Complex processes, confusion between different cycles in different themes, energy transfers and differences between C3, C4 and CAM	19	Confusion between different cycles in different themes, energy transfers and differences between C3, C4 and CAM	18
Representation	Drawings made in class, pictures, videos, and analogies used	27	Analogies, songs, figures, diagrams and pictures used	22
Teaching strategies	Repeat explanations using different representations.	6	Use different figures and diagrams	7

The TSPCK evidence gained from the interviews, where specific questions were asked to prompt for TSPCK evidence, were confirmed by the video data. Both lecturers were more outspoken about curricular saliency in their classrooms than during the interview. Both lecturers showed a great deal of TSPCK although some aspects could be developed further.

4.2.4 Summary of findings on teaching orientations

Both of the lecturers showed more evidence of practicing TSPCK in their classes than what they suggested in the interviews. This finding supports the literature that with experience and sufficient content knowledge lecturers learn to use TSPCK without specific formal training (Van Driel, Verloop, & de Vos, 1998). The lecturer's learning goals are shaped by their experience. Ms Amy's learning goals focused only on the students and the knowledge they need for further studies, while Prof James had personal learning goals as well as goals for the students. Prof James' experience caused him not to expect absolute silence in the class. He also did not believe in disciplining the students as he believes that they are mature enough to take responsibility. Ms Amy wanted to discipline the classes because she believes a quiet class ensures maximum learning potential for the students. The TSPCK for the lecturers are very similar, possibly because they work very closely in planning the lessons. Their emphasis on different sections could be due to their different academic disciplines. The personal styles and teaching orientations were still evident in the different times that they spent on the same big ideas. In the next section, the time that the lecturers allocated to each big idea with the pages covered in the textbook was compared.

4.3 Time allocation

It was anticipated that there would be a difference in the way that the two lecturers allocate their time to the components of the topic. The big ideas in photosynthesis were defined by using the textbook and the study guide for MLB 111 as described in chapter 3.

The time allocation per big idea provided insight into what each lecturer deemed important or where they anticipated that the students might need support, thereby serving as an indirect source of information on their learning goals. Inexperienced lecturers who do not give their teaching much thought might simply teach from the prescribed textbook and structure their time allocation accordingly. It was important therefore to compare the time allocation of Ms Amy and Prof James with the coverage of the big ideas in the textbook.

The video footage of both lecturers was first analysed for the time spent on each big idea. A log was prepared for each lecture to indicate when a lecturer started and completed the teaching on each of the four big ideas and the time spent on revision at the end of the theme. This data is given in Appendices 6 and 7. The time distribution across the subtopics was compared with the percentage coverage of each big idea in the textbook. Table 4.6 presents a complete exposition per lecture period and total per big idea.

Table 4.7 presents a comparison between the percentage coverage of each big idea in the text book and that of the respective lecturers. The percentages for the textbook were calculated by dividing the page space allocated to each big idea by the total space in terms of the number of pages devoted to the topic of photosynthesis (Appendix 9). The percentages for the lecturers reflect the time that each lecturer spent on each big idea relative to the total teaching time used for photosynthesis. The data in Table 4.7 is presented in graphical form in Figure 4.1.

Table 4.6: Time allocations by each lecturer for big ideas in photosynthesis

Big Idea	**Ms Amy (BL)**		**Prof James (EL)**	
	Time per lesson (hrs:min:sec)	**Total time** (hrs:min:sec)	**Time per lesson** (hrs:min:sec)	**Total time** (hrs:min:sec)
1. Photosynthesis converts light energy to chemical energy;	Lesson 1: 00:00 - 16:00	00:16:00	Lesson 1: 00:00 - 21:14	00:21:14
	Total	**00:16:00**	**Total**	**00:21:14**
2. The light reactions convert solar energy to the chemical energy of ATP and NADPH.	Lesson 1: 15:50 – 39:21	00:23:31	Lesson 1: 21:14 -43:34	00:22:20
	Lesson 2: 00:00 – 44:38	00:44:38	Lesson 2: 00:00 – 46:05	00:46:05
	Lesson 3: 00:00 – 42:37	00:42:37		
	Lesson 4: 00:00 – 3:00	00:03:00		
	Total:	**01:53:46**	**Total**	**01:08:25**
3. The Calvin cycle uses chemical energy of ATP and NADPH to reduce CO_2 to sugar and	Lesson 4: 03:00 – 28:50	00:25:50	Lesson 3: 00:00 – 41:20	00:41:20
			**Lesson 4: 21:22 – 23:30*	**00:02:08*
	Total:	**00:25:50**	**Total**	**00:43:28**
4. Alternative mechanisms of carbon fixation have evolved in hot, arid climates	Lesson 4: 28:50 – 41:48	00:12:58	Lesson 3: 32:50 – 40:40	00:07:50
	Lesson 5: 00:00 – 15:51	00:15:51	Lesson 4: 00:00 – 21:21 23:31 – 40:47	00:38:39
	Total:	**00:27:58**	**Total:**	**00:45:89**
Revision	Lesson 5: 15:51 – 31:44	00:15:55	Lesson 5: 00:00 – 23:00	00:23:00
	Total :	**00:15:55**	**Total**	**00:23:00**
Total teaching time		**03:19:29**		**03:22:32**

**The Calvin cycle is explained again but in the context of the Alternative mechanisms of carbon fixation.*

Table 4.7: Comparison between the coverage of big ideas in the text book with that of the respective lecturers

Big idea	**Textbook**		**Ms Amy (BL)**		**Prof James (EL)**	
	Nr of pages	**% coverage**	**Time spent (min)**	**% coverage**	**Time spent (min)**	**% coverage**
1. Photosynthesis converts light energy to chemical energy;	3.4	**16.1**	16.0	**7.3**	21.3	**10.5**
2. The light reactions convert solar energy to the chemical energy of ATP and NADPH.	8.6	**40.9**	133.8	**61.0**	68.4	**33.8**
3. The Calvin cycle uses chemical energy of ATP and NADPH to reduce CO_2 to sugar	2.6	**12.3**	25.8	**11.8**	41.3	**20.3**
4. Alternative mechanisms of carbon fixation have evolved in hot, arid climates	4.4	**20.9**	28.0	**12.7**	48.6	**24.0**
Revision	2.0	**9.5**	15.9	**7.2**	23.0	**11.4**
Total	21.0	**100.0**	219.5	**100.0**	202.6	**100.00**

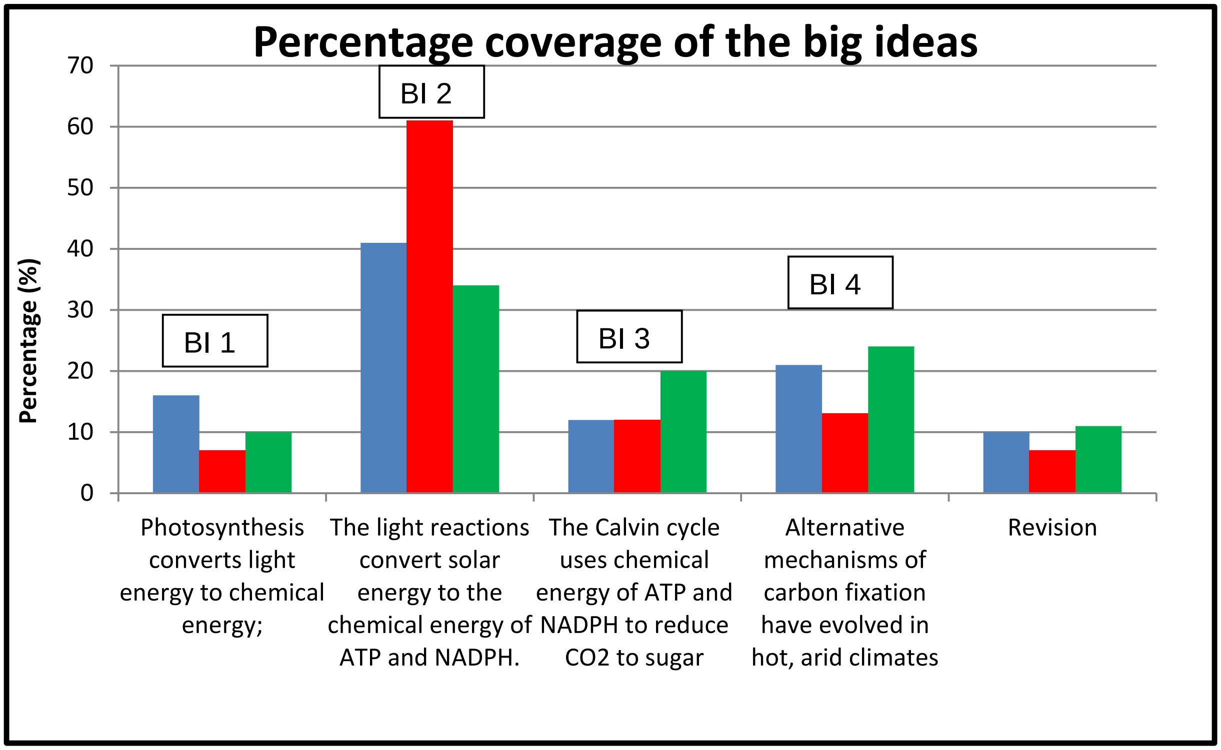
The four big ideas represented in the graph are:

BI 1 Photosynthesis converts light energy to chemical energy

BI 2 The light reactions convert solar energy to the chemical energy of ATP and NADPH

BI 3 The Calvin cycle uses chemical energy of ATP and NADPH to reduce CO_2 to sugar

BI 4 An alternative mechanism of carbon fixation has evolved in hot arid climates



Percentage coverage: Textbook 🟦; Ms Amy 🟥; Prof James 🟩

Figure 4.1: Percentage coverage of the big ideas

It is evident in Figure 4.1 that the time allocation of the lecturers showed some correspondence with the space allocation in the textbook. There are marked differences as well which should be investigated. Each big idea will be discussed separately in order to compare the lecturers' allocated time and coverage in the textbook.

Both spent less time on big idea 1 than the textbook, but the difference between them is relatively small and probably not significant. Both lecturers cut down on the introduction time but applied the extra time on different big ideas.

Ms Amy spent a disproportionate amount of time on big idea 2 (49% more than the textbook) and provided the reason for that during the interview.

> *that is what I don't like about the textbook, the textbook shows you the electron transport chain shows you it gives you ATP which is not true.*

Because of her expert knowledge as a botanist she felt compelled to improve on the presentation in the textbook to prevent misconceptions. However, this resulted in her coming short on time for big idea 4 and revision, despite her awareness that it is a challenging concept for the students.

Compared to the textbook Prof James spent less time on big ideas 1 and 2, adding extra time to big ideas 3 and 4. He stated during the interview that he knows that the students find big idea 3 challenging and he himself was not familiar with big idea 4 because it was a pure botanical section. He seems to have managed his time carefully in order to cater for the needs of the students.

Ms Amy allocated the same time to big idea 3 than the textbook, which is characteristic of an inexperienced lecturer that knows the work that needs to be explained well (Clark, 1988). Prof James spent more time than Ms Amy and the textbook on this big idea. Both the lecturers identified the Calvin cycle as difficult. The increased time spent by Prof James suggests that he is more aware of the needs of the students, which may be expected of an experienced lecturer. Alternatively, this could indicate that he was within his area of expertise in terms of the redox reactions in metabolic cycles where he could enrich his teaching and provide more scaffolding to the students.

Prof James allocated more time on big idea 4 than Ms Amy and the textbook. Ms Amy spent less time on big idea 4 than the textbook. As a biochemist Prof James rarely teaches photosynthesis. He admitted that he found this topic challenging and thus he became like a beginner lecturer in this section because he had to overcome his own lack of knowledge on the concepts associated with big idea 4. Ms Amy found this topic easy although she acknowledged that the students and Prof James found it challenging. She was the expert on the theory behind the big idea, but she did not cater for the needs of the students which showed again her lack of experience.

Both lecturers used the rest of the time available to do revision. Because Ms Amy spent so much time on big idea 2 she had less time available than the textbook and Prof James. Prof James had more time to do revision and from the graph it is evident that he stayed closer to the time allocation of the textbook which may be ascribed to his experience. To summarise the lecturers have been sensitive to the demands of the big ideas and tried to provide appropriate scaffolding for learning. However, Prof James seems to have been more disciplined on his choice of where to focus his attention than Ms Amy, who ran short of time for big idea 4 due to an excessive investment in big idea 2.

4.4 Analysis of the students' journal entries

This section seeks to answer the second research question:

How do students experience the teaching of each lecturer?

After every lecture, whilst the experience was still fresh, the students had the opportunity to answer the questions provided in the journal template. This was done in an attempt to obtain an honest report of what the students experienced on the specific topic on that specific day. The students responded to the same questions in the journal template after every class for the duration of the photosynthesis section. The questions prompted students to identify topics covered in the class, and to comment on topics they felt were explained exceptionally well and the topics they still found unclear. They could also give general comments. The questions can be seen in Appendix 10. These responses were coded with ATLAS.ti. Coding with ATLAS.ti generates themes which can be illustrated with quotes. Themes are then clustered into super themes. The report of such an analysis includes the themes with the frequency of occurrence.

The responses of students were categorized according to the big ideas. This was possible because the students listed the topics that were covered before they answered the questions on what was explained exceptionally well and which topic (theme) was still unclear. It was interesting to see that students did not necessarily know what topics had been covered during a class. When they answered the questions on sections still unclear and explained exceptionally well, it was not always about the topics they had listed as being covered in that period. It could be that more than one topic was covered in one period or that the students really did not know what was covered in class. Another reason could be that the lecturers did not always announce the big idea, keeping in mind that the notion of big ideas was not something with which the lecturers were familiar. The topics that the students had listed were disregarded when this contradiction happened. Only the topics listed were then categosized according to the big ideas.

In this section the journal entries of the students were analysed in terms of positive and negative responses for each lecturer. The quotes given are examples of the most frequently obtained responses. Not all of the students gave reasons why they found a topic explained exceptionally well or still unclear. The Afrikaans data was freely translated into English for the purpose of the report. The original Afrikaans version and the translation are shown.

4.4.1 Responses on the content

Ms Amy

All of the students had positive responses to Ms Amy's presentation style but for different reasons. It is evident that although the drawing of cycles is the main teaching strategy that she mentioned, the students benefitted in different ways. All of the students commented favourably on the way Ms Amy repeated the work, aiding the students' understanding of the topic (Appendix 11).

Quotes of big ideas explained exceptionally well

Examples of the reasons given by the respondents as to why they experienced the different big ideas as explained exceptionally well are provided below:

- Photosynthesis converts light energy to chemical energy (big idea 1)

> ***'….*** *emphasised certain points and provided examples and analogies that helped me understand what was going on.'*
>
> *'I felt that our lecturer explained the part about the electron transport chain really well.'*

- The light reactions convert solar energy to the chemical energy of ATP and NADPH. (big idea 2)

> *"photosystem II. She not only drew a simplified picture of the process but also explained in detail in simple sentences repeatedly what occurs at this stage of photosynthesis"*

- The Calvin cycle uses chemical energy of ATP and NADPH to reduce CO_2 to sugar. (big idea 3)

> *'I really understood the carbon fixation, reduction, etc. (part of the cycle) as we drew diagrams and she explained it slowly and made sure we understood it. As we drew the diagrams I could picture the process happening which helped me a lot'*

- Alternative mechanisms of carbon fixation have evolved in hot, arid climates (big idea 4)

> *'.... drew a comparative of C4 and CAM photosynthesis and it really clarified the similarities and differences as well as cemented what happens where'*

> *'C4 and CAM plants. She explained it twice using two different methods: Drawing and using a pointer and diagram.'*

Quotes on big ideas still unclear

Students were asked to name the sections that were still unclear to them and give a reason as to why they were still struggling. An example of the reasons given by the respondents as to why they experienced the different big ideas as still unclear, are provided below and the rest are listed in Appendix 11.

- Photosynthesis converts light energy to chemical energy (big idea 1)

  No remarks

- The light reactions convert solar energy to the chemical energy of ATP and NADPH. (big idea 2)

  I am still unsure about the specifics regarding the noncyclic electron transport

- The Calvin cycle uses chemical energy of ATP and NADPH to reduce CO_2 to sugar. (big idea 3)

  > *'I feel that if a concept is misunderstood Ms Amy just explains it again, in the exact same way. I didn't understand the way she had explained it the first time round, so merely repeating the explanation was a futile attempt. she should consider trying to explain difficult concepts in different ways and she should maybe simplify it, i find it to be muddled up and if she could be more blatant in explaining certain aspects i feel i would understand it a lot better. This is especially true for the different cycles and parts of respiration and photosynthesis.'*

- Alternative mechanisms of carbon fixation have evolved in hot, arid climates. (big idea 4)

  > *'I found that the way the lecturer explained the C4 cycle as well as the CAM cycle in a more confusing manner than yesterday. This may be because the lecturer drew the cycles on the board and I find it is better if I am given an image to visualise the process.'*

Fewer reasons were given by the respondents as to why the work was still unclear (Appendix 11). Some of the respondents mentioned that the section was still unclear without giving reasons. Some respondents experienced Ms Amy's drawing confusing and found it frustrating that she explained only in one way and did not change her approach when she repeated her explanations.

When we compare the positive and negative responses it is evident that the same teaching strategy works for some students while others find it confusing. This emphasised the fact that different students learn in different ways and that more than one teaching strategy should be used to accommodate more students.

Prof James

Quotes of big ideas explained exceptionally well

An example of the reasons given by the respondents as to why they experienced the different big ideas as explained exceptionally well is given below. The Afrikaans responses were translated into English for the purpose of this study.

- Photosynthesis converts light energy to chemical energy. (big idea 1)

> '…. dosent was baie entoesiasties oor hoe die proses verloop, en dit het my laat belangstel. / *Lecturer was very enthusiastic about how the process takes place, it made me interested'*

- The light reactions convert solar energy to the chemical energy of ATP and NADPH. (big idea 2)

> '….prof. het die werk eers behandel en daarna weer vir ons 'n lied gesing wat die proses beskryf en dit help my om die werk beter te verstaan en meer te geniet / *prof first explained the work and we then again sang a song that explained the process and it helped me to understand the work better and enjoy it more'*

- The Calvin cycle uses chemical energy of ATP and NADPH to reduce CO_2 to sugar. (big idea 3)

> Calvin siklus, baie in detail verduidelik, en werk goed in a diagram opgesom / *Calvin cycle, explained in detail and the summary in a diagram was good*

- Alternative mechanisms of carbon fixation have evolved in hot, arid climates. (big idea 4)

> ‘Die manier hoe Prof. vir ons verduidelik het hoe om die 3 verskillende soorte plante te onthou. Hy het dit net so verduidelik dat mens logies daar aan kan dink en die 3 verskillendes sal kan onthou en onderskei van mekaar / *The way Prof explained to us how to remember the three different kinds of plants. He explained it in such a way that one can think about it logically and will be able to remember the 3 different ones and distinguish them from each other*

The most frequent reason provided by the students for the work explained exceptionally well was the songs that Prof James sang after each session. The students also mentioned drawings and examples as reasons. Prof James was correct when he said that students learn when they have fun. One of the students wrote an interesting comment, saying that the lecturer is good but nothing was explained exceptionally well. This specific student did not respond as expected to the formulated prompt, because the wording of the question did not make provision for his interpretation. Misinterpretation of the question was something that was not taken into consideration.

> ‘ek is van opinie dat niks besonders goed verduidelik is nie. die dosent is wel goed om die inhoud van die werk aan ons deur te gee maar of jy as persoon dit gaan verstaan en onthou hang af hoe hard jy gaan leer en oor die werk nalees / *I am of the opinion that nothing is explained exceptionally well. The lecturer is good to give the content of the work to us, but whether you as a person are going to understand and remember it will depend on how hard you are going to study and read up on the work.’*

This is a very honest response. It did not fit into either of the two categories that were created but it presented an interesting perspective. This specific student realised that his performance is his own responsibility and does not depend on the competence of the lecturer. It is also interesting that there was not a single topic that this particular student found explained exceptionally well or still unclear.

Quotes on big ideas still unclear

Students were also asked to name the sections that were still unclear and to give a reason as to why they were still struggling. Similarly, an example of the reasons that the respondents gave on why they experienced the different big ideas as still unclear is given below and the rest are listed in Appendix 12.

- Photosynthesis converts light energy to chemical energy. (big idea 1)

> ‘Die fotosisteem I en II. Dit was 'n vreemde konsep en is vinnig behandel. / *The photosystem I and II. It was a strange concept and it was covered fast’*

- The light reactions convert solar energy to the chemical energy of ATP and NADPH. (big idea 2)

> ‘Die deel van die chloroplaste is effens onduidelik aangesien dit vir my voel hy het dit moeilik verduidelik. Iets wat maklik behoort te wees. / *The part of the chloroplast is a bit unclear since I feel that he explains something that is supposed to be easy in a difficult way ‘*

- The Calvin cycle uses chemical energy of ATP and NADPH to reduce CO_2 to sugar. (big idea 3)

> ‘Hy gee so klas, dat dit moeilik maak om enigsins notas te maak, hy herhaal nie, - … Meeste van vandag se lesing veral van waar die prosesse plaasvind sal vir my about selfstudie wees. / *He lectures in such a way that it is difficult to take notes, he doesn’t repeat … most of today’s lesson, especially about where the processes take place will be self-study’*

- Alternative mechanisms of carbon fixation have evolved in hot, arid climates. (big idea 4)

> ‘Ek is nog heel onseker oor die reaksies in plante … want daar was heeltyd gespring tussen twee slides, en as mens nog notas moet neem ook, kan mens nie sien waarna hy verwys en watse slide nie. / *I am unsure about the reactions in plants… he jumps between two slides and if one has to take notes, you can’t see which slide he is referring to…..’*

More students remarked on Prof James' representations as reasons to why the work is still unclear to them. The students complained about the speed of the presentation which prevented them from making notes.

At least one respondent of each lecturer gave a reason for each BI that was explained exceptionally well. The question on which BI was still unclear to students, they often listed the BI but did not give reasons why they felt that way. It is interesting that the same way of explaining a section can get positive and negative remarks. The different responses on the same presentation method gave the feeling that the students were honest and gave their own personal experience. More responses were given to the BI's on which the lecturers spent more time.

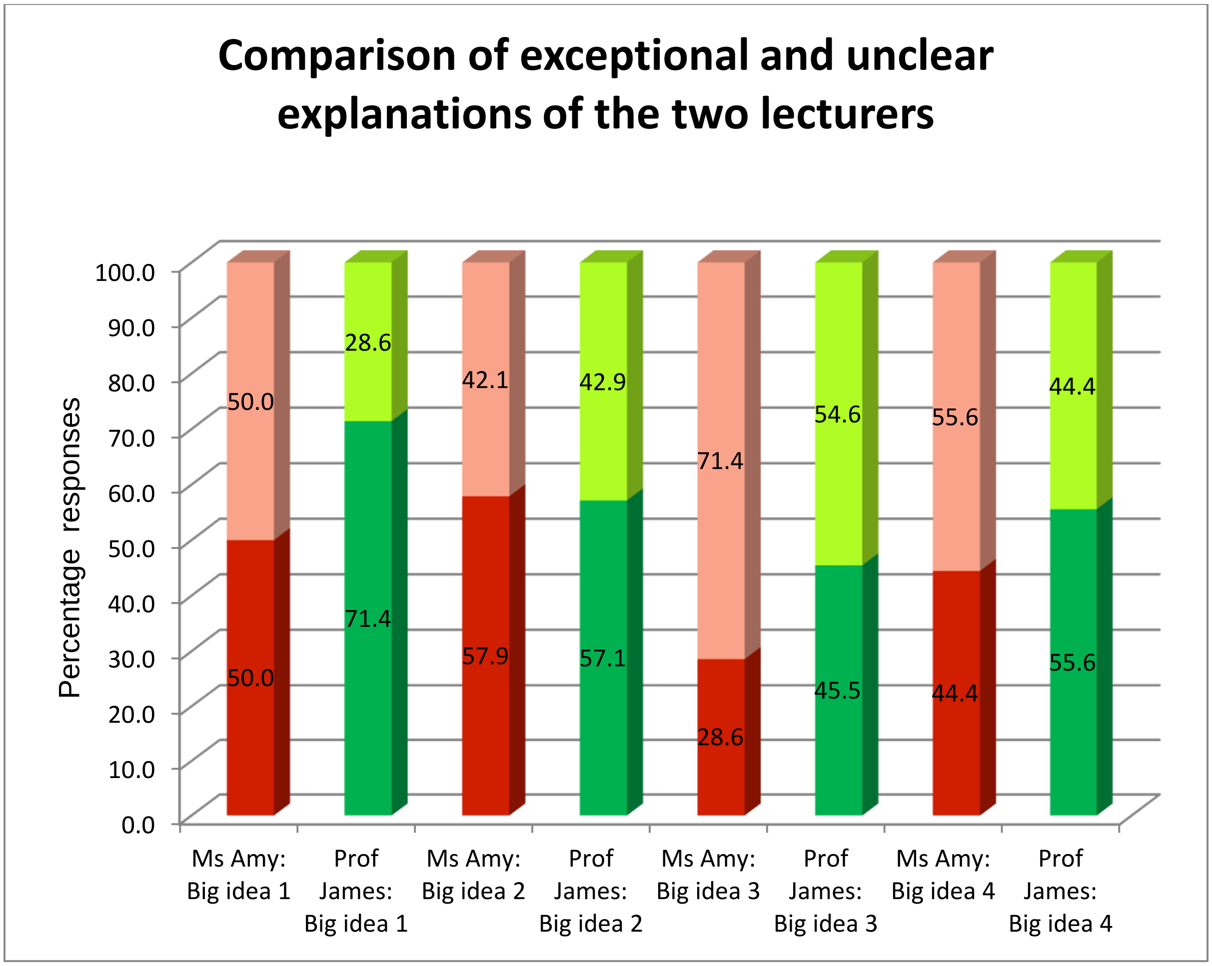
Owing to the fact that the number of journal entries varied between big ideas and between lecturers it was necessary to normalise the number of responses to allow for a direct comparison. All of the students' responses were counted and the totals were converted to percentages per lecturer per big idea as presented in table 4.8. Percentages for the occurrence of themes were calculated by dividing the frequency of positive remarks on a big idea for a specific lecturer by the total number of responses for that topic for the same lecturer.

Table 4.8: Comparison of the students' responses for both lecturers *

	MS AMY: BIG IDEA 1 (%)	PROF JAMES: BIG IDEA 1 (%)	MS AMY: BIG IDEA 2 (%)	PROF JAMES: BIG IDEA 2 (%)	MS AMY: BIG IDEA 3 (%)	PROF JAMES: BIG IDEA 3 (%)	MS AMY: BIG IDEA 4 (%)	PROF JAMES: BIG IDEA 4 (%)
Explained exceptionally well	4 (50)	5 (71)	22 (58)	12 (57)	2 (29)	5 (45)	4 (44)	5 (56)
Still Unclear	4 (50)	2 (29)	16 (42)	9 (43)	5 (71)	6 (55)	5 (56)	4 (44)
Total	8 (100)	7 (100)	38 (100)	21 (100)	7 (100)	11 (100)	9 (100)	9 (100)

* The percentage (%) of the frequency of a comment is given in brackets in the table.

Table 4.8 is graphically represented in Figure 4.2 for the comparison of the exceptional and unclear explanations of each lecturer for each big idea.



Ms Amy (BL): 🟥 topic explained exceptionally well; ▨ topic still unclear. Prof James EL): 🟩 topic explained exceptionally; ▧ topic still unclear. **Big ideas**: 1) Photosystems convert light energy to chemical energy, 2) The light reactions converts solar energy to the chemical energy of ATP and NADPH, 3) Calvin cycle uses chemical energy of ATP and NADPH to reduce CO_2 to sugar, 4) Alternative mechanism of carbon fixation have evolved in hot arid air climates

Figure 4.2: Comparison between the two lecturers for exceptional and unclear explanations

The survey questions were formulated to prompt both positive and negative responses from the students regarding the teaching that they experienced (Figure 4.2). A roughly even frequency distribution of positive and negative remarks was expected from the way the survey was structured. Therefore, of interest were those topics for which a deviation from 50:50 was noticeable. There was more than one way to do this comparison.

Firstly the percentage of positive and negative responses for each lecturer on each big idea was compared: In big idea1 half of the respondents of Ms Amy felt that the big idea was explained exceptionally well, while 57, 9 % of the respondents felt that big idea 2 was explained exceptionally well. A higher percentage of Ms Amy's students reported that they found big idea 3 and 4 still unclear. Prof James's respondents reacted positively on big ideas 1, 2 and 4. Big idea 3 was still felt unclear by more than half of Prof James'

Secondly a direct comparison between the responses for the two lecturers was analysed. The respondents rated both the lecturers equally high on big idea 2, but on the other BI's Prof James was rated higher than Ms Amy (Figure 4.2). Based on the student ratings overall, big idea 1 was taught best and big idea 3 least well. The difference in rating may be a consequence of time allocation or may reflect the inherent difficulty of a particular section of the work. However, it should be interpreted with care because it could also reflect a cultural difference between Afrikaans and English speaking students.

When the time that each lecturer spent on each big idea (paragraph 4.3) was compared to the experiences of the students the following could be seen. Ms Amy spent most of the time on big idea 2 and that is the big idea that more students in her class felt was explained exceptionally well. This was also the big idea where the students commented that she went slowly and repeated the work more than once.

Ms Amy spent less time on big idea 3 than Prof James and the coverage in the textbook. Despite the fact that Prof James and Ms Amy spent a comparable amount of time as allocated in the textbook on big idea 4, most of the respondents still found this topic difficult. The conclusion is that this content could just be a difficult big idea for the students to master.

4.4.2 General comments made by respondents in their journal entries

Apart from feedback directly related to content, the responses also contained unrelated comments. These comments could be divided into three main categories: 1) lecturer's teaching, 2) characteristics of the lecturer and 3) the students' personal experiences and feelings about the class. An example of these responses is given below and all of the responses from the students are tabulated in appendices 11 and 12.

Ms Amy (characteristics of the lecturers)

> *'It was a very well explained lecture. It seemed Ms Amy is very passionate about this work'*

Prof James (lecturer's teaching)

> 'Die liedjie het gewerk omdat mens net liedjies beter onthou. / *the song worked*

> *because one remembers songs better'*

Both lecturers (feelings about the class)

This general comment about both lecturers was made by one of Prof James' students:

> *'I know that if I study this I will understand all the components in this theme. Hopefully I will do better in my next semester test and will be selected as one of the few to study medicine. Well done to Prof James and Ms Amy they have done a tremendous job, may the almighty God shower them with blessings and may they continue to help others they have helped me to understand better!'*

4.4.2.1 Teaching strategies of the lecturer:

The students generally gave very positive feedback for both of the lecturers. The students experienced Ms Amy as a good lecturer because she used analogies, and examples, and gave the students a chance to take notes. However a few students had the complaints about Ms Amy saying that she always used the same examples and they found the way she used the Bamboo pad to draw diagrams frustrating and confusing. Prof James' students were very positive about the way he explained the work, the songs he sang and the examples he used. The complaints were also about the same topics. Some students felt that he explained the work too fast for them to make notes, he did not repeat the work, and that he tended to jump between the slides.

4.4.2.2 Characteristics of the lecturer:

The students saw Ms Amy as an amazing, patient and optimistic lecturer who loves her subject. There were no negative remarks about her personality from any of the respondents. The students experienced Prof James as an excellent lecturer who put a lot of effort into the lessons. His lessons were lively and he sang a lot. On the downside some of the students experienced him as a lecturer who only focused on the students in the front of the class.

4.4.2.3 The students' personal experience (and feelings) of the class:

Ms Amy's students generally experienced her classes as enjoyable and fun with good examples, while a very small group felt that her classes were vague and noisy and that there was a lack of respect for her. The students in Prof James' class experienced his classes as entertaining and enjoyable. Some felt that because of the singing in his classes, they would not forget the cycles. The few students that gave negative comments said that nothing was explained well.

Unsolicited remarks about the lecturing, the characteristics of the lecturers and the class experience were overwhelmingly positive. The students' responses about the subject content were less positive (Figure 4.2) than their responses about the lecturers and the lectures. One can thus conclude that in general students did not see the lecturers' teaching orientations as the reason for content that they still found unclear.

To summarise the responses, the number of positive remarks were divided by the total number of remarks for that lecturer. This summary is presented in table 4.9.

Table 4.9: Summary of positive remarks *

	Ms Amy: Teaching Remark (%)	Prof James: Teaching Remark (%)	Ms Amy: Characteristics (%)	Prof James: Characteristics (%)	Ms Amy: Student Experience (%)	Prof James: Student Experience (%)
Total Positive	27 (75)	19 (79)	6 (100)	12 (85)	13 (86)	14 (77)
Total Negative	9 (25)	5 (21)	0 (0)	2 (15)	2 (14)	4 (23)
Total Responses	36 (100)	24 (100)	6 (100)	14 (100)	15 (100)	18 (100)

* The numbers in brackets are the calculated percentages.

It is important to note that the frequency of responses must be read in conjunction with the time spent per big idea. Where less time was spent on a big idea, fewer remarks were made. It also happened that some students did not complete the questionnaire every day. However, caution should be exercised in making inferences from this data given the small number of responses received on the majority of the big Ideas. More important for this study is an interpretation of the content of the statements rather than the number of occurrences.

There is a correlation between the time that the lecturers spent on each BI and the number of respondents that felt that it was explained exceptionally well. The less time Ms Amy spent on a

BI, the more respondents felt it was still unclear. The BI that she covered more extensively than Prof James and the textbook is the one that her students felt they understood best. The same was experienced with Prof James.

4.4.2 Summary of findings on student experiences

The students generally experienced both classes as good and enjoyable. Negative remarks for both the lecturers were limited in all of the categories. More than 70% percent of the remarks were positive. Students do not blame the lecturers and their teaching orientations for possible problems with the theme.

4.5 Conclusions

When the analyses from the interviews and the video materials of lectures were compared it can be concluded that the lecturers' class room practices correlate with what they said in the interviews. The teaching orientations of the two lecturers are overall different but at first glance seem similar. The good working relationship that exists between Ms Amy and Prof James may have influenced their teaching orientations. They compared notes on a daily basis and made every attempt to ensure that the students would not be adversely affected different lecturers teaching the same topic.

The responses from the students indicated that a combination of factors influenced their experiences of the lecturers and their teaching methods. The time a lecturer spent on a specific big idea, the inherent difficulty of a topic and their own preference for a specific learning style influenced the students' positive and negative responses. The findings were triangulated in order to draw conclusions and answer the research questions in chapter 5.

CHAPTER 5: DISCUSSION AND CONCLUSIONS

5.1 Introduction

This study compared the teaching orientations of a beginner and experienced lecturer using two different lenses. The first lens was the comparison between their teaching orientations and this lens answered the first research question:

> *How does the teaching orientation of a beginner lecturer differ from that of an experienced lecturer?*

The second lens was the experiences of the students and it answered the second research question:

> *How do students experience the teaching of each lecturer?*

5.2. Teaching orientations of the lecturers

Teaching orientations are composed of learning goals, teachers' beliefs and their TSPCK (Friedrichsen et al., 2009). The teaching orientations of the respective lectures are discussed separately before they are compared in the conclusion.

5.2.1 Teaching orientation of the Experienced Lecturer (EL)

Prof James, the experienced lecturer, has more than 15 years' experience in teaching large first year classes. He is a qualified biochemist. He has been a lecturer at UP for the last 39 years and a professor for the last 29 of those years. He was also Head of the Biochemistry department for three years. In this time he has earned the title of experienced lecturer. Photosynthesis is not his field of expertise, but he has taught it at first year level for many years.

5.2.1.1 Learning goals

Learning goals is, in short, the aim towards which the lecturer works (Gess-Newsome et al., 2011; Kember & Gow, 1994; Kreber, 2003; *Molecular and Cell Biology Study guide* 2013). These goals include the reason for teaching the theme and the outcomes that the lecturer wants the students to reach as discussed in chapter four, paragraph 4.1.2. The interview data was analysed for evidence of the lecturer's learning goals.

Prof James fits the description of an experienced lecturer found in the literature. As an experienced lecturer (in his daily planning of the lessons) he puts emphasis on the bigger picture and interconnectedness of all of the themes (Abd-El-Khalick, 2006). He concentrates on the finer details of the reactions possibly because of his biochemistry background. This also fits the description of a beginner lecturer (Friedrichsen et al., 2009). These findings were discussed in chapter four.

5.2.1.2 Beliefs

In this study, beliefs were defined as the teacher's belief in the reasons for teaching the topic, their personal abilities as a teacher, and the students' abilities in learning the content (Magnussen et al., 1999; Settlage, 2000).

The view that Prof James had of the students reflects that of experienced lecturers. He admitted that he lost track of their academic preparedness for first year and thus expected more knowledge from them. Through experience he has learned that having fun makes learning easier for students and also helps with the discipline in the class. He regards freedom at the university very highly and only intervened if the students were totally unruly. He believes that if students have fun there will be no discipline problems.

5.2.1.3 Topic specific pedagogical content knowledge (TSPCK)

TSPCK has been proposed to consist of the following five categories:

1. Student prior knowledge
2. Curricular saliency
3. What makes the topic difficult?
4. Teaching strategies
5. Representations (Geddis et al., 1993).

Although Prof James had no formal training in pedagogy and in education theories the categories of TSPCK manifested in his lecturing. The fact that TSPCK is evident in Prof James' lectures shows that TSPCK can be gained through experience (Abd-El-Khalick, 2006; Gess-Newsome & Lederman, 1995). The fact that he admitted that he expects more prior knowledge from students suggests that he might not be totally in touch with the academic levels of first year students (Table 4.4). Prof James puts a lot of emphasis on macro curricular saliency and there is less evidence that micro curricular saliency is important to him. His experience and his attention to detail allow him to not only identify possible problematic big ideas but also specific aspects of the content in the big ideas that students might find difficult (Table 4.5). He is of the opinion that the students may find the theme difficult because they might not be interested in the topic and do not see the connectedness with other themes. It was evident from the classroom observations that Prof James' teaching strategy was fun orientated. He sang a lot although the songs were also used for the reinforcement of concepts and to provide the students with a learning aid. He also used analogies and different sketches to make studying easier for the students. In his teaching strategy he used different examples and explained the topic in more than one way in an attempt to make the work more understandable. As an experienced lecturer he planned his lectures to have a definite start and finish. His planning on the time spent on the big ideas was not always the same as the coverage in the textbook. He spent more time on the Calvin cycle as it is an important foundation in biochemistry. This suggests that he is aware that this big idea is important for the biochemistry modules that follow in later years. This is an enactment of his curricular saliency. Prof James also spent more time on the big idea with which he admitted that he does not feel familiar, as well as one with which he knew the students would struggle.

5.2.1.4 Synthesis of findings

Prof James is very comfortable in his role as a teacher. His lectures were well planned to fit in a lecture period giving enough time to reinforce the core concepts through songs. His learning goals were bigger than the content itself. All five components of TSPCK were evident in his practice, with abundant evidence for his wide repertoire of representations and his awareness of what makes the topic difficult. However it was very difficult to find evidence for curricular saliency in his practice, contrasting to what he revealed in his interview.

The teaching orientation of Prof James fitted the literature description of both an experienced and a beginner lecturer. The way in which he presented photosynthesis has some resemblance to that of a beginner lecturer. He focused more on the content detail in his presentation which would make it more accessible to students.

5.2.2 The teaching orientation of the Beginner Lecturer

Ms Amy, the beginner lecturer, has less than five years' experience in teaching large first year classes. She has an MSc degree in Plant Sciences. She has been lecturing for the last nine years in various departments at UP. While the study was in progress, she had only three years lecturing experience in large first year classes. As a botanist, photosynthesis lies in her field of expertise.

5.2.2.1 Learning goals

Ms Amy focused on the importance of photosynthesis for later courses in plant sciences. She explained the different concepts without delving into the specific chemical reactions in detail. She felt that some of the reactions in the Calvin cycle were not that important. The broader picture was important to her. Her emphasis on the bigger picture according to literature, is typical of an experienced lecturer and could be due to her expertise in botany (Table 4.2).

5.2.2.2 Beliefs

Owing to her lack of experience in teaching large classes she struggled with discipline. She did not expect prior knowledge of photosynthesis therefore emphasised prior knowledge on the different reactions in photosynthesis. Ms Amy left specifics out if she felt it was too difficult for the students. She felt that the concepts in photosynthesis were important and not the energy transfers, as is the case for the biochemists. Her choice of teaching strategies were informed by her personal preferences rather than her perception of the need of students.

5.2.2.3 Topic specific pedagogical content knowledge (TSPCK)

Similar to Prof James. Ms Amy's TSPCK manifested in the lectures. This was in line with the literature that stated that TSPCK can be developed through teaching (Abd-El-Khalick, 2006; Gess-Newsome & Lederman, 1995). Ms Amy is more in touch with the level of knowledge of the first year students and expected little prior knowledge of them, but she did not put emphasis on detailed reactions. Ms Amy preferred drawings as an instruction tool, which was her personal way of studying, although she used analogies and videos effectively. When her time allocation was compared to the coverage in the textbook it was evident that her emphasis on big ideas differed from the textbook. Ms Amy spent a disproportionate amount of time on big idea 2 (49% more than the textbook) and provided the reason for that during the interview. Because of her expert knowledge as a botanist, she felt compelled to improve on the presentation in the textbook to prevent misconceptions. However, this resulted in her coming short on time for big idea 4 and revision despite her awareness that it is a challenging concept for the students.

5.2.2.4 Synthesis of findings

Although Ms Amy was an effective teacher she was less comfortable in her role. As a botanist she was very well versed in the content, but was negatively affected by the restlessness of the class. Both her beliefs and learning goals were confined. They were determined by the immediate content and context with which she was dealing.

Ms Amy's teaching orientations manifested in practise. She was in touch with the level of knowledge of first year students and led them by constantly referring to their prior knowledge. She also made students aware of possible problem areas in each of the big ideas by mentioning possible problems that may arise. She experienced discipline in the large classes to be challenging which might be due to her lack of experience in large classes. The time allocation per big idea for Ms Amy was determined by the challenges that the content posed for her, and was less informed by her judgement in what would be difficult for the students. Although she was a beginner in lecturing the large classes she was experienced in teaching photosynthesis and thus only concentrated on the bigger picture because she taught this theme in different levels of tertiary studies Ms Amy fitted the literature's definition of an experienced and beginner lecturer.

5.2.3 Discussion

Overall the characteristics of Prof James and Ms Amy fitted what is described in the literature for beginner and experienced lecturers. Prof James emphasised the bigger picture on where photosynthesis fitted in, while Ms Amy concentrated on the specific place of photosynthesis in the studies of botany.

Prof James also demonstrated characteristics of a beginner lecturer, and Ms Amy also demonstrated characteristics of an experienced lecturer. These findings can be attributed to the fact that the topic of photosynthesis was within the disciplinary expertise of Ms Amy which enabled her to make informed judgement of what detail to exclude in terms of the disciplinary requirements of higher level courses. In addition, based on the disciplinary expertise. Ms Amy allocated more time to an aspect of the content where she felt that the textbook could convey the wrong information or could foster misconceptions. Prof James on the other hand, was not an expert on photosynthesis as such, but his disciplinary background in biochemistry made him an expert in metabolic cycles and the redox reactions and the energy changes associated with them (big ideas

2 and 3). He was less familiar with the adaption of plants for specific conditions (big idea 4) and taught that section with particular attention to detail as would be expected from a beginner lecturer.

Both lecturers were aware of which aspects of the content would pose the bigger challenges to students. Prof James accommodated perceived student needs better in his time allocation and choice of teaching strategies than Ms Amy.

Prof James was more comfortable and at ease in his role of an instructor of a large first year class than Ms Amy. This can be expected as he is a senior professional and had the benefit of experience. Ms Amy felt threatened by the conduct of the students in a large class and resorted to disciplinary measure in an attempt to maintain order.

It is evident that both lecturers have similar teaching orientations with minor differences, irrespective of their level of experience. One of the reasons for this could be the close professional relationship between the lecturers and their attempt to ensure the students get the same information from both of them.

5.3 Student experience

This section focuses on the findings relating to the students' experience of the teaching of each of the lecturers. The data obtained from student journals was analysed inductively to generate the findings.

The experimental design did not make it possible for students to compare their experience of the teaching of one lecturer with that of the other. I had to infer this information from their comments about one lecturer only. I thus decided to use the ratio of positive and negative responses for a particular lecturer as the statistic for this purpose. There is a possible bias in this approach because of the possibility that one group, e.g. the Afrikaans group, may have been more reluctant or more forthcoming to express positive opinions than the other group.

The students' experiences from their journal entries were analysed according to the big ideas in chapter 4. The journal entries of the students can be divided into topic specific replies and replies on the characteristics of the lecturers.

5.3.1 The experiences of the students in the respective classes

The students answered the same questions after every class. A different number of students answered every day. This may be due to tests in other subjects and general university activities. Some students would just enter that they did not attend class or that they were in class but did not pay attention. These entries were not used. The time spent on each big idea also influenced the number of entries and comments that were received for eachs big idea.

5.3.1.1 Students' experience of the Experienced Lecturer

5.3.1.1.1 Comments related to content

The students found the majority of the big ideas were explained exceptionally well. According to the number of responses, big idea 1 was the topic that was explained the best by the EL (71.4%). Big ideas 2 and 4 were seen as explained exceptionally well by a slightly more than 50% of the respondents. Big idea 2 was the big idea where the EL spent less time than the textbook and the BL and EL spent more time on big idea 4. The problem lies with big idea 3. This is the only big idea where only 45.5% of the respondents felt that the topic was explained exceptionally well although the EL spent more time on this big idea compared to the textbook and the BL (Table 4.6 in relation to Figure 4.1). This is the big idea that the EL identified as being possibly difficult (Figure 4.2). The fact that the majority of responses indicated the satisfaction of the students implies that the EL judged their needs well and pitched his teaching at an appropriate level.

5.3.1.1.2 Comments related to the lecturers' characteristics

The majority of respondents experienced Prof James' teaching, personal characteristics and the experience in his class very positively. The few negative remarks from the respondents can be linked to his lack of connection with the students on an individual level.

5.3.2.1 Students' experience on the Beginner Lecturer

5.3.2.1.1 Comments related to content

Figure 4.2 gives a summary of the experiences of the students. In big idea 1 50% of the respondents felt that this big idea was explained exceptionally well. The respondents were really satisfied with the way Ms Amy explained big idea 2 71.4% of the students felt it was explained exceptionally well. This is the big idea where Ms Amy spent slightly more time than the textbook and Prof James. There is a noticeable difference in the responses of the students in big idea 3 and 4. More than 50 % of the students felt that these two topics were still unclear. Although Ms

Amy identified these two big ideas as possible problem areas she spent less time on them (Table 4.6 in relations with Figure 4.1). The teaching strategies of Ms Amy were not successful for all of the big ideas. The big ideas that she spent more time on were, explained very well according to the students. Ms Amy mentioned that she thinks big idea 3 and 4 are very easy, the respondents did not agree with her. She also spent less time on these big ideas compared to the coverage in the textbook, suggesting that she is not necessarily in touch with the study needs of the students.

5.3.2.1.2 Comments related to the lecturers' characteristics

The students that commented on the characteristics of the BL were all very positive and more than 70% of them were very happy with the teaching, personal characteristics and the experiences of the class. There were no negative remarks about the personal characteristics of the BL (Figure 4.3).

5.3.3 Discussion

The comparison of the experiences of the responding students must be handled with the utmost care as some days a very small number of students completed the journals. The number of responses was also low when a small amount of time was spent on a topic. Cultural differences between the Afrikaans and English speaking students who completed the journals could be obderved in the journal entries.

Based on the student journals, all of the respondents found big idea 3 and 4 difficult and not explained as well as the other topics. Both lecturers identified these big ideas as possible challenging topics. Prof James spent more time on these big ideas than Ms Amy. The difference in time allocation can be a reason for why fewer of Prof James' students found the big ideas still unclear. Prof James' expert knowledge in biochemistry resulted in his careful planning of these topics and his structure of his time allocation. He spent more time on the topics that both lecturers identified as possibly problematic. Prof James targeted potential problems in big idea 3 and 4 more effectively by paying more attention to the detail and spending more time on them than Ms Amy. The students found his approach more favourable than the approach of the Ms Amy in these two topics. His experience had a positive outcome. Prof James has a much more nuanced insight into the difficulties that students encounter in the big ideas.

Despite small differences the overall finding is that the students experienced the teaching of both lecturers as very positive.

5.4. Conclusion

Students reported an overwhelmingly positive experience of the teaching of both lecturers. This finding speaks to the adaptability of students when presented with different teaching orientations and characteristics of lecturers. First year students respond positively to lecturers who are enthusiastic, well prepared and committed to deliver to the best of their abilities, even if they feel insecure in the role of an instructor to a large class of students.

The teaching time available was inadequate for the majority of students to feel comfortable with the material. While it is reasonable to expect that much learning at tertiary level must happen outside of formal lectures, student feedback suggests that more attention should be paid to big idea 3 in class.

The poor performance in photosynthesis is definitely not due to the teaching orientations of the lecturers. This is shown in the overwhelmingly positive responses. A more likely reason for poor performance is the way photosynthesis sessions are structured. The topic is inherently difficult. The practical that was performed before the theory was covered resulted in poor practical marks. The time allocated for the theme is not long enough for lecturers to ensure that students grasp the different difficult big ideas. Photosynthesis is also covered very early in the first semester of the first year which means that students are still trying to adapt to the new environment, the big classes and the fast pace of tertiary instruction. In order to improve the marks of photosynthesis the department should consider allocating more time to photosynthesis and to move the practical session later in the semester.

5.5. Implications for management of teaching assignments within the cluster of departments

The fact that the lecturers shared the theme developed both of the lecturers professionally. Ms Amy was exposed to the experience of Prof James in terms of handling the classes and what should be covered in more detail, because it is not only the plant sciences that require knowledge of this theme. Prof James on the other hand was reminded that he has lost track of the academic abilities of first year students. He thus attempted to close the ‘gap’ between the professor and the first year students.

The time allocation should be re-evaluated. Lecturers must be careful not to spend too much time on a section in the textbook that is covered very well. Rather spend more time on the sections that are not well covered in the textbook in order to bridge the gaps for the students.

All lecturers should be made aware of TSPCK and they should be encouraged to attempt to address all aspects of it in their planning and classes. An ideal situation would be if all of the lecturers teaching MLB 111 get the opportunity to work in teams on the same theme. This would ensure that they were able to answer any questions on content asked by the students instead of referring them to other lecturers. This would also develops the lecturers professionally and equip them to stand in for each other in this module.

5.6. Areas for further research

The students' marks for each big idea in tests and examinations could be compared to see if students perform better in the big ideas which they identify to be explained exceptionally well. Comparing specific lecturer's students' marks would also indicate if students were biased in their comments.

5.7. Limitations in this study

This was a qualitative study. Traditionally qualitative studies are hampered by the fact that findings cannot be generalised outside the context of the study. The study can easily become too long and not rigorous enough. Great care was taken to create an un-biased report and stay true to the findings. This study is unique and only of interest to a specific department of the University of Pretoria. This was a convenience sample because the students took part voluntarily.

5.8. Reflections of researcher

Being a lecturer myself I did not expect similar teaching orientations between the experienced and beginner lecturers. I also had specific ideas on how the sections should be covered and explained. The students looked at the lecturers with totally different expectations to me as a lecturer. I experienced a difference in the teaching orientations of the lecturers that is not reflected in the study. I also expected a better developed TSPCK for the experienced lecturer than that of the beginner. The similarities between the lecturers can be explained by the close professional relationship between them and their attempt to make sure that all of the students get the same information and content knowledge from them.

I learned a lot from this experience in terms of my own teaching orientation. I am definitely more aware of my TSPCK and attempt to ensure that I adapt my teaching strategies and representations to emphasise possible problems and to accommodate the different learning styles of my students. Refection and evaluation are becoming an integral part of my daily activities to ensure that I can make changes in my teaching orientation for topics that students still do not understand after the class. This research study was a positive journey and an experience that developed me as a teacher and also equipped me with the knowledge to assist other teachers in developing their TSPCK.

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Appendix 1: Semi structured interviews

Ms Amy

It is Wednesday morning at 9:00. We are sitting in Ms Amy Amy's office. Ms Amy Amy, Professor Marietjie Potgieter and Mrs. Hester Kriel are present. The purpose of this interview is to get an understanding of the teaching orientations and methods that Ms Amy used in her lecturing of the photosynthesis classes of the first year molecular cell biology.

Amy you are more than welcome to give your opinion at any time during the conversation. We are recording this interview for referencing purposes and it will not be made public to anybody. Prof Potgieter is present to so that she can verify my report on the interview.

Please note that we would like to have a second interview with you after I watched the DVD's of the contact sessions. You are welcome to get a copy of your lessons as well.

Amy, I prepared the questions in English, you are free to choose the language of communication and to answer any question in English or Afrikaans.

1. *I want to know for the photosynthesis sessions how did you divide the section into lessons?*

   My lessons are structured. It is divided into 5 lessons. I try to do an intro lesson lecture then I try to do each of the different components in a lecture and the last lecture is supposed to be a revisions and try to put everything together and help the students with what they struggle with, so I did intro, the light reaction, the Calvin cycle and c4 in one which was a little bit of a problem and then I did C4 again, C4 and CAM again, so I try to structure it in such a way that so that each component is a different lecture.

   If I look at that do I understand correctly that you only see three components in photosynthesis?

   Yes, there is an intro part that where you have to understand the basics of light properties *so that is also a section?* That is also a section and then you start with the light reactions and chemo osmosis that goes with it, the next one is the Calvin cycle and the other part if it is C4 and CAM but it is supposed to fit in with the Calvin cycle

2. *Did you keep to this division in your teaching?* Not completely no, because one of my lectures took longer than expected.

   .

Which one took longer can you remember which? The Calvin cycle.

3. *I noticed that you dismissed the class on a specific day a bit early although you told the students that you are falling behind. You started the next class with the slide on the absorption spectrum. What was your reasoning behind that decision?* Ok the absorption spectrum is the last part of the kind of the light part of photosynthesis and I didn't want to start with the light reactions because you have to do it as a whole In order to do it, so I stopped although I knew I was supposed to start with that and after the class some students come and ask me their specific question about that slide that I repeated so I just thought I'll help them out.

4. You used the tablet in your class, why did you choose to use the tablet instead of the pointer or any other way? For me personally I especially with stuff like photosynthesis and respiration it is easier to explain if you can draw it step by step. It's a personal thing, I know of many people do not do it like that. I study by drawing so I teach by drawing. *Interesting thank you*

5. *How do you feel about class discipline? With the big classes that you're teaching?* I feel that the students tend to push you like a 3 year old, they push the boundaries until you set it and then they are ok for a while and I find that they try you out if you are a new lecturer because we are three lecturers they will try you out as the new lecturer in the first lecture to see what happens. If you don't discipline them there and then, then it just gets worse. Uhm I think the big classes influence the discipline to a great extend because you cannot teach in quiet and when you sit at the back of the class the students cannot hear you if the students in the front of the class are talking.

   How do you discipline them? You said in the first lesson you need to discipline them what do you do to discipline them?

   The first lecture I stood there waiting for them to quiet down and they didn't and I tried talking to them and they didn't hear me so I packed up and I left, I came back but I packed up and I left and they got such a fright *Did it work?* YES. Uhm In previous years I tried the screaming and preaching, it doesn't work but the threatening not to teach kind of helps. *How long did you stay out of the class?* No I just switch of my computer and then they got the message so I told them if I have to do it again I'm really going to leave. *Oh Okay.* I switched of so I had to switch on again so I missed about 5 minutes but it seems to work for a while. *And then they forget.* Yes and the walking out of the class. In each class there will always be students walking out when they did it while I'm do classes I tell the student to come here I give me your student card and tell them to leave and then I tell the class how disrupting it is to us and the other students if they do it and they must respect me and their fellow students and if they come into class they must please sit still and no one ever walks out again because they got such a fright because I took the student cards, very nasty but……… *Did the students come and collect their cards again?* Yes and apologized.

6. *You were lecturing an extremely big class. How do you feel about questions in the class?*

I think it's a good thing, because if one person asks a question in the class it means that about halve of the class doesn't get it, because after the class all of them will ask you the same question. So if they ask you in class it's nice you can go back and do it again. But it's very difficult in the very big classes because the students doesn't want to ask any thing and the questioning frightens the all ones 7:20 *and if you ask the questions?* It depends on how you structure it sometimes they do not want to engage and then it depends on what I want to get out of it. If I just want to see if they understand and they answer me then it's fine, if it's just a question to get the lesson going and they don't answer then I give them the answer or I tell then, good this might be a good exam question and I leave it at that so that they know they must go back and look at it. And sometimes I ask those questions very specifically in the exam so that they…….. *If you tell them this is a good exam question do you give them the answer as well in class?* It depends on how they respond *ok* sometimes you get these very engaging classes and they get something out of it. If they do not respond at all then I will tell them this is a good exam question. If they come and ask me after class I will give them the answer but I think it is a mutual relationship. I try to engage them but also depend on so many things, if they write a semester test that evening they might as well not be there so there is no response whatsoever and so I just do it again later 8:42

7. *Do you experience difficulty in getting the students involved in the class?*

Yes it's difficult in the big classes.

Any plans on how to get them involved?

I have lots of plans but to implement them is a little bit uhm in photosynthesis I didn't do it this year because I'm still trying to think of a good way. In my other class what I do is I give them a very specific uhm worksheet to do in my first lesson and I tell them you do it doesn't matter if you don't know what's going on I will fill in whatever you need to know as we go along so keep it with you. That seems to help but in photosynthesis I couldn't do it this year it's just too crazy and I'm still thinking of a good plan. In the smaller classes that I taught photosynthesis I had them build models but in the big classes it's impossible because we don't have the resources. Also thought about clickers, but we don't have any so, and that really engages them, it does it really helps. So I have lots of plans but it is very difficult to implement them in the big classes 9:59 *Do you expect students and this still part of engaging the students. Do you expect from the students to take notes in your class?* Yes but I don't expect them to write down everything that I put on the slides because the slides are supposed to be a supplement to the textbook so I expect them to read the textbook, take notes in class and then make a whole out of it. *And you tell then that?* I told them that when I started of my other lessons not mu photosynthesis lesson. *Oh okay 10:34*

8. *10:45 how do you experience the 10 min after the class is dismissed*?

Uhm It depends on what I'm doing sometimes when the work is difficult I find that the students will come and ask me the same question over and over again. But because I'm also doing the admin most of the time for me it is sorting out admin problems. (11:00)So you have your students that come and ask you very specific questions but I also have that thing of sorted out everyone's problems.

(11:13) does that make the 10 minutes effective if you have to sort out admin problems as well?

No. (11:21)*So uhm is there a way to get around that or is that just a thing that you survive?* I think it's one of those things I just take it as I go along. Usually the admin problems I tell the students listen come to my office. Whereas the students who have legitimate questions I will try to explain to them at the end but it takes time and then you don't have enough time although I then do it I tell them I will explain it tomorrow in class again.

9. *(11:50) how do you feel about the fact that students record your lesson and take photos of the slides?* Uhm I must say at some point I felt it was okay, I'm not crazy about the video thing, that kind of puts me of but I'm getting used to it. At some point I thought it was okay but now…..I don't know why the students do it, I think they do it not because they want the information but because they want to be able to sell it later because that's what most of them do. So uhm I don't think it's a bad thing but I think they should rather try to understand what I'm trying to explain rather than just taking a photo of the question so that we can have it later for the exam. The video thing I don't like so much because they can come back and tell you said this quit out of context and that might not necessarily be true. Not that anyone ever come back but……….*it possible* it's possible. And I know it's against University rules to do it but I haven't said anything yet. (12:59)*Is it against the university rules?* Yeah Quinton says it says you are not allowed to take videos uhm in class, in any class without authorization so unless I tell them they can do it they are not really allowed to do it. But they don't know that

10. *(13:18)Do students come and see you after class in your office about the lessons?* Yes. *Often?* This year I have quite a bit, I probably have about 10 students which come to me. I had one this morning in tears who will come to see me. So I get it quite a bit especially with the more difficult work. They seem to struggle to put the concepts together and that is easier to do on a one to one basis. *Can you remember the types of questions or the work they ask you about, the content?* Uhm, One of the students, it was respiration based uhm the other most if the students either come to ask me about the principle of chemo osmosis or they come to ask me about how uhmC4 and CAM fit into the whole picture. That whole you know they understand the different parts but putting everything together to fit together they don't get. So most of the time that is a very specific thing that they cannot do. (14:26)**When you see sorry when you say 10 students come to see you is that per day on average or in total?** Uhm On **the topic of photosynthesis** on total while I was teaching there's been about 10 students **on photosynthesis** yeah on photosynthesis. Through the period. **Thank you** *Thank you, I actually assume it was in total.*

11. *(14:47)I noticed that you sometimes refer questions after class from students to Prof James. Why is that?* Uhm, Sometimes especially with the respiration some people would come and ask questions about respiration and the enzyme stuff that he does with them. Uhm I feel uncomfortable answering the questions because I do not know what he told them in class (15:14). There is different ways of approaching the same thing. So I prefer that the lecturer that actually teach that part of the course answers the question unless I really I know very well what they were told in class. And most of the time when I refer them to Prof James because of work that he did with then that I have no involvement with (15:33) *you used the words now there is different approaches to the same topic and to answer the same question. Do you think it will be a problem for students of yeah for students to get something explained in two different approaches?* Uhm. No not necessarily but the work they ask about was usually the enzyme and the pH work, I'm NOT a Biochemist so I'm not going to go there and I don't I mean the respiration is fine because I also taught it but that work is his and his alone so….. (16:00)*If they ask you something about a question about a topic that YOU were familiar*

with will you answer it? Yes *Okay. (16:20)*But most of the time that was not the case the usually ask me about something completely different so……..

12. (16:27)H*ow do you experience teaching in the two different teaching venues*? Uhm…. It's a little bit disconcerting because the one has a lot of technology that you can use that the other one the other venue just don't have. (16:43)So and I think it is unfair to use technology in the one venue that you cannot give the other students so I think we can do a lot more if both venues have the same kind of technology and the visuals. I know the visuals in the Roos hall is a big problem. Uhm and I feel it is unfair to the students. Uhm jah *Do I understand you correctly now? Do you use the limited technology that you have in the Roos hall in uhm Thuto as well? (17:19)* Yes *To make sure it is the same?* Ja in Thuto you have the ability to project on two different uhm walls and you can use two different things to project. You don't have to…. So I can put one picture there and draw on the other slide so that they can see where I'm coming from which I can't do in the Roos Hall (17:39) It would make life it a lot easier if you could have like one thing to explain on and one thing to explain from but I can't do that because the Roos hall don't have the facilities to do that (17:49) *Okay.* So……

13. (17:51)*Does your knowledge of what the students know, don't know and what they struggle with, influence your planning?* Uhm…….. not really, because uhm biology is not a pre requisite to get into B.Sc. so we assume they know nothing and we start from as basic as we can possibly go. So I assume they know nothing and those that do know what's going on they just sit and listen. (18:23) *Do you take in account that there is certain uhm topics that the students struggle with when you do our planning? (18:37)* We try. *How do you do that?* Well…while my lecture is going and some students come and ask me the same question over and over again I will try to do that in revision or help those students specifically. (18:53) But I also…..uhm some of the topics, I mean I can do the Calvin cycle five times and there will still be students that have no clue and that's (19:03) unfair to the other students because then you don't get to all the work so I will do it two to three times and tell them come and see me afterwards.

14. (19:17)*Could you please give me the most important sections in Photosynthesis in the smallest amount of sentences a few sentences?* **Can I rephrase that?** *Yes because I suddenly think this sounds wrong.* **If you had to identify within the content topic the big ideas what would you……… a big idea is something you can summarize in a single short sentence (19:51) So if you if you as the lecturer think of what photosynthesis is**

all about what pops up (20:00) right away to you in your thinking of the whole topic as big ideas? Give me a minute **Take your time because this is something which is important to us. (20:14)** Okay first of all they have to understand the concept of the light reactions creating energy to be used later, and how that is done (20:33) through chemo osmosis t hen they have to understand where that energy is used in the Calvin cycle and how it is incorporated and what you actually get out of the system (20:51) **Please try and do that again.** How the Calvin cycle, how the products from the light reaction is used in the Calvin cycle and what you get out of the Calvin cycle (21:06)How those energy products is incorporated in the molecules of plants and animals to use it later. They need to be able to link why the one happens so that the other one can happen so you convert light energy to chemical energy. (21:25) and then the very last part that they find very difficult is just the adaptations that plants have through unfavourable environment. **This is well done, thank you so much.** (21:44)

15. *Which part of photosynthesis do students REALLY struggle with?* C4 and CAM that must be, The Calvin cycle I must admit the Calvin cycle, and just physically getting them to understand how many C you have to put in to get something out and how much energy you use doing that. That energy incorporation and then the adaptations to that Calvin cycle that is by far the thing they struggle the most with. *(2:25) what did you say about energy and the energy* The Energy how the energy is incorporated into the molecules **How many C's are processed.** Ja, how many C's you have to put into a system to get a sugar out and the energy inputs that you that goes with that. *(22:44) so you gave me four now: C4 and CAM Calvin cycle and the number of C's you put in to get a sugar out.* Ja but that all goes with the Calvin cycle *that's part of the Calvin cycle that's not separate problems that they have?* No the Calvin cycle in its self the problem that they find with the Calvin cycle is trying to work out how many things you need to put in to get out with the energy. *So the number of C's plus the energy is part of the Calvin cycle.* JA. (23:07) **so its book keeping of C's and book keeping of energy components.** Ja (23:12) **in the Calvin cycle.** In the Calvin cycle. And the other thing that they seem to get wrong but that is photosynthesis and a respiration problem is that they don't understand the purpose of electron transport to create ATP. (23:29)And then should I explain what I am trying to say there. **Not to me** *I've been in the class remember.* Oh okay 23:44 *from the four that you give me now, C4 and Cam which is the adaptation the Calvin cycle and the process of the electron transport to ATP which one does you think is the biggest problem?*

(23:55) Probably the Calvin cycle *and then* the CAM and a….. *Then the electron transport?* Yes (24:06)

16. *How do you prepare for your classes?* Uhm *You know I 'm gonna ask that.* Yes I usually take my class notes and I print them out then I go through my textbook I have 5 different Biology textbooks so I Do you use *All of them?* Sometimes it depends uhm then I would sit in front of my computer and look at the different animations that I do have regarding that theme then I would try to incorporate it plan what I'm going to show then what I'm gonna tell then usually I write on my class notes for that specific slide what they need to know, but the slides that I have I got from my husband they are very well summed up but I do not use all of them. I prefer (25:01) to teach with (……..) *(25:05) that is my next question. I notice that you don't use all the slides that are given to the students.* It is I don't use it I give it to them because they like it. I tried last year, I took everything out that I didn't use and it confuses them. And so at one point I just put everything back. But I tell them this is a summary so that when you read through the notes you know where you are I use the pictures because I can draw on them So that is how I prepare I usually go uhm and sit and read through my picture so that I know what I want to say and then write on my notes what is important there.

17. (25:49)*What do you do after every class?* I go and write somewhere if I remember usually have like 700 little papers of possible questions or I will just write what I gonna do for the next lecture if I somebody ask me something that I find that they keep on getting wrong I would write that to remember to see to it. (26:11)*Do you do any corrections or changes on your slides after lessons if you feel that it didn't work very well?* Uhm no I usually do it the next year. *Do you still remember?* Ja because I keep my notes. *Oh okay* I have all my notes from actually I have Quentin's notes as well *So you change your slides just before you go to class again? (26:39)* mmm because sometimes the notes that they get on clickUP and my notes are not the same because when I sit and prepare I would add something or take something out of the notes. (26:05) just this is much easier for me to remember. *I noticed that and I also saw students taking pictures of your extra slides. (26:57) that was not on clickUP.* Ja you see *sometimes* you just think of something while you are doing it so you quickly add it in. *Do you make it available to the students afterwards? (27:08)* No *Not at all?* No, I feel if they miss this one slide because they are not in class it's not necessarily the good ones (27:16) *Then you must understand that they are going to take a photo of that.* Ja, that's fine as long as they take a photo if they were in class but I'm not gonna put it on clickUP again I mean it's only one slide. *Kay (7:29)*

18. *Uhm this might be a bit of a difficult question for you to answer,* Ok *I want to know when you explain the Calvin cycle why did you explain it in the specific way you did.* How did I do it? Drawing it? *Yes you draw it but there is more than one way to start it. Did you start with the energy that goes with it or did you start with the C's?* I usually start with the C's. *That's right that's what you did. I want to know why.* Ok alright the first thing that they have to understand (28:08) is that it's a cycle so everything that you put in you either needs to take out or it needs to be regenerated. Which for them is a very difficult concept to get? So if you count the C's in the Calvin cycle and (28:25) you know where they go you do not have to remember how to work out the energy, you can count the energy molecules (28:32). That is why I always start with the C because if you know how many C's you put in you can by influence work out how much energy you need. **That's where you lose me as the non-biochemist. (28:45) how come you equate C's and energy** What happens is (28:52) in the Calvin cycle is uhm you have one 5C molecule that that binds to a CO_2 molecule to give you a very unstable 6C molecule that gets broken down into two 3C molecules (29:07) uhm immediately. Now in most textbook they either explain putting in 3C's one at a time or 6C's one at a time. (29:17) Now for each one molecule so we have 2 of those 3C's molecules for each one (29:33) molecule that you put in there you need one ATP and one NADH so it doesn't matter how much that you put in on top if you know what you get out you can just count your energy molecules. (29:37)*So that's what the students ask as well.* Ja

19. *I want to ask the same question to you about photo systems I and II? (29:46)* uh-huhm. *Where uhm there is again 2 ways of explaining it one is of the energy and one is of the transfer of electrons. (29:54)* Uhm, I'm not with you. *How did you explain photo systems?* Usually I tell them what a photo system is that's important to know you have to know what it does that it converts energy light energy into a form of chemical energy in order to (30:14) be able to do work. So I explain that first then I explain to them what the electron transport chain does and then I link that to ATP synthesis. (30:25)because if you tell them immediately that you get ATP that is what I don't like about the textbook, the textbook shows you the electron transport chain shows you it gives you ATP which is not true. (30:39)the electron transport chain actually gives you uhm a proton gradient and that (30:46)proton gradient actually creates ATP 26and that confuses the students they have to understand what the photo systems do first (30:53) before you can understand what you get out of it. That is why I start with that instead of with the energy. *Like the textbook does.* Yes. (31:03) the textbook shows you get ATP and that's not necessarily true you have to get something else before you can get that.

(31:11) that's my issue with the textbook. *Do you have any questions?* **Uhm I have three questions(31:21)**

20. **I would like to ask about content if you can identify students with the textbook with your notes where do they develop misconceptions. IN other words (31:41) where do they despite engaging with the textbook, despite listening to you in class build up a conception that's wrong (31:52). Can you identify such misconceptions?** The one big one that I found out this year that I never (32:00) knew because one of the students fail last year and she came back me and said (32:04) it's the first time she understood it. Was the difference between C4 and CAM? Most students for some weird reason think it's the same thing. (32:13)and there is a very small difference between the two but it's still a difference and they don't get that so that's one (32:18) big misconception that I'm not quite sure how to overcome because there's only so many ways one can explain that. (32:26) and the other big misconception that confuses them is because it's actually 2 things because respiration and photosynthesis both use chemo osmosis to create ATP, they confuse the 2 systems and (32:42) exactly where it happens and what happens. The other thing is just merely because it is a circle they confuse the Krebs cycle with the Calvin cycle. (32:51) so it's the misconceptions of the two systems very related but not really being the same thing. (33:00)

21. **Ok Can you tell me what gives rise to such a misconceptions. I think you answered that but let's just clarify if you can go back first to the confusion between C4 and CAM can you pinpoint what gives rise to the confusion.** Uhm if I have to think about it (33:30)I think the textbook has a very small part on it it's just two little pictures there's not a uhm there's a description there but they don't always read that they just go and look at the pictures I think that might be a problem. The other problem is it is (33:50) to much work that you have to do in one lecture in order to get them to understand all the concepts. (33:59) I think that kind of and it's usually the end of the lecture so then they are so confused by what you did now and you add to it and then they just kind of loose the plot (34:11) I think that would be probably where it goes wrong (34:17) **Super answer then you want to ask something Hester?** *Ja is there a way to prevent this or solve this?* (34:27) I know you have to it's such a short little section that you can't say I devote the whole lecture to this. I don't feel you could devote…… or it should be (34:39) removed completely because the students that need this will do it again in botany 1 in the second year in the third year.(34:47)And they missed the plot completely after the first year when they do the Calvin cycle and have no clue. (34:53) because it's too much information at one specific stage that is there are two ways to do it,

either do it separately or skip it completely (35:02) *If you sorry if you could feel that it is not that important uhm in last year's paper it counted quiet in the last three years papers the uhm CAM and C4 question counted quite a few marks.* Uhm *Why do you do that (35:20)* I am not saying it isn't important *I* think it is very important *Ja* uhm but I think because we have to deal with the medical students, and we have to deal with the dentists and we have to deal with the animal science students and they don't necessarily need this but there is some things expected from us in the other courses I mean if the other courses..161 they want to at least know they have heard about this so we have to do it and we have to test the knowledge, and it is a nice C4 and Cam *question* it gives you a nice idea if they understand the other work *ok* because if they can't do the other work they can't do that either If you can't do C4 and CAM it means that you probably don't understand what is going on in the Calvin cycle. That's what I found if I ask them if the student asks me a question about that and I go back to the Calvin cycle immediately I see that they don't understand what happens there so it is a nice conceptual question to ask the students to see if they understand something. And it is one of the few things in MLB where we can test a little bit of a deeper understanding. Because most of the previous work that you do in MLB before photosynthesis and respiration is very basic so there is no insight and we want the students to be able to use their brains to get a little bit deeper and that is a nice way of doing that. (36.59)

22. *Can I put you a bit on the spot? If you do uhm Calvin C4 and CAM in the same period. Do you think that the students really realize that is that it can be a nice conceptual question?* No. *If you look at the amount of time that you spent on that specific section.* No they don't realise it but when I must admit first year students are not completely in tune with what can be that's why we changed our study guide a little bit this year to tell them they must be able to relate everything *ok* and we expect of them to go and use the study guide when they study to see that they must be able to relate it. *Thank you*. **I want to ask whether you can pinpoint exactly what causes the confusion between the Krebs cycle and the ….. (37:48)** that is a very difficult question. Because I don't know. I never got confused. It I think it is just the students get confused first of all you have ATP in both cycles and you have the same energy. The one you have NADH the one you have NADPH. That is something that confuses them to know in which belongs where we have told them more than once this year that it is two different things uhm and I think just because it is two cycles and when you look at them like visually they almost look the same and you have some of the same molecules in both the cycles cause students cannot always distinguish between the two. (38:38) they do

completely different things but you have like polices has spiral rate somewhere in the Calvin cycle it is just the confusion of terms because they don't quite understand what is going on. **Could it possibly be because of the visual representation that is just …..** It could be **uhm** but there is really no other way to do it I mean the prep cycle is a cycle and you have to do it like that and the Calvin cycle is also a cycle and you have to explain it as a cycle in order for it to work. It could be it is probably a visual thing. **And then there was a third one which I didn't understand and …** *respiration and photo synthesis.* ***Can you pinpoint what exactly is the reason for the confusion?*** *(39:28)* Uhm because of all they confuse where it happens it happens in two different places the one is in the … and the other one is in the (39:44) in the membrane of the ….. you do remember and the ATP … molecules are actually switched around it all depends where your proton gradients is situated where your ATP gets made and where it gets used and the big thing is in uhm respiration you put a lot of focus on how many ATPs you get out of a specific system. In photo synthesis uses how it gets how it gets there and just because it looks so much the same and it is so much the same because it really is it is almost exactly the same system but how you approach to what you get out of it is different and that confuses them. Because in respiration you take molecules you break it down to get uhm ATP or your energy (40:34) and you can work out exactly how many molecules is ATP in fact synthesis you use light to create energy to be used later and that they do not get.

23. **I've got two questions would you like to follow-up on anything?** *No I just thought of something else I would want to ask but you can continue first. (41:07)* **my next question is uhm what is the influence of your background in plant science in your approach to teaching this? Can you...** I think there is a big difference because well especially I mean from … respiration now as well just to get things going and I would prepare for my respiration lecture and I would think ok this is what I want them to get out of the question or out of this and I would phone him and ask him what is important here because he is the main lecturer for this and he sets the paper what do they need to know and it would be completely different from mine and when we prepared our photo synthesis because we prepared our exam questions before the time and one day we were having a discussion about some things and he talked about something and I was like "you never said that to any of the students" (41:57) because I don't feel it is important he was like "but it is" you know so it's just I feel the concepts is important for me in biology and biochemist focus a lot especially the respiration of exactly how much you get out of where and what is reduced and what is oxidized. For me that is not

important because that is not something you use in botany that oxidation reduction thing for ……..that is important. I have never asked that and I will I must tell you I have never explained it to the students because it confuses them. **(42:47) Can you pinpoint exactly what he felt was important but you never said.** I can't remember now. Uhm It was something about metal being excited. I can't remember I gonna have to go and check. But the one thing I remember is in the Calvin cycle they talk about an ago??……height molecule being reduced to a compoxil. I mean I don't care it is just it is adding energy (43:03) that's what for me it is what is important you are adding energy to your system. He wants them to know that this is being reduced to that. That is the one thing that I just quickly remembered I have never even said it I said it this year uhm because some students tend to remember it a little bit better if you give them that little extra. But for him it is very important. So I think there is there is a very big difference in approaches between different disciplines if you can say it like that. (43:20) Because I remember when we did our second semester test with … now uhm de Waal Roux she edit and she kind of checks if it is a fair assessment because there is so many lecturers and she said we have like three different cycles with energy inputs and she said it is just a rush it is too much focus on one thing and that I mean all these questions are a focus on energy and mine isn't mine is concepts. (44:09) so I think that is but I remember specifically that reduction oxidation thing. **Okay.** It is...**Then I want to know a last thing and that is the team. There is a team of lecturers involved in teaching this course. It had a specific configuration for photosynthesis but not for the rest of the course. Where in the rest of the courses I understand it a specific lecturer takes responsibility for a specific section and would teach all of the classes. Please describe the dynamics of interaction between the lecturers throughout the course and how it differed in this specific incidents. (44:42)** Okay the first year that we did this everyone just did??? something uhm so we just you just did what you had to do and last year we decided we gonna go through the study guide and try to integrate at least some of the different lecture themes for the students by actually adding a study unit into saying you have to be able to relate this to a study unit …. So actually we collaborated a little bit more. What we also did is when we set the papers all of us will edit that and would have we would make comments (45:32) on what we think especially if we think it is too difficult uhm for the students because I mean if I as a lecturer cannot answer the respiration questions it becomes a problem because then the students will also not be able to do it. So we have a little bit of an if not so much with uhm the genetics because it is very difficult to link some of the genetics with what we do its just genetics is very conceptual. This year was nice when I fought with Prof James because we sat and we discussed the questions we decided what we were going to do with the discussion classes so it was nice it gave me an idea of what they think was important it gave me an idea because he told me he found the photo synthesis confusing which I was quite surprised I mean he has been here like forever. (46:38) Uhm and when I found out through talking to him that uhm what he didn't understand so I could and the other thing that we also did which was very nice is while we were setting the questions, especially when we did multiple choice he has a lot of experience in that so he taught me a lot of setting questions, so that setting questions which the students cannot guess uhm that experience of having something help you set these types of questions uhm makes it a good learning experience for me as well. It made it a good learning experience for me as well. I think that interaction between that was very good for the scores this year. **I hear a lot of interaction that is functional** uhm **in other words setting an exam** uhm **uhm and but I would like to know how much interaction there was that's uhm more teaching strategy wise. (47:12)** Well before each lecture usually we would uhm have a talk and well actually right before each photosynthesis lecture we did photosynthesis we sat one day and we went to work and we decided uhm what I thought was important and what he thought was important but we did sat by setting questions. Because that is the easiest way to do it (48:18). If I set a question and he thinks it is not important then we would like either rearrange it so in that way we went through the work deciding what we wanted to focus on and I think and then we also decided we sat and we decided ok how will we gonna do the notes are we gonna split it up his notes and my notes and we decided it's unfair so I gave him one set of notes and he changed his notes according to what he needed and I changed mine according to what I needed. (48:01) So that influenced us also thought about how I felt if I am not going to use …. To withdraw …. so he said he feels uncomfortable doing that so we decided not to do that. So we had a bit of a discussion about teaching but him being an experienced lecturer he has his own way of doing it and I don't think I could or would want to influence him on that. And I can only teach the way I teach. I don't think it was a good exercise in uhm getting to know what is important but not necessarily in how you approach teaching.

24. **(***49:24) I want to ask you, you said on more than one instances the two of you had different view in terms of what is important for students to know or not. Did you compromise on that or did you simply insert that I am the expert in photosynthesis we do it my way?* No I we comprised we decided I mean if he said something was important I would add it into my lecture I mean it was just a little bit of extra information and he also if I told him I know the

students wouldn't understand this he would also say ok let's try this. So there was a compromise there was no I am the bigger dog here.

25. *Something else you said that you found from Prof James that what he don't understand students most didn't understand students most probably also won't understand did that change your way of explaining that specific section?* No not really. So He just came to me and said he found photosynthesis a little bit daunting he had to go and read through it quite a few times but there are only so many ways you can skin a cat. (50:14) So I mean I try to have a different approach with the drawing and you know doing it both ways , but I know only what I actually wanted to do and I wanted them to build a model but I couldn't actually quite phantom the logistics of it. So maybe if I try to think in the second semester I will be doing it that way. *?? Something similar to building the cells like you did last year? (50:30)* Uhm No I actually wanted them I try to get little round papers because I want them to physically take build a fiber carbon molecule at a carbon build that cycle because if you can built it you can do it. You know. uhm But finding like how many thousand little round things would. **We've got the book Chemistry it might be useful** (50:47) okay **The Chemistry they issued with it when they enroll that for CMY.** Ha. Good to know maybe I will try that next year. *Would all the student's in your group have chemistry as well?* **Yes they would have had.** *So which means that you would have the kits***.** Mm That's a good idea I would try that next year because I have been trying for two years to find a way to get enough little thingy mgigs for them .. **I teach explicitly with that. And we also in the pack we actually but we detracting now …..**

26. (51:37) I have one last question and that is the most controversial one. Is respiration a reverse reaction of photo synthesis? No. *Why not? What is your opinion on that*? My opinion on that is uhm if you tell the students that it is a reverse reaction you confuse them. It is respiration breaks-down glucose I mean it releases the energy. But it doesn't actually break-down break-down the glucose in exactly the same way it is build-up. So I never tell my students that it is a reverse reaction because it confuses them. *Based on your notes?* Ya I added that in for Prof James sake. *It was in last year as well*. Really? *Yes*. *Because the* Oh no the only reason why I put that in the notes is we I tell the students I might have forgotten this year, that that synthesis is a build-up of glucose whereas respiration is the break-down, photosynthesis builds-up energy and respiration uhm **release** releases that energy. But it is not if you tell them it's the opposite they think it is just reverse reactions like the reverse of the Krebs cycle which is not true. So no *I don't think so* in my mind it is not. I know many people disagree with me but I will get confused if I am a third year and someone tells me that. **Ya I agree with you. Because I mean in chemistry a reverse reaction is exactly the same molecules going through exactly the same start ….** Ya… **(53:32) product molecules is going to start** Ya **it's there is two arrows there that is what it refers to** Ya **in chemistry so in that sense it takes terminology that they are familiar with from another context** Ya **and then implies the same meaning here which is not true.** Ya. **But Let me ask you about the mythology where things happens. Uhm in in seeing Hester's schemes and maps and everything it look to me there is significance in terms of the whole process of things happening in specific places. (54:06)** Yes**. Now my question about this is uhm is this important to you that are the first part of my question that students know what happens where? In other words how the plant is structured to do this? (54:22) and whether that emphasis is unique to you as a plant scientist? Or whether that is shared?** Uhm in MLB we do not especially in three four and five there is quite a big difference in the anatomy of the plant. I do not put any emphasis on the anatomy I tell them there are two different cell types that is what they need to know. In plant science they do the detail. We expect them to know if we ask you what reaction they should be able to tell me. This is exactly where it happens. So in terms of where the different reactions happens it is important because uhm especially in photosynthesis where the energy molecules get formed is where they will use next then we also expect them it is very important that they know in respiration where the different reactions happens because where the different reactions happen depends on how much energy you get out of your system. So that anatomy of the different organelles is important for them to know. And then they also have to understand the distinction that only plants photosynthesize but all organisms and depending on say for instance it is the yeast we gonne get permutations so they have to understand the distinctions of that but the anatomy in NLB is not something we focus on the anatomy of plants is not something that we focus on because it is something intricate and different and they do it later on anyway if they need it. So it is in the notes, I know it is in their notes it is in their textbooks so that they can use it as a reference. But the only thing we ever really ever ask them is two different cell types and that's what they need to know. ……..Otherwise there is too much detail. I know Hester is like her head was like spinning because there is so much work. *There is too much work. I am officially done with my questions. Thank you…….. I really appreciate it.* Do you need our paper? *Yes*

Prof James

Time: 11h35

Date: 10 May 2013 Room 310

We are sitting in Prof James office Prof James, Prof Marietjie Potgieter and Hester Kriel is present.

The purpose of this interview is to get an understanding of the teaching orientation method that Prof James used in his lecture for the photosynthesis transfer of the first year molecule cell in Biology. You are more that welcome to give your opinion at any time during the conversation. We are recording this interview for referring purposes and it will not be made public to anybody. Professor Potgieter is present so that she can verify my report on the interview. Please note that we would like to have a second interview with you after I have watched all the DVD's of the contact mission and you are welcome to get a copy thereof if you are interested. I will attend to the question in English and you are welcome to choose a language of communication and to answer my questions in English or in Afrikaans.

1. *How did you divide the Sections or the Section of photosynthesis into lessons?*

   There is a practical element. In there we do it according to the study guide the study guide has got the work divided into study aims. I then go and I prepare the whole thing as a unit and I then hunt according to the study aims I hunt for sensible starts and stops so that we do some things to completion so that we don't take out something or the middle of a study aims so that one study aim is then half way in one lecture and then there is the last half of the same study aim in the next section. So I then do that in the total overall planning of the whole thing. I divided them in I think it was 5 lectures that we this theme and I have then divide it into 5 sensible groupings of study aims.

2. *I am going to go to a question that I actually wanted to ask you later on because it relates to the one you answered now. I note that sometime you finish a lecture before the time*

   Yes. *The reason behind that?* I do allow time for interactive work so if I prepare my lectures close to that I have to talk fast in order to meet into 50th minute then that would not allow room for any interactivity. So in my preparation I allow enough time for interactivity if then the questions are not there then of course we end earlier. Also, sometimes in my preparation in the division into 5 sessions it could be that in order to have a sensible stop at one lecture and a sensible continuation in another lecture that it might be shorter in one part and longer in the other part never extending of course the 50 min time stamp that we have.

3. *Did you keep to the divisions that you've had for yourself?*

   Yes absolutely I even put in lecture one and end lecture two as they fly so that the students knew that I was continuing were I was prepared to.

4. *You didn't use a bamboo device in your class you prefer to use a pointer? Why?*

   I also cannot play rugby and I am a horrible shot at garage build so my hand eye co-ordination is simply not good enough for using is. I did try and in my defense it is a thing that the genetic depart gave us I was at home and tried using it and I just couldn't see myself using that thing in class and then losing my confidence when I write off the board or something like that I couldn't use it I tried.

5. *Please explain the reasoning behind the singing in your class?*

   a. It is always good to get the student in an attitude where they enjoy the class so that is very important to generate a positive attitude from the learners. So if the students would have taken negatively to it if I would have sung my first song, remember this is not the first time I do it this comes over several years. If it was going to be negatively or mockingly accepted then I would not have continued with it, but I found it from experience to very positively received and I thought it was a good way to therefore create positive attitudes and fun in the class room and the students mentioned also in the students assessment they usually say they recommend and they would like other lectures also to make the class more fun to attention. So that is one reason.

   b. The other reason is, usually the songs are always beyond the level of 1st year students so it is too difficult for them so the one with the nice beat on the restoration I use for creating atmosphere and we rush over that and I use a soundtrack so I am not singing myself, but on the photosynthesis I sang because that was at the level of 1st years and a number of students actually told me they want the words initially I was not going to give the words but eventually I did they wanted the word because they say it helped them to learn. They found it fun to learn as well as when they knew they had the words of the song with them.

6. *How do you feel about class discipline?*

This is not a high school so personally I regard freedom at the University very high so unless it is extremely disturbing if students would get up in the middle of the class to walk out I would do absolutely nothing to stop them, but if it is extremely disturbing and disruptive then I would stop them, but I am hoping that by making the class fun that I get their attention from a positive attitude and that I am not frustrating them to them becoming noisy or that they are disgruntled and talk to one another so but no I am not strict on class discipline, although class discipline must be there for the class to succeed. In my assessment with the classes that you now attended the class discipline didn't go that wrong that it was seriously disrupted. That is my perception of course.

7. *Do I understand you right that you try to solve discipline by having some classes and not disciplining the student?*

Yes. *I just want to make sure I do not understand you wrong. If you are lecturing an extremely big class how do you answer questions in the class?* I like that and there are a few things to remember. First of all if a student asks a question and he or she does not have a sound system and therefore you have to repeat their questions so I took time to walk through the students if I cannot heard then listen to what the student say and then repeated the question and then answer it. In no case indications that you have attended there was not a single question that was not of general application to all the other students I recall. When students ask questions that is of worth only to that particular student I would then have stopped that and said ok come and see me after class, but there was no necessity for that in the classes that you have attend. So I could answer those questions as positive contributions to the whole lecture.

8. *Do you feel that you experience difficulty in getting students involved in the class?*

No I felt they were right there and I had their attention.

9. *How do you experience the 10 min after the lecture or after the class dismissed?*

I come under pressure when the next lecturer walks in so I am at ease with the students coming forward and asking me questions, but sometimes if the next lecturer comes in then I invite the students to join me to go outside and then continue the discussion there, but I have no problem with that I think a spontaneous answer to a spontaneous question directly after the lecture is worth a lot even more than having it postponed a day or two because then the students may never ask what troubles them because them it is for them to much trouble to make the appointment so I appreciate feedback directly after class and try to accommodate that. Usually I do not have lectures directly afterwards sometimes I do and then I have to cut it short unfortunately, but I appreciate the students coming afterwards.

10. *It is fortunate in the sense that you are not doing the administration is there any other questions than questions about the lesson or the academicals in that session?*

    I would say the most questions that I get is of administration nature and the students have not read the study guide and therefore ask my advice on how they should now proceed and then I simply tell them to go to Ms Amy and ask.

11. *How do you feel about the fact that the students recording your lessons and takes photos of your songs?*

    I am not going to remain serious. *You do not have to (laughter).* I am not famous and I love having my picture taken [laughter] … *good answer [laughter].* I have no problem at all if students take my photo but I think it could be that I do not realize the consequences because the people said that if I sing to the students like that it will appear on Facebook singing somewhere and I am not on Facebook I am unsophisticated in my electronic command of communication and it could be that I am singing on Facebook all over the world and I don’t know and I don’t realize that I could be. *I think it will be positive [laughter]* we’ll see [laughter]

12. *Do the students come to you after class in the office?*

    That is not the usual thing, but yes I get students. *Is it about the section or topic?* Then they come with worked out question and then they say they have problems with this or they have conflict and the tutor could not answer them because I always refer them to the tutor first and if they cannot get it right there I accommodate them here.

13. *Can you give me more or less an idea of how many students you see for photosynthesis?*

    I will be confused with the photosynthesis and the restoration you know I can’t remember because it sometimes covers both topics sometimes it is a central conflict so I can’t really distinguish amongst the different themes, but I think I have been consulted around 20 times personally in my office by 1st year students on administrative issues because then it is many times more that they come here and then refer them to Ms Amy.

14. *I noted that sometime you refer academic question conflict questions from students to Ms Amy, why is that?*

    Only if they ask something that is to such a degree related to botany that I regard her as the best expert because she is a qualified plant scientist and I am a biochemist. *If it is a question that you can answer would you?* Yes. *Even if you didn't teach the topics?* Even if I didn't teach the topic, now I thought all topics so I teach restoration and photosynthesis so it is no relevant and I restrict lectures whether I am now in the Afrikaans class in which either she or me the previous section did. It didn't cross my mind.

15. *I noted that for the photosynthesis section you only lectured one class and for the restoration you taught two classes and still would like to ask you a question and that question is about the venue. How do you experience teaching in two different classes?*

    Well the quality is very different my favourite hall is the tutor one, but I only lectured this year in the tutor one, because they messed up the speaker system so technically I had two sessions where the volume of the voice was to low and I cannot set it myself it has to set outside and I think it is totally irresponsible of these Technicians to go about and make the volume of the speaker system to make that lower than it is applicable to a 600 seating class. I think it is very irresponsible and so I have immediately reported them directly to the Dean when that happened. I couldn't handle it because what happens is you lose the professionally of the class. If you do that wrong and you address 600 people and I sat in the back of the hall when Amy was teaching one class I know how easily distracted one become and how frustrated one can become if you don't heard properly and students just walk out of my class in large numbers when the speaker system was not working properly and I also note that class attendance was affected directly after that class. So students immediately got the perception that this is not a professional Joe and then they act unprofessional and that is why I think the logistics around teaching large classes must be a priority at the University.

16. *Any comments on Roos Hall?*

    Roos Hall the quality of projection there is not as good as in tutor so the colours for instance don't come out well red doesn't show red. The impact is on 600 students per time. I think just changing the projector for R3000.00 or R4000.00 for a better one is a very small investment for the University to make to see to it that high impact modules are properly logistics are looked after. The sound system in Roos also needs renewal so it is doable but it is old fashion I think all the electronic stuff there has crystallized their materials and it should totally be replaced, because tutor is so much better if the technicians can look after the it properly. The problem at tutor was two times it didn't work and at the Roos hall is was one time I couldn't get the projector going for some reason of multiple use and people step onto the connection and the connector was damaged and I couldn't use it and it is hugely frustrating and in a high impact module one lecture not professional students respond in a nonprofessional way then of course being the big losers. We cannot afford to act unprofessionally when you work with 1st year students the logistics must be perfect the show must be perfect the preparation must be perfect everything must be perfect or else you lose contact with your students and your students will not pass. *That is a mouth full……….*

17. *Does your knowledge of what the students know or don't know and what they struggle with influence you planning?*

Yes. *Please explain it to me?* I am not as sensitive to this as my younger colleagues. I can't say no because I am a professional scientist I do have 50 papers to me some of them are in high impact journals and I do attend at my age to assume student know and that assumption is wrong so I am always surprised with the type of questions the students come up with afterwards that I though gee I thought I was being professional and that I had to go right down to such low levels of explanation, however this lectures sessions about cell restoration was given by Annabella Caspar one of our younger colleagues and she did a good job in rewriting the restoration, and all the other times before that rewriting it on a level that was more fees able for now a day's 1st year students. Could be that she had a daughter while the daughter was attending the University and while she was teaching one on one and to my mind the quality of her slides in terms of their contents thought me on what level to meet the students and on what level the students are on and how to meet them so what you saw om my slide on restoration at least 60% of that came directly from Dr. Annabella Caspar in which she simplified many contents especially on the chemistry and I learned that it is the correct procedure to go. If you talk about the redox reaction there she goes and gives a very simple explanation of what the redox reaction really is and I have to give credit to Dr Annabella Caspar. I try to think the level that they are on and I did in my days do this like 3 or 4 year ago I had about 5 to 6 years of experience in being internal moderator for chemistry at school level, so I think I have some experience, I rely on that to know where the students are because I was part of that moderation process of national schooling, so I rely on that if I don't know how talented I am really to use that in designing of the lectures but I try to consider that all the time, but Annabella is very much better.

18. *Explain the most important section in photosynthesis in a few sentences and I do not know whether you still want to rephrase it - Ms Amy – Yes, I did it for Amy and I will do it here as well.*

We would like you to identify the most important big ideas in this topic. By big idea we mean an excellent conceptual effort that can be phrase in a single sentence of a fragment. For me the important thing of photosynthesis is 50% of what makes life go. You can say the anabolic part of life and then the rest is the catabolic. So the respiration is the catabolic path the braking up of whatever that was produced or the extraction of energy in the process of breaking down that is respiration wherein photosynthesis is the generation of these compounds and also the recovery of gasses like CO2, oxygen balance, CO2 being produced by respiration CO2 being used and fixed in photosynthesis. So I think one of the most important aspects on photosynthesis is to demonstrate the connectedness how it is connected to all the other aspects of life and environment and health. The connectedness is important the connectionism is the same there are enzymes used both in photosynthesis and in the restoration there is no sunlight used in the respiration so the energy source is different, but always I concentrated on the connectedness and I always refer back to how photosynthesis is one process connected to all other processes of life but essential because life started by photosynthesis it didn't start by respiration and it is maintained by photosynthesis and respiration is consumerism and photosynthesis is in the production and you can't go without photosynthesis and therefore when you are a medical doctor and you are only going to work with human bodies and not with plant you have to understand about the environment the connectedness where the gasses come from what keeps us healthy and the roll of photosynthesis in keeping us healthy and my main aim was to feature the connectedness of Biology and its very, very important 50% roll of photosynthesis in that. *That was a summary. Can you within that identify sub big ideas?* Ok the electron transport chain happens in both respiration and photosynthesis even though in photosynthesis the proteins are different never the less the concepts is the same so I paid attention to demonstrate to the students how the electron transport system relates between respiration and photosynthesis, however in the reverse way the protons are pumped into opposite direction for creating of proton gradient necessary to drive the reactions into opposite directions. So that is one very important aspect. The Redox reactions of oxygen and cabin dioxide what is reduced in respiration is oxidized in photosynthesis all the time the one the invert of the other, but my main theme through all there will be different concepts where I have picked out and emphasized conflict that show the connectedness all around. So we had the electron transport chain, we had redox reactions that were reversed we had orientation of ATP synthesis in opposite direction. We compared the grana or the chloroplast with mitochondria the mitochondria through the respirations chloroplast to the photosynthesis, both organ cells use the same machinery so that one set of machinery produces oxygen and the other set of machinery uses oxygen and I was emphasizing along the connectedness. To me that was very important all the time in every lectures the connectedness had to come out. The understanding of energy in electricity, because both respiration and photosynthesis uses electricity and the understanding on what is high energy molecules and low energy molecules and why water cannot be used as fuel because the electrons are low energy potential. So the understanding of both photosynthesis and respiration and electric processes to understand different energy transformations, chemical energy, potential energy, electronic circuits and electric circuits and that kind of things. *Sjoe thanks a lot that was a mouth full*

19. *Photosynthesis, does the students struggle a lot with that, according to you?*

Yes they struggle. *Why?* First of all let's think of the connectedness with me emphasizing connectedness the moment you come to cam and C4 it is a specialized topic so it goes into a corner of specialization and students may experience at a higher concentration level because it becomes a specialization if it is not a usual general thing there is nothing in the respiration that relates to the difference between cam and C3 and C4 so we enter into a specialization direction. Medical doctor students may now ask why I should know the difference between cactus and grass. They could be difficult, not difficult, but because it does not motivate them as strong in their studies let say 50% or 70% of the class because 70% of the class is veterinarian, medical doctors and people aspiring to be either of those is 70% so it could be that the students are not as motivated and not trying to understand. The other thing is that it is on a higher level and you already have to understand the basic concepts of photosynthesis in order to apply the basic concepts of photosynthesis in a higher specialized understanding because now all of a sudden you need to understand shuttle transport of oxolo acetate from the recycled cell to the balance sheet cell, so once again you have to understand the shuttle system but the shuttle system a complex biochemical concept to understand so I think we could teach at a higher level it is simply at a higher cognitive level. It is regulation more how different plants regulate photosynthesis rather than how all plants simply use the basic connected same principal of fixing CO2. *Is there any other section of photosynthesis?* Not straight forward but as difficult as everything else, but I took the C4's and also when I sat in Amy's class they repeatedly asked the question to have it re-explained again and in my class I can remember it one time that I had to re-explained one thing so I get most questions relating to that so then it is difficult to move from the general thing that applies everywhere to a regulation of the normal stuff for specialization for different plant under different conditions. Regulation of metabolism is more difficult than just metabolism, the basic parts of it.

20. *How do you prepare for the lectures?*

Prepare, when I shuttle back home at night here I take the concept of the class from the previous year I know what to put together then I rush through and I act it out all the way actually my first year class preparation is to me a big priority and I act it out in class, I act it out in going home, I think of how and when we should sing I think of exactly what moment I should say this or that and for me it is very important because I think first years students in those numbers should be entertained or they lose interest so inspired by our famous actor Nataniël I give them a show and I want them to have a show, but sometime classes are not amenable to that and them I simply go on and hope that the previous class inspire them enough to now sit through the next one and where we have to really explained details so I cannot always entertain them, but then I make that out in bold on my way home as well and then I know well today we are going to work through those study aims.

21. Do you apart from preparing in a bold do you use resource material?

I do research on the internet on connectedness and I try to find other examples and I usually check my facts on the internet to see whatever is new which I may just through in but not with the textbook alone, it is a very good textbook, but sometime I just need to check the generality of it on the internet so I look at the concepts through the internet on what is new and a better way to explain it and maybe I can get a better picture and I flip in a better picture sometimes. During the preparation in other words what is on paper is not there which I have caught on and sometime on such pictures are not dramatically additional material it is just another more simplifying and getting it through to them.

22. *What do you do after class?*

Drink coffee. *And when you have drank coffee do you reflect on the day you had?*

Absolutely, that is why I drink coffee. I sit down drink coffee and think things over and what went down well and what topic I should avoid next time and every year the challenges is there and it is never boring, never retractive all new challenges new types of students asking new questions, new personalities, every year other preparation because we must have the most volatile of school education in the world and every year we have students prepared or unprepared in a brand new way that we never thought of before. We have to adjust them we have to kind of find out from the students when they come to you after class where are you over and where do they need to connect so every year that is a challenge and then off course lecture one especially if lecture one is to be repeated on a different day or on the same day then I learned from lecture one influences its repeat later on then I adjust it better to what I have learned from class one, but when the two classes follow immediately follow after one another than I do not have enough time for reflection and changing.

23. *You mentioned that you know what to use the next time and what works well, the correction that you then do, when do you do it? Immediately or next year?*

I make a note on my slides. There is room on the slide to make a note and sometimes I write 10 on the study aims as well. Sometimes I think the study aims did not really do it and we need new study aim. In one of the lectures on photosynthesis we added new study aims that were not there before and we announced to all the students we mentioned that we have adding a new study aim. That is also what Annabella did on the basic scene one. She added new study aims as the students become less prepared in terms of the assignments they got and then we added basic chemistry into chemistry 111 which was very volatile to them, because we couldn't wait for chemistry 117 to reach them because we have to pitch that right from the beginning so we have put in a few study aims for them to understand better how elements and what happens to bonded form molecules. If you do not like chemistry it is too late and it is usually school preparation and it is not more adequate enough or I find the student's ill prepared in chemistry. They are ill prepared when they come from school to university.

24. *Can you please tell me why do you explain the Calvin cycle in the specific way you did?*

Connectedness, remember I want to do the connectedness I want to all the time. We did the balance of the Krebs cycle so let's do the carbon balance of the Calvin Cycle so my approach is regulated by my background. I am the bigger picture person so I want them to see the bigger picture always and that is why I did the Calvin Cycle the carbonization part I did in a particular way that I have learned what was difference from my Amy's notes. We have compared notes Amy and me, I lay emphasis on balancing on all those HP's and carbon's and where they go. I made a big issue of that because I wanted to show which part of the Calvin Cycle works just like psychology in reverse. Each part is just like psychology in reverse. What is intorgonic now in the Calvin cycle that is also intorgonic in the restoration and exsorgonic, so the energy concepts to make all the themes also relating to each other because the energy concepts are theme 5, respiration is theme 6 and photosynthesis is theme 7 and they all are connected so I go right back to use the concept of team 5, 6 and 7 so that they all integrate there even though direct questions on that will not necessarily be asked all though they do ask a lot about intorgonic and exsorgonic relating to recycle and Calvin Cycle.

25. *For fairness I have to repeat the questions for photosynthesis one and two although I know what the answers is going to be. Again why did you explain photo systems 1 and 2 one and two in the specific way you did it?*

First off all there is a balance issue. A balance issue is you need more ADP and NADH. If you take the text book photo system one and two next to one another you get equal numbers of ADP and NADH and you run short of ADP. Now there is the physic photo system one that has the part that only produce ADP. It is important for the students when they do the balance that they know photo system one works at least double that hard as photo system two in the physic way in order to make for the ADP lost, so from the balance point of view it is important for me that they know why photo system one activates and when we did the cam and the C4 provided the ideal opportunity to demonstrate to the students that we need photo system one

26. *Students have access to class notes, text books, study guides and your lectures?*

Yes. *They still form misconceptions?* Yes. *Where does that come from?* I think if we solve that all marriages will last. It is human nature. Misunderstanding is human nature and you have to out in a lot of energy into proper communication which is why just married couples misunderstand one another regularly and when you are at my age it doesn't matter anymore we understand each other because I can only say two words and my wife reads the whole paragraph.

27. *Can you specify specific misconceptions which you are aware of?*

Misconceptions I have discovered in the discussions class the concept of the difference between the occulation and phosphor relation for the students to link the phosphor relation to the formation of ADP in two difference ways that is one misconception knowing this from experience and this year reemphasis or I over emphasis that concept in order to make sure they understand and still the student indefinite complexes so you still see they struggle with the relationship between that. So that is a very prominent example I do not know where it comes from and I do not know how or why that particular misconception should be a misconception. *The other one?* The other one is the electron transport chain since I have been explaining that as a normal electric device like the kettle it made more sense to the students that we are actually driving thumps with electricity and that it should not be seen in isolation if you have electric energy then they must relate and make the connection they must get the connection between electron transport chain to a normal electric device like driving an electric motor or heating up an element of a kettle, but since then it is much better. Then the other one is Chemi-osmoses the process that ends electron transport chain. Most of the first year's students do not know how a battery works you know where you get potential difference of the membrane and the separation over charge and the membrane is what batteries is all about. The students find it hard to get that concept that is why I always talk of NHDA as the charged batteries and NHDA plus as the flat battery in order to keep on emphasizing to them we are talking of the concept we use every day. *Any other one?* Oh you were actually asking about photosynthesis. The concept of the sun's energy being transformed into chemical energy which happens by way of activated electrons. So the concept of a photo sensitive plate which is the plant leave that is actually commercial photo sensitive plates that you put on your roof. I think the concept of energy from the sun being converted into chemical energy is a rather concept that they need to relate to.

28. *You said the difference between relations the ions is substantial and the other one oxidized phosphor relation. Is that relevant here?*

Yes, it is all oxidated phosphor relations in photosynthesis.

29. *And for lecturing purposes.*

For lecturing purposes when one theme goes over into another and we have another member of the team talking we get all the members of the team together so the member involved in the previous team is there when we go over to the next theme and there is a handing over so we have a relay speech so I propogate the next lecture for the knowledge she have and she then starts the class by saying on how important it was to have the previous lecture by the professor to lay the basis for the next lecture so the students are under the impression that it is not only the text book, but also the lecturer and the appreciate the inter connectedness .

30. *If it comes together do you work on teaching packages together as well?*

As a group yes we do our students evaluation of the court we do together with coffee and we shout out and analyse under chairpersonship of the relevant department of genetics we analyse our students evaluation with one another. *Is it weird to be proactive?* Well when we have the connectivity lectures of course then we work out who is going to what and how.

31. *And when you and Amy sharing photosynthesis did you do it more on a regular basis?*

What we did is that we had a number of sessions before and how we are going to approach the respiration and the photosynthesis together so we had a long discussion on what to change in the class notes and to explain to the other person while he was not here and then I told her where I was and then to most likely to change the slide a little bit in order to fit me style of lecturing but we have agreed on it. So no in terms of content and where the emphasis was going to be we also compared it before the time.

32. *Is in important for the students to know happened where in photosynthesis?*

Of course. *Why?* It is a dimensional connectedness. So the timing that I have mentioned and space is the dimension to when we go the highest level of the difference of CAM and C4 of plants the one using the time dimension and the other the space dimension of regulation I think it is exceptionally important to learn that as they have a difficult life.

33. *I want to end this interview with a very controversial question. Is respiration a reverse action of photosynthesis?*

No. *Why not?* It's specialized – the outcomes and the inputs what is outcomes for the one is inputs for the other and connectionisms to produce those are similar but also identical and it should be understood as similar meganisims our emphasis is on having them seeing on how the two processes are and how the meganisims are related and how the meganisims are similar then same ATP energy currency of ATP the same the slightly modified redox potential being the same kind of proactive in the NHDPH and NADH. So that they must understand and nature uses the same code – the genetic code is for all the same and similar processes using the same currency like NHDPH, NADH, ATP, and Proactive. *Thank you very much. Marietjie is there anything you like to ask?* Yes

Prof Marietjie asked about question no 10 and she is not sure if the questions are marked correctly – about the 10 Minutes after the lecture – I want to ask about that and also the consultations you had with the 20 students that visited you after the lectures. Can you remember in particular what those 20 students came to ask you, in other words can we have more or less a breakdown of how many asked about his or that if you can give us an indication?

The one is about the balance of what goes in and out in photosynthesis and respiration that I would say is the main thing and for them to understand the bigger picture I would say half of the hall's question evolved around that. The concept of understanding NHDH has only 2 ATP potentials and NADH has got 3 ATP potentials for them to understand that and where I get that from I then explain to them look these are the number of protons that are driven by the electricity generated by the complaints in NADH whereas NADH 2 uses 2 protein complexes and not 3 and therefore relates to how much energy they contained. In order to get to that balance one SAD is one currency **and then the tollgate effect** that is sometimes less than 3 NHDH. Those are the main thing they asked about.

1. **50% of them was in and that other was out is that the Bookkeeping there and the balance and the recues.**

For me to explain to them how the study guides relates to what they should learn – Students ask: Prof are you going to ask us protein complexes – Prof says: I said well take your study guides what do you think I you read study aims and so does that instruct you on whether or not I may ask you a question on protein complexes, electron transport chain? Student says: oh yes Prof Maybe. And how should we learn. Prof says: let's look at what it says – lets draw the protein complexes in the electron transport chain if you can – student says: oh , but they do not read their study aims. So either 50% is instructions I would say on how you apply the study guides and study aims to what the limitation are for the borders of within what you are being questioned in the assessment. **Perfect**

Now back to the section of the 10 minutes after class mostly administration? The question is what about the study aims must we learn that for the test. I get that more often as well.

I also listen to the question and if there is time enough to explain that I do usually do so in the hall or it will be done in the discussion class or it will be done in the DVD and then we will have enough opportunity to have that done or else they make an appointment.

Do you take what happens in terms of the feedback you get from students saying they do not understand or they do not get it or they need more information to make an appointment to ask this? Do you go back to your class in terms of planning the next section or is there just not enough time?

Not so much in photosynthesis, but in the respiration I get questions and then in the next class and then I get hundreds of questions from students. In photosynthesis hardly ever. I can't even remember one incident you know photosynthesis you keep you microphone on and I kept it on for no reason because there were not questions. Thank you very much for your time Prof and thank you for your hard work during this year. Also thank for your detailed answered.

Appendix 2: Daily journals

12 April 2011

Number	**Did you attend class today? /**	**Which lecturer's class did you attend?**	**In which venue was your lecture today?**	**Which sections were covered in class today?**	**Which part/aspect of this section did the lecturer explain exceptionally well? Why did it work for you?**	**Which part/aspect of this section do you still find confusing or unclear? Why?**	**Any other comments about today's class?**
R001	Yes	Prof James	Roos Hall	fotoosintese	die siklus want hy dit gesing	Krebs siklus en ander maak my deur mekaar	was lekker
R002	Yes	Prof James	Roos Hall	Theme 7	All aspects. Really enjoyed the lesson	None	<Unanswered>
R003	No	None	Roos Hall	I did not attend the class as the time slot for query consultations relation to our Sociology Semester Test 1 was the same as this class	I did not attend the class as the time slot for query consultations relation to our Sociology Semester Test 1 was the same as this class	I did not attend the class as the time slot for query consultations relation to our Sociology Semester Test 1 was the same as this class	I did not attend the class as the time slot for query consultations relation to our Sociology Semester Test 1 was the same as this class
R004	Yes	Prof James	Roos Hall	Die begin van fotosintese	Die liedjie wat hy gesing het, het die inleiding van fotosintese baie interessant gemaak.	geen	geen
R005	No	<Unanswered>	Roos Hall	Nie seker nie. Het vandag se lesing gemis as gevolg van n standards afspraak.	Het klas gemis as gevolg van n tandarts afspraak	Geen.	geen
R006	Yes	Prof James	Roos Hall	Die inleiding tot fotosintese, asook die kelvin siklus. Die verskille tussen die kelvin en die Krebs siklus was ook uitgelig.	Die Algemene link tussen fotosintese en die Kalvin siklus, omdat daar 'n prentjie by was waarop hy gewys het.	geen	Nee dankie :)
R007	Yes	Prof James	Thuto 1-2	the metabolic pool and anaerobic and aerobic pathways with an interesting introduction to photosynthesis	the metabolic pool processes it was explained in simple words with the use of diagrams and examples, and it was not rushed through thus making it easy to comprehend	none	Professor James is just an amazing and entertaining lecturer. There's no day we leave his class without a laugh... and listening to a song!

Number	Did you attend class today? /	Which lecturer's class did you attend?	In which venue was your lecture today?	Which sections were covered in class today?	Which part/aspect of this section did the lecturer explain exceptionally well? Why did it work for you?	Which part/aspect of this section do you still find confusing or unclear? Why?	Any other comments about today's class?
R008	Yes	Prof James	Roos Hall	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R009	Yes	Prof James	Roos Hall	Tema 7	Fotosintese	Geen	Nee
R010	Yes	Prof James	Roos Hall	Fotosintese	Die hele gedeelte tot by die; Watter golflengtes van lig dryf fotosintese die beste? Prof gebruik verskillende voorbeelde om ons bekend te maak aan wat aan ons verduidelik word en dit stel ons in staat om die werk deeglik te verstaan.	Geen	geen
R011	No	None	None	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R012	Yes	Prof James	Roos Hall	Respiration and the beginning of photosynthesis	The Respiration because easy flow diagrams were used to explain it and the Photosynthesis because a flow chart was also used as well as a song which made the class interesting and the lesson fun. The song also helped me remember the work	None.	The microphone needs to be adjusted. I could not hear the lecturer sometimes.

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R013	Yes	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R014	Yes	Prof James	Roos Hall	fotosintese	die hele les was verstaanbaar, die Prof verduidelik baie goed en het self's vir ons n liedjie gesing	<Unanswered>	<Unanswered>
R015	Yes	Prof James	Thuto 1-2	type: circle span chapter 9	protein pumps work in the cell	first part of chapter	the lectures are little bit fast
R016	Yes	Prof James	Roos Hall	introduction of the Calvin cycle and the end section of theme 7	photosynthesis, because converted the note into lyrics of the music	how the Krebs cycle works	It was absolutely awesome and interesting a lot, more understandable.
R017	No	None	Roos Hall	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R018	No	None	Roos Hall	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>

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R019	Yes	Ms Amy	Roos Hall	Electron transport	The basic process of photosynthesis. The illustrations used was clear and very descriptive	What the aim of electron transport actually is	The class is really early and then the lecturer only presents a 20 minute lecture. Can we have a 40 minute lecture on Mondays and get Fridays off?
R020	Yes	Prof James	Roos Hall	end of theme 6	everything	nothing	Prof James makes it easier to pay attention by implementing the songs in his lecture
R021	Yes	Prof James	Thuto 1-2	The differences between the Calvin and Krebs cycle.	The differences between the two cycles. it was easy to understand because he referred to the work we had done the day before	none	the professor is inaudible and tends to focus on only the learners in the front
R022	Yes	Prof James	Roos Hall	photosynthesis	die chemiese proses	none	none
R023	Yes	Prof James	Roos Hall	Die fotosintese se belangrikheid in die plant en watter produkte vrygestel word en opgeneem word is vandag in detail behandel.	Die deel waar die proses in vloei diagramme gesing is. Dit het gewerk omdat dit partykeer lekker is as n dosent die lesing probeer lekker maak.	Die deel van die chloroplaste is effens onduidelik aangesien dit vir my voel hy het dit moeilik verduidelik. Iets wat maklik behoort te wees.	Redelik interessant.

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R024	Yes	Prof James	Roos Hall	Fotosintese	Hy het vir ons n liedjie oor iets gesing	<Unanswered>	<Unanswered>
R025	Yes	Prof James	Roos Hall	theme 5energy,enzymes and metabolism in the cell	He explained how aerobic and anaerobic function in the cell in relation to the mitochondria. It worked form because the summary he gave us which was understandable.	<Unanswered>	It was interesting as always and very interactive.
R026	Yes	Prof James	Roos Hall	Study Aims 15 and 16 of Theme 6.	Study aim 15 of theme 6 because he related the process to what actually happens to the person, not only focusing on the cellular aspects but also gave examples to understand the process. The main process of photosynthesis where he used the songbook to explain the diagram on the projector. I could understand using the song to understand the process as we sang along.	Study aim 15 of theme 6 (Kreb's cycle in general)	Absolutely fun and was quiet different because we used songs to understand the process of photosynthesis

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R027	No	None	None	How Photosynthesis was linked to cellular respiration.	<Unanswered>	<Unanswered>	<Unanswered>
R028	Yes	Prof James	Thuto 1-2	Last part of Respiration. Introduction to photosynthesis, namely the similar aspects of both photosynthesis and respiration.	The use of other organic substances for sources of energy. I found it relatively simple to understand.	No certain point was unclear maybe a few definitions remain unclear.	None
R029	Yes	Prof James	Roos Hall	Fotosintese Die verskil tussen die krebsiklus en die kelvin siklus. Hoe organismes koolstof en energie verkry. Ontdekking van fotosintese. Lig & Elektromagnetiese spektrum. Interaksies tussen lig en atome. Chloroplaste & Chlorofil.	Die verskil in die kelvin- en krebsiklus, omdat hy die proses gesing het.	Die gedeelte van chlorofil en die absorpsie spektrum, omdat dit aan die einde van die lesing was en ek nie meer gekonsentreer het nie.	Prof James verduidelik die proses van Fotosintese baie interessant en kreatief en al verstaan mens nie dadelik wat alles is nie, kom 'n mens agter, wanneer jy leer, hoekom hy dit op so 'n manier verduidelik het... Dan maak alles meer sin!

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R030	Yes	Prof James	Roos Hall	Fotosintese	Die sisteem se stowwe wat dit vervaardig en gebruik om te vervaardig.	Sommige dele van die golflengtes.	Die liedjie was baie goed!
R031	Yes	Prof James	Roos Hall	The end of theme 6 on respiration and Prof Verschoor introduced the beginning of theme 7: Photosynthesis.	I don't feel like there was any specific part that was explained exceptionally well.	The explanation on the difference between the Krebs Cycle and the Calvin Cycle.	Prof James sang a song for the class which wasn't particularly helpful but it did make class a little lighter and funnier and I think that it is a good way of making things that aren't necessarily fun a little more entertaining.
R032	Yes	Ms Amy	Roos Hall	autotrophic, heterotrophic, phototrophic and chemotrophic organisms	Distinguishing between the different types of organisms. it worked for me because we were also given examples and what not	none	no additional comments
R033	Yes	Prof James	Roos Hall	Fotosintese: outotrofe, heterotrofe,..... fotone	Die siklus van fotosintese waar hy die lied vir ons gesing het. Sal dit nooit weer kan vergeet nie.	Sover is nog niks verwarrend of onduidelik nie.	Prof James is een van die lewendigste mense by wie ek klas het.

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R034	Yes	Prof James	Roos Hall	Fotosintese leerarea 1-4	Hele lesing, goeie skyfies, Prof. het self's vir ons gesing	<Unanswered>	<Unanswered>
R035	Yes	Prof James	Thuto 1-2	We were completing the section of respiration and photosynthesis.	The section of the relationship or how photosynthesis and ATP/ADP contribute to one another.	I am not really sure about that.	Today class ended early but i think that time could have been used to revise the parts we did not understand.
R036	Yes	Prof James	Roos Hall	Die inleiding tot fotosintese (chlorofil, lig en golflengtes, hoe organismes koolstof en energie verkry en vervaardig) en 'n kort oorsig van fotosintese as 'n proses.	Die oorsig. Hy het net die kern en die nodigste feite duidelik en akkuraat weergegee.	Ek het nie 'n deel onduidelik gevind nie.	Prof James behou altyd my aandag, want hy is onkonvensioneel en stel prosesse duidelik. Sy voorbeelde is relevant.
R037	Yes	Prof James	Roos Hall	Photosynthesis	the song	the diagram	songs done should be made available on click up or at least their lyrics because the summaries very well
R038	Yes	Prof James	Roos Hall	cell respiration	how it all goes back to ATP and the song he sang for us helped	how it all starts the with glucose, the diagram had 3 arrows leading to 1 place	loved it

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R039	Yes	Prof James	Thuto 1-2	we concluded study unit theme 6,and only did the introduction to photosynthesis	today was just an introduction	nothing yet	It was fair
R040	Yes	Prof James	Roos Hall	Fotosintese	Watter tipe en kleur lig plante absorbeer vir lig, die strukturele funksies van die inhoud van die chloroplaste asook hoe die elektron opwekking en vrystelling werk.	Geen afdeling van die werk is vir my meer verwarrend nie. Prof het alles goed en deeglik verduidelik vandag.	Dit was vir my regtig 'n baie lekker klas met die humor wat ingebring is toe Prof vir ons sing.
R041	Yes	Prof James	Roos Hall	Fotosintese	Fotosintese. Oulike liedjie gesing	Calvin siklus	<Unanswered>
R042	Yes	Prof James	Thuto 1-2	introduction to photosynthesis	the summarized importance of photosynthesis	none	<Unanswered>
R043	No	None	None	None.	None.	None.	None.
R044	No	None	None	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R045	Yes	Prof James	Roos Hall	fotosintese	chlorophyll	i don't know	no

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R046	Yes	Ms Amy	Roos Hall	Tema 6 - krebsiklus ens.	Ms Amy het die krebsiklus verskeie kere verduidelik, maar dit is steeds onduidelik.	Krebsiklus	Die studente is besonders luiddrigtig, wat dit moeilik maak om te konsentreer. Ek dink ook egter dat dit nie nodig sal wees om 'n afdeling verskeie kere te herhaal, as dit die eerste keer stadig en in detail verduidelik word nie. Ek dink bv. die krebsiklus moet verduidelik word deur vereenvoudiging van die proses deur sleutel woorde in 'n vloei diagram vir die studente uit te beeld, in stede daarvan om net haastig daaroor te praat. Hier deur sal die studente behoorlik kan volg, deur op die diagram te kyk, en persoonlike aantekeninge te maak, wat hulle manier van verstaan sal skik.

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R047	Yes	Prof James	Roos Hall	Concluded Respiration Introduction to Photosynthesis (Song of the process) Farewell of Prof. James	At the end of each Cycle involved with respiration the Prof. would play us a song as a form of summary - aid in remembering the most important aspects of the cycle The prof would always commence a lecture with a review of the previous day's work Great explanations adjacent to the slides	All very clear and understandable - All that remains is to study said theme	<Unanswered>
R048	Yes	Prof James	Roos Hall	Fotosintese en die prosesse daarvan	Hoe fotosintese werk	Geen	Ek het baie daarvan gehou toe Prof sy fotosintese liedjie gesing het
R049	Yes	Prof James	Roos Hall	Waar organismes koolstof en energie vandaan kry, die ontdekking van fotosintese, lig, elektromagnetiese spektrum, interaksies tussen lig en atome/molekules, chloroplaste, chlorofil as hoof pigment van fotosintese	Dat plante net sigbare lig kan absorbeer en dat die res van die spektrum skadelik is vir hulle. Die werk is goed en verstaanbaar op die skyfie, wat ook in die klasnotas, is uiteengesit. Prof. James het ook bykomende inligting oor hierdie studie doelwit aan die klas oorgedra sodat dit meer verstaanbaar is.	Hoe die interaksie met lig molekules/atome oksideermiddels maak. Dit is werk waarmee ek nog altyd gesukkel het.	Prof James toon 'n goeie sin vir humor en toewyding tot die studente om hulle die werk te help verstaan deur oor fotosintese te begin sing uit die Biochemists songbook, en dan die diagram wat gewys is hier deur te verduidelik.

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R050	Yes	Prof James	Roos Hall	Fotosintese	Die struktuur van die chloroplast en waar die lig-afhanklike en lig-onafhanklike reaksies plaasvind.	Geen	Prof James se sang het die klas interessant gemaak.
R051	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R052	Yes	Prof James	Roos Hall	Today we finished theme 6 (respiration) and discussed how respiration and photosynthesis link together	Sometimes Professor James uses songs that he finds on the internet to give us an overview of the concept. Today he shared the photosynthesis song. I like this because it helps me to remember the concepts which can sometimes be very complicated and it makes the material more interesting because I find molecular and cell biology subject matter a bit boring.	I'm not one hundred percent clear on the actual process of glycolysis and the Kreb's cycle which were covered this week but that's probably because I haven't yet had a chance to read the textbook and try to get to grips with these concepts	Today was our last lecturer with Prof James. He is a really good lecturer and I wish he could be our permanent lecturer (although, of course, I understand why it doesn't work this way) He always makes MLB more interesting and has a way of explaining that I think is clear and helps students to grasp complicated concepts.
R053	Yes	Prof James	Roos Hall	Respirasie	The last part, the song made it fun	<Unanswered>	<Unanswered>

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R054	Yes	Ms Amy	Roos Hall	Krebs siklus	Die vorming van ATP. Die inligting was herhaal en dus was als meer duidelik met die toepassing van die siklus.	geen	<Unanswered>
R055	No	None	None	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R056	Yes	Prof James	Roos Hall	Fotosintese	Die overall werking van fotosintese, omdat ek die groter prentjie kon sien	Calvin Cycle, Dit was nie regtig lekker verduidelik nie	<Unanswered>
R057	Yes	Prof James	Roos Hall	Fotosintese : ooreenkomste en verskille tussen respirasie en fotosintese	Overview of photosynthesis. for me it is easier this way to know if we go into detail where what fits in And why.	Nog niks sover nie.	Dit maak dit makliker om te konsentreer as daar humor in die lesings is. Byvoorbeeld prof. James se singery.
R058	Yes	Prof James	Roos Hall	the final processes of respiration	<Unanswered>	<Unanswered>	<Unanswered>
R059	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>

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R060	Yes	Prof James	Thuto 1-2	comparing and contrasting aerobic and anaerobic pathways used by cells to extract free energy from nutrients, photosynthesis introduction	everything	Nothing	he created a sing to help us understand photosynthesis which was great
R061	Yes	Prof James	Roos Hall	Fotosintese	Hoe lig saam gestel is en hoe fotone werk, en hoe die proses van fotosintese werk, die dosent was baie entoesiasties oor hoe die proses verloop, en dit het my laat belangstel.	Geen	Prof James kan oulik sing
R062	Yes	Prof James	Roos Hall	summary of cellular respiration	<Unanswered>	<Unanswered>	<Unanswered>
R063	No	Ms Amy	Roos Hall	N/A	N/A	n/a	i couldn't attend so i cannot make any comments at the moment
R064	Yes	Prof James	Roos Hall	Fotosintese	lig reaksies gepaard met die Calvin siklus	Geen	Prof. James is n uitstekende dosent!

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R065	Yes	Ms Amy	Roos Hall	Die maniere hoe verskillende organismes koolstof verkry, (outotrofe, heterotrofe, fototrofe en chemotrofe). Die chloroplast en lig en lig-afhanklike en lig-onafhanklike prosesse.	Die verskille tussen fototrofe, outotrofe, heterotrofe en chemotrofe. Dit is `n gedeelte waar jy maklik dit met mekaar kan verwar. Geniet net die vriendelike manier waarmee die dosent die werk aanbied.	Die chloroplast en die manier hoe dit gaan inskakel met die res van die tema.	<Unanswered>
R066	Yes	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R067	Yes	Prof James	<Unanswered>	Chloroplasts absorption spectrums	<Unanswered>	<Unanswered>	<Unanswered>

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R068	Yes	Prof James	Roos Hall	The end of respiration/summary of respiration and an introduction to photosynthesis	I believe the lecturer explained everything in the lecture well as I clearly understood everything. It worked for me as Prof. James makes the lectures interesting by applying them to situations we can relate to, explaining them in an easily understandable way and he also makes it very interesting by playing songs, for example the photosynthesis song. He is very enthusiastic which makes me want to learn about what he is saying.	Nothing. Everything is clear.	It was an enjoyable lecture.
R069	Yes	Prof James	Roos Hall	Fotosintese- outotrofe, heterotrofe, fototrofe, chemotrofe, chloroplaste, elektromagnetiese spektrum, en wat met 'n elektron gebeur wanneer lig inval op die plant.	Chloroplaste, elektromagnetiese spektrum	Wat met die elektron gebeur as lig inval op die plant.	Ek het baie daarvan gehou toe Prof. James vir ons gesing het!
R070	Yes	Prof James	Thuto 1-2	Study aim number 15 and 16 on theme 6 and an introduction on theme 7.	All of them.	None.	The lecture was interesting and exceptionallly good. Many confusions were eradicated.

15 April 2011

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R073	Yes	Ms Amy	Roos Hall	Introduction to photosynthesis	Excitement of electrons. She used analogies that I could relate to.	Photosystems, Calvin cycle	No
R076	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	How organisms obtain energy and carbon	how different colours of light have different energies	None	none
R080	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	introduction	The whole lesson was explained exceptionally well. The lecturer explained the work at a moderate pace and ensured that everyone understood concepts before continuing.	<Unanswered>	<Unanswered>

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R091	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Photosynthesis: 1. Light 2. The Electromagnetic Spectrum 3. Chloroplasts 4. General Definitions	How the electromagnetic spectrum - especially wavelengths as well as light - plays a huge part in photosynthesis. I thought that the analogy of the man on the trampoline was a great way to remember that a wave has a high energy when it is short, and a low energy when it is long. Also I remember the analogy with Carrots - being Carotenoids. How they are associated with an antioxidant and how they reflect orange and yellow light. These worked well for me because I seem to remember something better when I have something real to compare it to.	What the Chlorophyll molecule is composed of and why. I don't understand how the different components have different roles in chlorophyll.	<Unanswered>
R093	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	The process that feeds the biosphere. Chloroplasts. Electromagnetic spectrum. Photosynthetic pigments. Exitation of chlorophyll by light	The section on the photosynthetic pigments.	Exitation of chlorophyll by light.	The animation made the process easier to understand.

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R103	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	The section considering Autotrophs, Phototrophs and Light	The part of light, their function or purposes in photosynthesis and how these lights differ from one another	The Autotroph and Phototroph part because she was too quickly on them.	It was not a bad class just normal as everyday class
R107	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	An introduction to photosynthesis, including its overview and development historically, electrons, orbitals and energy, the electromagnetic spectrum and wavelength and energy.	The overview of the entire photosynthesis process. The accompanying video clearly illustrated her points further and it helped me to develop a better visual idea in my head.	Well we're only at the beginning of photosynthesis, so everything is still vague. But it shall all be explained further on.	<Unanswered>
R109	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Distinguishing between autotrophs, heterotrophs, photogenic and chemotrophic organisms. Describing the chloroplast.	Describing the structure of the chloroplast. This is because a video was shown describing the process in details.	so far there is non	the lecture was fun
R120	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Light, photosynthesis molecules as well as chlorophyll	It was when we elaborated on the chlorophylls part	It was photosynthesis an its molecules	A fair lecture
R121	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	The introduction into photosynthesis as well as various physics components	Explanations regarding photons, energy and the electromagnetic spectrum. These explanations were made using analogies.	None. The introduction was brief and to the point.	I enjoy watching the videos that provide an overview of a particular theme.

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Number	**Did you attend class today? /**	**Which lecturer's class did you attend?**	**In which venue was your lecture today?**	**Which sections were covered in class today?**	**Which part/aspect of this section did the lecturer explain exceptionally well? Why did it work for you?**	**Which part/aspect of this section do you still find confusing or unclear? Why?**	**Any other comments about today's class?**
				in the understanding of this process.			
R123	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Chloroplasts, Light	Excition of electrons, linked well with oxidative phosphorylation in respiration	None	None
R131	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	We did a basic introduction into photosynthesis, looking at where photosynthesis occurs and learning definitions for different types of organisms example autotrophs and heterotrophs	i especially liked the video that the lecturer played because it was easy to understand, caught my attention and illustrated photosynthesis in a way that was easier to understand the just plan diagrams	None	It was an overall good lecture that was rather simple to understand and follow
R141	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	photosynthesis, light, chlorophyll, mesophyll etc.	none	none at the moment	<Unanswered>
R146	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	ORGANISMS OBTAIN CARBON ORGANISMS OBTAIN ENERGY DISCOVERY OF PHOTOSYNTHESIS LIGHT INTERACTIONS OF LIGHT AND ATOMS	THE SECTION ABOUT HOW LIGHT IS REFLECTED AND ABSORBED BY DIFFERENT MATERIALS INCLUDING PLANTS OR IN SHORT ELECTROMAGNETIC SPECTRUM. SHE WAS JUST SO	ALL CLEAR	SHE WAS NICE AND SHORT AND STRAIGHT TO THE POINT. ITS REFRESHING TO GET OUT OF THE LECTURE QUITE EARLY

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				CHLOROPLAST CHROROPHYL	CLEAR ABOUT IT, MADE EXAMPLES AND I ACTUALLY LEARNED MLB111 TOGETHER WITH PHYSICS		
R152	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	introduction to photosynthesis	How wave length relates to the energy of the wave	None	it was joyable
R156	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Introduction to Photosynthesis. The first 15 or so slides. We focused on the two types of chlorophyll, and the properties thereof.	Properties of chlorophyll.	The structure of chloroplasts.	I liked the video. It was informative.
R168	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	The introduction on photosynthesis	nothing that much because it was just an introduction, so she just touched on the basic stuff, nothing deep	everything was clear for now	no comment
R171	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	organisms obtaining carbon organisms obtaining light interaction of molecules with light	Each aspect was explained exceptionally well as the lecturer works and explains at a moderate pace and always asks after each slide if everything was understood and if repetition of the explanation is needed.	None	none

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R175	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Photosynthesis Different modes (sources) of nutrition, light and energy mechanisms used by plants Overview of the process of photosynthesis.	Modes and sources of light and energy tools used by plants. An easy concept well explained by the lecturer.	Nothing.	None
R178	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Introduction to photosynthesis	Interactions of light and atoms Explained using diagrams	The different types of chlorophyll	No
R179	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Organisms obtain carbon and energy. Light Electromagnetic spectrum Interactions of light and atoms Chloroplast Chlorophyll	chlorophyll	None	no comment

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R185	No	None	None / Geen	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R186	Yes	Prof James	Roos Hall	Siklies en nie sikliese elektron transport. Chemiosmose en die Calvin siklus	Krebs siklus, want hy verduidelik dit aan die hand van 'n liekie of ruimpies	Ek is nie seker hoeveel ATPs en NADPs ens word gebruik en geproduseer tydens die Krebs siklus nie. Dit maak my deurmekaar. En in die tutoriaal het baie sulke vrae voorgekom oor hoeveel van watter molekules word gebruik en gevorm. Dit het dus veroorsaak dat ek baie gesukkel het met die tutoriaal want mens kan slegs daardie vrae beantwoord as jy fisies die werk gaan leer het of baie voorbereiding gedoen het. Die klas notas is ook voldoende vir die tutoriaal en meeste antwoorde kom uit die handboek en dit vat langer om uit die handboek uit voor te berei.	Sien bogenoemde vraag

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R187	Yes	Ms Amy	Roos Hall	photosynthesis to noncyclic electron transport	the process of photosynthesis and it redox reactions	chemiosmosis	no comment
R188	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	REDOX REAC	<Unanswered>	<Unanswered>	<Unanswered>
R189	Yes	Prof James	Roos Hall	Calvin cycle song about the photosystems	die Calvin cycle moet 12 keer eers gebeur voordat 'n glukose gevorm kan word	hoeveel atp's gevorm word en hoeveel nadh gevorm word en hoeveel nadh's na atp's lei	dit was entertaining
R190	Yes	Ms Amy	Roos Hall	The light dependent reactions and the noncyclic electron transport was covered.	The light dependent reactions were explained very well, particularly when she drew them as it gave a more simplified view and made it more interactive if you took down the drawings.	The role of PS 1 and PS 2 is still unclear and it is confusing when stated that photosynthesis occurs at a range of wavelengths but PS 1 and PS 2 occur only at 680 and 700 nm. The noncyclic electron transport is also confusing as the diagram is very confusing as its very busy and I would have preferred the steps to be broken up more.	<Unanswered>

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R191	Yes	Ms Amy	Roos Hall	photosynthesis	what to expect on the tests	<Unanswered>	no comment
R192	Yes	Prof James	Roos Hall	Fotosintese	Die algemene begrip	Die twee afdelings	<Unanswered>
R193	Yes	Prof James	Roos Hall	Die Calvin siklus en fotorespirasie.	Die Calvin siklus. Die vloei diagram help om die werk beter te verstaan en ook redelik makliker te verstaan.	Niks van die werk wat vandag behandel is onduidelik nie, maar die Krebs-siklus en die Calvin-siklus is verwarrend. Dit is verwarrend, want dit is amper die selfde, maar om alles te onthou van altwee verwar my, maar ek is nie seker hoekom nie.	Geen opmerking.
R194	Yes	Ms Amy	Roos Hall	Chlorophyll, main pigment of photosynthesis. The energy conversion, light to chemical energy. Redox reaction. Trace atoms. The two phases. Light dependent reactions. Photosystems. Noncyclic electron transport	The photosystems part	Noncyclic electron transport	it was good

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R195	Yes	Ms Amy	Roos Hall	Visible light spectrum Action spectrum of photosynthesis	Visible light, the shorter the wavelength the greater the energy of each photon blue and red light are the wavelengths that work best for photosynthesis chlorophyll structure: have thylakoid membrane that absorb light energy <bl />	The Action spectrum I don't understand the Calvin cycle and the conversion of ATP and NADPH Other than that, everything was clear to me	<Unanswered>
R196	No	None	None / Geen	Ek het nie vandag die klas bygewoon nie.	Ek het nie vandag die klas bygewoon nie.	Ek het nie vandag die klas bygewoon nie.	Ek het nie vandag die klas bygewoon nie.
R198	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	phases of photosynthesis, the types of photosystems, the noncyclic electron transport and the action spectrum	the phases of photosynthesis .It worked because i started to understand it better when it was introduced in the noncyclic electron transport	the light harvesting complex and photosystem two.it was confusing because i could not understand how the oxygen comes in and how the electrons come about	the class was a bit fast today
R199	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	How products of the light dependent reactions are needed for the light independent reactions. The structure of two different photosystems by explaining	The two structures of photosystems. The differences in chlorophyll a and chlorophyll b. How electrons flow in photosystems.	How products of the light dependent reactions are needed for the light independent reactions.	It was actually enjoyable.

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				the function and products produced by them. Differences between Chlorophyll a and Chlorophyll b as well as their functions. How electrons flow in photosystems.			
R200	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	the Calvin cycle and the different cycles of photosynthesis such as the light dependent and the light independent parts of it	the election transfer chain	<Unanswered>	<Unanswered>
R201	Yes	Ms Amy	Roos Hall	absorption and action spectrum, photosynthesis experiments, photosynthesis reaction equation(redox), the two phases in which photosynthesis is divided	none, they were all moderately explained to a satisfactory level	non cyclic electron transport	Would have loved to watch a video to better understand what was being said
R202	No	Ms Amy	Thuto 1-2 / Thuto 1-2	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>

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R204	Yes	Prof James	Roos Hall	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R205	Yes	Ms Amy	Roos Hall	How plant can absorb the light energy and how the electrons are energized using the energy	The process of how the electrons move through the plant structure	None	<Unanswered>
R206	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Light dependent reactions of photosynthesis.	The mode of action for the light harvesting complex.	<Unanswered>	<Unanswered>
R207	Yes	Prof James	Roos Hall	Fotosintese	<Unanswered>	<Unanswered>	<Unanswered>
R208	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Which lights suite photosynthesis best and reactions of photosynthesis.	The different light and its relation to photosynthesis.	The thylakoid membrane part.	It was fine.
R209	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>

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R210	Yes	Ms Amy	Roos Hall	photosynthesis an overview of the citric acid cycle	The co2 coming into the plant through the stomata, and diffusing through the thylakoid membrane.	I still find the terminology difficult to remember.	today's class went well
R212	Yes	Ms Amy	Roos Hall	Photosynthesis and photosystems	Photosystems as she went over it more than once	None	has good slides
R213	Yes	Ms Amy	Roos Hall	photosynthesis how the chlorophyll work	how it generates power	how the pyruvate is being broken down	all in all i understood everything
R214	Yes	Prof James	Roos Hall	Calvin siklus	Hoe die Calvin Siklus plaasvind.	Waar al die ATPs vandaan kom. >	Die klas het oor die algemeen baie goed gegaan.
R215	Yes	Ms Amy	Roos Hall	photosynthesis	almost all	<Unanswered>	<Unanswered>
R216	Yes	Ms Amy	Roos Hall	Cycles	no part at all m still confused everything	Everything	horrible
R217	No	None	None / Geen	Redox reactions in photosynthesis	<Unanswered>	<Unanswered>	<Unanswered>
R218	No	None	Roos Hall	Ek het nog nie na die recording geluister wat een van my vriendinne gemaak	Geen	<Unanswered>	Belykbaar was dit n belangrike klas om te skip. Hopelik is die opgeneemde deel voldoenbaar.

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				het nie, maar volgens hulle is fotosintese behandel.			
R219	Yes	Ms Amy	Roos Hall	The absorption and action spectrum, the chemical reactions that take place during photosynthesis as well as the two phases of the photosynthesis process.	The chemical reactions and the elements involved in these reactions.	The two phases of photosynthesis.	No further comments.
R220	Yes	Prof James	Roos Hall	Die verduideliking van hoe die proton gradient oor die tilakoiedmembraan totstand kom asook hoe ATP-sintase werk. Asook alles tot betrekking met die Kelvin siklus.	ATP sintese en die kelvin siklus. Hy het dit interessant gehou en goeie gebruik van sketse en aanwysings gebruik om dit te illustreer, tesame met `n bietjie humor, hou die res van die studente se aandag.	Die proton-gradient oor die tilakoied membraan, omdat ek dit nog nie genoeg tyd daaraan bestee het om dit te verstaan nie.	<Unanswered>
R221	Yes	Ms Amy	Roos Hall	the different photosystems, the redox equation of photosyntesis	The function of the products produced by the different photosystems. The slide was easily readable and the lecturer did not use a very technical terminology.	None	none

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R222	Yes	Ms Amy	Roos Hall	Light dependent reactions Photosystems etc.	Photophosphorylation	None	Got through a lot
R223	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	The first step of photosynthesis, an overview of the two phases and the light dependent phase.	The light dependent phase. The lecturer covered this topic twice.	I find the various types of models explaining the concept of tracing elements of photosynthesis slightly unclear only because I have not covered this section in the book as yet.	None.
R224	Yes	Prof James	Roos Hall	Twee fases van fotosintese en vergelyking tussen fotosintese en sel respirasie	Alles ewe verduidelik.	Geen.	Nee :)
R225	No	None	None / Geen	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R227	Yes	Ms Amy	Roos Hall	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R228	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	The differences between chlorophyll a and b, general equation of photosynthesis, light dependent reactions of the first phase of photosynthesis,	The structure and the function of a photosystem. She explained it twice using a clear diagram.	The classical experiment to show how chlorophyll a and b differ.	<Unanswered>

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				photosystems, and how photosystem II works.			
R229	No	None	Roos Hall	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R230	Yes	Ms Amy	Roos Hall	General things concerning Photosynthesis, Light reaction and absence of light reaction.	The two different light systems, because she used examples to explain them.	None actually.	No
R231	Yes	Ms Amy	Roos Hall	Photosynthesis	<Unanswered>	<Unanswered>	Helpful!
R232	Yes	Ms Amy	Roos Hall	chlorophyll photosynthesis Redox reaction two phases: light-dependent and carbon fixation Light-dependent reactions: photosystems 1 and 2 Started noncyclic electron transport	Photosystems 1 and 2	Noncyclic electron transport	no comment

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R233	Yes	Ms Amy	Roos Hall	Light-reactions	No part stood out as exceptional	No part was unclear to me	None
R234	Yes	Ms Amy	Roos Hall	photosystems	the method in which electrons become excited and cause a so called chain reaction with adjacent chlorophyll molecules	Photosystems and their absorption of colour. i was distracted and didn't hear the complete explanation	The speaker system in Roos is terrible, the lighting created a glare on the projector so it was difficult to see. class was very cramped
R235	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	visible light spectrum and how photosynthesis comes about	None. I found myself confused	the entire lecture especially when she started mentioning some diatomic like molecule	<Unanswered>
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R236	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	photosystem 1 and 2	all sections were thoroughly explained	None	the lecture hall was empty this usually happens when Mgrs. lectures
R237	Yes	Prof James	Roos Hall	Die Calvin siklus.	<Unanswered>	Alles was n bietjie verwant maar ek is seker ek sal beter verstaan sodra ek dit net eenkeer self deur gegaan het.	:)
R239	Yes	Prof James	Roos Hall	Nog steeds fotosintese	geen spesifieke deel nie	Geen	geen
R240	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	not sure	the process of photosynthesis	None	no comments

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R241	Yes	Ms Amy	Roos Hall	photosynthesis	Redox reaction. She explained the equation in detail	The only part i understood was the introduction of photosynthesis. With the others I'm stil little bit confused	no
R242	No	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R243	Yes	Ms Amy	Roos Hall		Photosystem II. She not only drew a simplified picture of the process but also explained in detail in simple sentences repeatedly what occurs at this stage of photosynthesis.	I don't fully understand how the noncyclic electron transport works nut it makes sense what she has said so far.	She makes plants interesting, it's not at all boring.
R244	Yes	Ms Amy	Roos Hall	The absorption spectrum, Engelmann's discovery, redox reactions in photosynthesis, atom tracing, the two phases of photosynthesis and noncyclic electron transport.	The atom tracing, light dependent reactions and Engelmann's discovery. Ms Amy emphasised certain points and provided examples and analogies that helped me understand what was going on.	The diagram on photosystems I and II. It was difficult to see the red ink that was being used to draw on the diagrams, and so it was difficult to follow.	I'm glad that someone left the door open to prevent people from slamming it closed every few seconds, but the constant in and out still broke my concentration. I think that the pace at which the work is done is easily manageable. The fact that Ms Amy places emphasis on certain

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							aspects of the work helps to identify key points.
R245	No	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R246	Yes	Ms Amy	Roos Hall	Photosynthesis, absorption and action spectra, light independent and dependent stages, photosystems I and II, redox reactions of photosynthesis.	Absorption and action spectra, redox reactions, photosystems. The lecturer explained it in an effective and easily understandable way (used good communication) as well as using the electronic pen to demonstrate further examples on the slideshow.	N/A	The content was well explained.
R247	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	sections on how organisms obtain carbon and energy, the discovery of photosynthesis, light, the electromagnetic spectrum, chloroplasts and chlorophyll	the section on light - it was simple	None	none

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R248	Yes	Prof James	Roos Hall	Fotosintese	Krebs siklus van fotosintese	benaming van sekere produkte wat gevorm word	geen
R249	Yes	Ms Amy	Roos Hall	photosystems and the difference between photosynthesis and respiration	Photosystem 2 and 1 and how nadh and atp are produced. This was explained sooo soo well because she explained it not only once but twice	None	it was helpful and interesting
R250	Yes	Prof James	Roos Hall	Calvin siklus wat in fotosintese voorkom	Die hele Calvin siklus	Geen	Geen
R251	Yes	Ms Amy	Roos Hall	Photosynthesis - overview of the Citric Acid cycle, Krebs cycle, etc.	The CO2 coming into the plant through the stomata, and diffusing through the thylakoid membrane. It worked fairly well for me because she showed us a video of the process, and I remembered that part the best.	Photosynthesis is a confusing aspect overall, because there are so many cycles and processes and figures to remember and understand very well. However, I do believe that there are definite improvements that can be made in Ms Amy's lecturing style that would ultimately benefit the entire class and aid us in understanding these difficult concepts better.	The class is extremely noisy and disruptive and Ms Amy does not command her authority in such a way as to earn the respect of her students.

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R252	Yes	Prof James	Roos Hall	Fotosintese	Alles. hy maak dit opwindend	Geen	nee
R253	No	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R254	Yes	Ms Amy	Roos Hall	photosynthesis is a redox reaction; Calvin cycle; electron flow;	Calvin cycle	redox reactions	didn't go through as much work as before
R255	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Light and the graphs of Action and Absorption spectrum	The light section was explained clear	The graphs of Absorption and Action spectrum	It was also a good class
R256	<Unanswered>	Ms Amy	Thuto 1-2 / Thuto 1-2	1. How the action spectrum came about and what it represents 2. Light dependent and light independent reactions 3. The different photosystems	I found that the lecturer explained the different photosystems extremely well. I was able to grasp the concepts because she went slowly and gave a detailed explanation of the work. I could follow and understand what was going on.	None	I was able to engage in the work and understand - I enjoyed the fact that concepts were explained in detail.

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R257	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Continued with pigments, the absorption spectrum of the pigments, started with the process of photosynthesis until the noncyclic electron transport system.	She explained all well- she used past experiments to explain trace atoms, she used the overhead projector and even included her own writing to make it clear to us.	The non-cyclic electron transport system, but was explained again in order to make doubly sure that we understood what the system is all about.	She is an amazing lecturer and she makes MLB very interesting.
R258	No	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R259	Yes	Prof James	Roos Hall	Calvin siklus en RuBP regenerasie.	Calvin siklus, baie in detail verduidelik, en werk goed in a diagram opgesom	RuBP, onderwerp wat geleer moet word om duidelik te kan verstaan dink ek.	-
R260	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	photosystem i and ii, light dependent reactions, photosynthesis redox reaction, chloroplast structure, electromagnetic spectrum, light	everything	Nothing	Brilliant lecture!
R261	Yes	Ms Amy	Roos Hall	We continued with chlorophyll and ended at the non-cyclic electron transport picture.	The action spectrum and chlorophyll.	I still struggle to grasp the concept of the general photosystem and	No.

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						how the two photosystems come together.	
R262	Yes	Ms Amy	Roos Hall	photosynthesis	the photosystems	None	no
R263	No	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R264	Yes	Ms Amy	Roos Hall	photosynthesis, colour spectrums and wavelengths	Outline of photosynthesis	Photosystems	Could not see where she was writing on the slide
R265	Yes	Ms Amy	Roos Hall	electron transport chain and light dependent reactions and photosynthesis 1 and 2 in thylakoid membrane	photosynthesis 1 and 2	<Unanswered>	it was ok
R266	Yes	Prof James	Roos Hall	Calvin-siklus	Die lied oor die tema en dat dit glukolise se inverse is	Geen	geen
R267	<Unanswered>	Ms Amy	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>

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R268	No	Prof James	Roos Hall	respiration	glycolysis, crab cycle and the transition reaction	there isn't any yet that i am uncomfortable with	no
R269	Yes	Prof James	Roos Hall	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R270	Yes	Ms Amy	Roos Hall	we covered the light dependent phase in depth...touched on the Calvin cycle but not really	The photosystems. The second time she explained i understood...	The photosystems at the beginning. She went through that part much too fast...	none
R271	Yes	Ms Amy	Roos Hall	Different types of chlorophyll and carotenoids. Action spectrum. Redox reaction of photo synthesis. The two phases: light dependent and independent. Photosystems 1 and 2.	the electron transfer system for the photosystem	None	none
R272	Yes	Ms Amy	Roos Hall	Noncyclic transport	Generally all of it. She was very patient in explaining it and making sure we understood everything	Not really a section but rather some added comments that she would make there wouldn't really be time to write everything down and sometimes you aren't sure if what	It was a very well explained lecture. It seemed Ms Amy is very passionate about this work

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						you wrote down was very important or not	
R273	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Different colours with various wavelengths that plants can absorb.	The experimental procedure taken in this part of this section	Nothing yet	None
R274	Yes	Prof James	Roos Hall	Fotosintese	everything	None	.
R275	Yes	Prof James	Roos Hall	Kelvin siklus	Die proses van die Krebsiklus.	Geen	geen
R276	Yes	Ms Amy	Roos Hall	how photosynthesis occurs in the chloroplast	the two types of photo reactions	the processes occurring in the chloroplast to produce energy	the pace was fast for me to write important points
R277	Yes	Ms Amy	Roos Hall	photosystems	All were explained fairly well	No aspect	<Unanswered>

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R278	Yes	Prof James	Roos Hall	Koolstof fissuring en die Calvin siklus van fotosintese.	Geen deel van vandag se lesing staan vir my besonders uit nie. Die hele sisteem is nog steeds vir my onduidelik.	Die Calvin siklus is nog vir my effens deur mekaar, maar niks ernstig nie.	Geen ander opmerking oor vandag se klas nie, dit was nie besonders goed nie, maar ook nie slegs nie. Ek voel net dat hoe Prof. James verduidelik veroorsaak dit dat as ek Iets verstaan dat ek dit baie goed verstaan, maar as hy dit nie goed oordra nie dat dit glad nie sin maak nie. Twee uiterstes van die spektrum.

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Number	**Did you attend class today? /**	**Which lecturer's class did you attend?**	**In which venue was your lecture today?**	**Which sections were covered in class today?**	**Which part/aspect of this section did the lecturer explain exceptionally well? Why did it work for you?**	**Which part/aspect of this section do you still find confusing or unclear? Why?**	**Any other comments about today's class?**
R279	Yes	Ms Amy	Roos Hall	from non-cyclic photo electron to chemi osmosis	photolysis	cyclic electron transport	the more she repeat something that where we understand most
R280	Yes	Ms Amy	Roos Hall	Photosystems and Chemiosmosis	All parts of today's lecture were explained well. It helped that she repeated the important parts of the processes.	None	I could still only see where she was pointing when she used the laser pointer. I could not see where she was, when writing on the presentation.
R281	Yes	Ms Amy	Roos Hall	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R283	Yes	Ms Amy	Roos Hall	Photosystems 1 and 2 in detail and the differences between them. Noncyclic electron transport and cyclic. Photolysis. hydrogen cation gradient	The hydrogen ion gradient and how it is kept.	none	It was helpful that the more difficult concepts were explained twice.
R284	Yes	Ms Amy	Roos Hall	non-cyclic electron transport chain	all aspects were explained well as it was explained until all students were confident that they understood what was said	nothing	<Unanswered>
R285	Yes	Ms Amy	Thuto 1-2 /	photosynthesis non-cyclic process	<Unanswered>	the process is quite confusing and i believe more time could be spent explaining all the processes	<Unanswered>

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			Thuto 1-2			more carefully and explaining how they tie in together	
R286	Yes	Ms Amy	Roos Hall	photosynthesis 1 and 2 (continued) and more of the electron transport chain	all were explained nicely	<Unanswered>	it was a very good class
R287	Yes	Ms Amy	Roos Hall	Photosystems 1 and 2, light reactions, non-cyclic/cyclic electron transport and a little more about photosynthesis as a whole.	She explained the electron transport cycles quite well, because she went over them two to three times. I find that when she explains a process, pointing out the steps and pathways etc. it always helps to repeat it again, in order to help us remember it and make sure we understand.	None.	It was noisy again as usual. Ms Amy really does need to earn the respect of her students, as Professor James has, no disrespect intended in any way.
R288	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Light Dependent Reactions to Non cyclic phosphorylation	The action of cytochromes and the creation of an electrochemical gradient.	none	No.
R289	Yes	Ms Amy	Roos Hall	cyclic and non-cyclic electrons	atp and nad+ production	the comparison between cellular respiration and photosynthesis	it was to the point and effective

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R290	Yes	Ms Amy	Roos Hall	The cyclic and non-cyclic electron flow	The idea of how electron flow work in the non-cyclic network as well as the concentration gradient created by the protons and how it leads to the formation of ATP and NADPH	none	she spoke too fast and finished fifteen minutes early
R291	Yes	Ms Amy	Roos Hall	non- cyclic and cyclic electron flow; proton gradient across thylakoid membrane	non- cyclic electron flow; proton gradient across thylakoid membrane	cyclic electron flow	overall great understanding of today's lesson
R292	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	1. The different photosystems and how they work within photosynthesis 2. Cyclic and non-cyclic processes 3. Chemiosmosis	The way in which the electron goes through the photosystems was explained exceptionally well. The lecturer was clear and concise. She elaborated and even asked the group if we needed further explanations.	None.	None.
R293	Yes	Ms Amy	Roos Hall	Cyclic n non-cyclic electron transport and a little chemi-osmosis	they electron transport systems, it worked because she asked if she should explain again, and the second time i got it	the difference between Chemi-osmosis, in respiration and photosynthesis, but	<Unanswered>
R294	Yes	Ms Amy	Roos Hall	Cyclic and noncyclic electron transport	all of the aspects	none	<Unanswered>

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R296	Yes	Ms Amy	Roos Hall	Cyclic and non-cyclic electron flow	cyclic electron flow	none	Please use the laser pointer
R297	Yes	Ms Amy	Roos Hall	photosystems 1 and 2,light reactions and non-cyclic/cyclic electron transport	The electron transport cycles.	none	Today's class was alright but a bit noisy.
R298	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	The noncyclic electron transport The cyclic electron transport How we establish a photon gradient : Pumping of hydrogen ions, photolysis and chemiosmosis	The noncyclic electron transport The cyclic electron transport	The process of the production of NADPH and ATP because i don't quite understand the Calvin and Krebs cycle very well.	It was fine and more productive because the lecturer repeated some of the study aims we didn't understand.
R299	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Cyclic Electron Transport, Chemiosmosis.	Cyclic Electron Transport. SHE Repeated it more than once	Chemiosmosis. I just could not comprehend the information the first time	fair
R300	Yes	Ms Amy	Roos Hall	photosynthesis	all of it	none	no
R301	Yes	Ms Amy	Roos Hall	the proton gradient of a plant's chloroplast(thylakoid)	the processes that occur in each photosystems	none	inspirational

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R302	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	noncyclic electron transport	chemiosmosis and how the concentration of H protons move in and out of the membrane	how is it connected to the Calvin cycle	none
R303	Yes	Ms Amy	Roos Hall	The cyclic and noncyclic electron transport systems as well as the process of photolysis.	The noncyclic electron transport system.	Chemiosmosis	No other comments.
R304	Yes	Ms Amy	Roos Hall	how electrons are replaced in a photosystem and how the system gets its energy	how a concentration gradient is produced and what causes it	none	it was actually very interesting
R305	Yes	Ms Amy	Roos Hall	Light dependent and light independent reactions in photosynthesis	I felt that our lecturer explained the part about the electron transport chain really well.	None	Ms Amy generally explains complicated concepts twice to make sure that we have a clear understanding of it. I feel that this really helps me and my fellow classmates in fully griping concepts.
R306	Yes	Ms Amy	Roos Hall	Noncyclic electron transport photolysis chemiosmosis cyclic electron transport	The photosystem2 (P680) and photosystem1 (P700) because she explained it drawing notes on the board as well as re-explaining using the laser.	About LHC. Reason been I couldn't make yesterday's class and missed out	Appreciate the Lecturer for being patience so that students hear her clearly

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R307	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Photosynthesis i and ii, non-cyclic electron transport. Photolysis, cyclic electron transport, chemiosmosis, accumulation of protons in the thylakoid lumen and what contributes to the proton gradient.	Chemiosmosis, especially when she compared respiration and photosynthesis and their relation to ATP.	The non-cyclic transport, the cyclic. and what contributes towards the proton gradient, the lecture was so clear that she repeated it 3 times, but i was still and still am very confused	NO
R308	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R309	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Non-cyclic and cyclic electron transport and chemiosmosis in photosynthesis.	Electron transport. She explained it twice.	None.	<Unanswered>
R310	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>

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R311	Yes	<Unanswered>	Roos Hall	completed section of noncyclic electron transport and chemiosmosis	part of chemiosmosis and cyclic electron transfer	no part is confusing	our lecture explained everything clearly
R313	Yes	Ms Amy	Roos Hall	The light dependent reaction was covered, including the Electron transport systems.	How the Photosystems work, because she took the time to explain it twice to the class.	None.	None.
R314	Yes	Ms Amy	Roos Hall	non cyclic electron transport	she explained very well why fd and Atp are the products in the cyclic transport system	I DONT UNDERSTAND HOW THE ELECTRONS GIVEN BY P700 ARE REPLACED BY ELECTRONS FROM PHOTOSYSTEM 2	NO
R315	Yes	Ms Amy	Roos Hall	Noncyclic electron transport, photolysis, cyclic electron transport and chemiosmosis.	Cyclic electron transport. This section was easy to understand because it is similar to the noncyclic electron transport, save for a few parts that are not present. Ms Amy explained the noncyclic electron transport to us twice before starting the cyclic electron transport, making it easier to understand. Linking topics in this way makes it much easier to piece information together.	I am still unsure about the specifics regarding the noncyclic electron transport. It was explained well, I just need time to get used to the different parts in the cycle. Perhaps doing what Prof. James did in earlier themes and asking us to name parts of the cycle will help to integrate the class and test overall knowledge.	I find it difficult to see the red ink being used to draw on the slides, but the explanations were repeated with the laser pointer a second time, so it wasn't a big problem. Other than that I enjoyed the class.

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R316	Yes	Ms Amy	Roos Hall	photolysis and cyclic proton transfer, chemiosmosis	photolysis and cyclic transfer of protons	chemiosmosis	it was exceptionally good
R317	Yes	Ms Amy	Roos Hall	noncyclic and cyclic electron transport, photolysis and chemiosmosis	The difference between cyclic and non-cyclic electron transport was made clear quite well, she broke down the steps of noncyclic transport and mapped them out which helped	The way the electron transport chain pumps hydrogen atoms wasn't explained fully enough and the role of the complex wasn't explained at all. The way NADPH was formed wasn't really touched on either.	<Unanswered>
R318	Yes	Ms Amy	Roos Hall	cyclic part of electron transport	everything	None in this section, yet.	It was goods because she repeats some of the concepts we don't understand.
R319	Yes	Ms Amy	Roos Hall	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>

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R320	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	non cyclic and cyclic electron transport	non cyclic and cyclic electron transport	none	Very productive. I was very impressed that the lecturer kept asking if she should go through it again.
R321	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	the non-cyclic electron transport and the cyclic electron transport	the non-cyclic electron transport because today she was not as fast as she usually is and she kept on repeating the process and we also had additional time so some of us were able to stay behind and understand it the last time as she used that time to explain it to us again and we also had time to ask questions	The pumping of electrons across the membrane to maintain a concentration gradient. I think i did not understand it because there was confusion on the concentration of proton ions on either side of the membrane	it was the greatest lecture ever with Ms Amy
R322	No	None	None / Geen	No work was covered.	<Unanswered>	<Unanswered>	We did not have class today.
R323	Yes	Ms Amy	Thuto 1-2 /	non cyclic transport system, cyclic transport system, photolysis, chemiosmosis	non cyclic electron transport and photolysis	cyclic electron transport and chemiosmosis	i would like it if she repeated chemiosmosis and the cyclic

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			Thuto 1-2	and the cyclic electron transport			electron transport, specifically the cytochrome complex
R324	No	None	None / Geen	nie vandag klas gehad nie	het nie op woensdae klas nie	<Unanswered>	<Unanswered>
R325	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Non-cyclic electron transport, cyclic electron transport and chemiosmosis.	Chemiosmosis	None. It was similar to respiration.	It was nice and short.

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R326	Yes	Prof James	Roos Hall / Roos saal	Die verskil tussen C4, C3 en CAM plante se fotorespirasie.	Die verskil tussen die plante en hoe hulle werk is vir my heel duidelik. Dit was logies uiteengesit en ook mooi duidelik verduidelik. Daar was voorbeelde en genoeg tyd om dit self te proseseer.	Ek is nog heel onseker oor die reaksies in plante, nie wanneer dit gebeur nie, maar wat die proses nodig het en wat die produk is. Waar die koolstofdioksied inkom en suurstof uit ens. Dit het nie vir my gewerk nie, want daar was heeltyd gespring tussen twee slides, en as mens nog notas moet neem ook. Kan mens nie sien waarna hy verwys en watse slide nie.	Geen ander opmerkings oor die klas nie.
R327	Yes	Prof James	Roos Hall / Roos saal	Ek kan eerlikwaar nie onthou nie.	Die dele waar die professor op 'n prentjie aangedui het.	Geen.	Nee. :)
R328	Yes	Prof James	Roos Hall / Roos saal	Fotorespirasie en C3 en C4 plante	Die verskille tussen C4 en C5 plante... Want hy het baie herhaal en die 2 prentjies wat hy met mekaar kontrasteer het, het dit makliker gemaak om die verskille raak te sien.	Die C4 Fotosintese. Dis moelike werk.	Geen.

R329	Yes	Prof James	Roos Hall / Roos saal	Verskillende Padwee van fotosintese	Verskille in padwee	Sikliese elektron vervoer	Ek moet my werk doen
R330	Yes	Prof James	Roos Hall / Roos saal	Die 3 verskillende strukture van plante en C3 en C4.	Die manier hoe Prof. V vir ons verduidelik het hoe om die 3 verskillende soorte plante te onthou. Hy het dit net so verduidelik dat mens logies daar aan kan dink en die 3 verskillendes sal kan onthou en onderskei van mekaar.	Geen.	:)
R331	Yes	Prof James	Roos Hall / Roos saal	light- and Calvin cycles	recap of the work	none	none
R332	Yes	Prof James	Roos Hall / Roos saal	fotorespirasie	verskillende sikliese in dag en nag	waar wat presies plaasvind	geen
R333	Yes	Prof James	Roos Hall / Roos saal	Ons het vandag die laaste afdelings behandel van fotosintese. Dit het oor die proses van C4 en CAM fotosintese gegaan en ons moet verskille tussen C3-, C4-, en CAM-plante kan verduidelik.	Die C3-, C4- en CAM-plante het die prof goed verduidelik. Dit het vir my gewerk, want hy het nie hoe woorde probeer gebruik wat mens deur mekaar maak nie. Die afdeling was in die algemeen die makliker van alle fotosintese waar ons die verskille tussen die verskillende plante moet kan verduidelik.	Niks. Alles is duidelik en verstaanbaar.	Geen.

R334	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	photosynthesis	the function of photosynthesis	nothing she explain everything very well	was really nice it’s just the people at the back that made a lot of noise

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R335	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Photorespiration as well as its equation and the consequences of the process. The C4 process and CAM photosynthesis by contrasting it with C3 photosynthesis. Physiological and anatomical differences in the C3, C4, and CAM plants.	The process of C4 and CAM photosynthesis by contrasting it with C3 photosynthesis.	Physiological and anatomical differences between C3, C4 and CAM plants.	Class was more of understanding how each cycle works and the products it produces.
R336	Yes	Prof James	Roos Hall	Hersiening van fotosintese en respirasie.	Die multi-choice vra oor die werk. Dit help mens sien hoeveel van die werk jy al rerig ken en hoeveel meer jy nog gaan moet leer.	Geen.	:)
R337	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	the main idea of photosynthesis	everything	all was clear to me	just a lot of noise

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R338	Yes	Ms Amy	Roos Hall	photorespiration; C4 and CAM photosynthesis	photorespiration	C4 and CAM photosynthesis	no comment
R339	Yes	Ms Amy	Roos Hall	Carbon fixation, carbon reduction, RuBP regeneration, the protein rubisco and both C4 and CAM photosynthesis.	No aspect of this section was explained; exceptionally well.	Almost all of it, lecturer said that we will repeat this section in the following lecture (23 April).	No other comments.
R340	Yes	Ms Amy	Roos Hall	Carbon fixation, CO2 uptake, carbon reduction RuBP regeneration, Rubisco, photorespiration, C4 photosynthesis and CAM photosynthesis.	The diagram of the Calvin cycle showing how to obtain G3P. Ms Amy explained it a few times and drew it, which allowed us to draw it ourselves and make notes as we went along. She then explained it again a couple of times, including once with the laser pointer. The number of explanations makes it a lot easier to understand the process rather than just reading the textbook's explanation.	The photorespiration and CAM photosynthesis. We did not have as much time to do it as the Calvin cycle, so it was a bit more difficult to understand, however we are supposed to go through it once again tomorrow.	The blue pen is much easier to see than the red, it could perhaps just be a bit thicker. Other than that I really enjoyed the class, especially the fact that Ms Amy asks us if she wants us to have her explain the diagrams again - some lecturers would explain it once or twice and then move on.
R341	Yes	Ms Amy	Roos Hall	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R342	No	None	None / Geen	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>

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R343	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Calvin cycle and its structure	the structure of the Calvin cycle	the processes that occur during the Calvin cycle	it was fair
R344	Yes	Ms Amy	Roos Hall	About to about the last 2 or 3 slides	It is all difficult and overwhelming to understand...	The majority of photosynthesis. I do not think lecturers fully explain what is in exams and tests and what needs to be more focused on.	Very quick paced, therefore uncomfortable.
R345	Yes	Ms Amy	Roos Hall	Respiration	Oxygen Transfer.	None	Brilliant Explanation on The Respiratory Processes
R346	Yes	Ms Amy	Roos Hall	The Calvin cycle	The actual cycle was explained quite well, I follow better when she draws the cycle out as it makes her go more slowly and I physically map out the steps so I can see what's going on. It makes it more interactive which helps as well.	The differences between C3 and C4 photosynthesis are still unclear as it was covered quite quickly and I don't understand when which occurs	<Unanswered>
R347	Yes	Ms Amy	Roos Hall	TYPES OF PHOTOSYNTHESIS	NONE	NONE	<Unanswered>

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23 April 2011

Number	Did you attend class today? /	Which lecturer's class did you attend?	In which venue was your lecture today?	Which sections were covered in class today?	Which part/aspect of this section did the lecturer explain exceptionally well? Why did it work for you?	Which part/aspect of this section do you still find confusing or unclear? Why?	Any other comments about today's class?
R381	Yes	Ms Amy	Roos Hall	completion of C4 plants and CAM plants and revision of photosynthesis	all parts	none	A wonderful class with all 3 lecturers- Prof James (who entertained us on the upcoming theme), Ms Amy and Mr. Oosthuizen. it was sad to bid farewell to 2 amazing lecturers- they will be missed dearly however i welcome and look forward to Mr. Oosthuizen being our new lecturer
R382	Yes	Ms Amy	Roos Hall	Revision on all important aspects of photosynthesis	Calvin Cycle	CAM Photosynthesis	A good summary of all important aspects. The questions really helped me to understand the concept.
R383	Yes	Ms Amy	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R384	Yes	Ms Amy	Roos Hall	CALVIN CYCLE	That the source of oxygen is water and not carbon dioxide and the experiments done to determine that.	where we have to determine the number of molecules required to form glucose	I know that if I STUDY THIS I WILL UNDERSTAND ALL THE COMPONENTS IN THIS THEME.HOPEFULLY I WILL DO BETTER IN MY NEXT SEMESTER TEST AND WILL BE SELECTED AS ONE OF THE FEW TO STUDY MEDICINE.WELL DONE TO MR James AND MRS Amy THEY HAVE DONE A TREMENDOUS JOB,MAY THE ALMIGHTY GOD SHOWER THEM WITH BLESSINGS AND MAY THEY CONTINUE TO HELP OTHERS

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							THEY HAVE HELPED ME TO UNDERSTAND BETTER!
R385	Yes	Ms Amy	Roos Hall	Revision of the Calvin cycle	<Unanswered>	<Unanswered>	<Unanswered>
R386	<Unanswered>	Ms Amy	Roos Hall	end of photosynthesis	what to expect in tests	no	it's sad to see Prof James leave as well as Ms Amy
R387	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	The photorespiration and its equation. C3, C4 and CAM plants explaining their differences with photosynthesis. The physiological and anatomical differences of C3, C4 and CAM plants.	Differences of C3, C4 and CAM plants. Photorespiration.	The anatomical differences in C3, C4 and CAM plants.	It was short and summarised the last parts of photosynthesis.
R388	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	THE CREB CYCLE	THE WHOLE SYSTEM BECAUSE OF REPITITION AND THE USE OF THE PAD....IT FELT LIKE HIGH SCHOOL	THE NAMES OF THE COMPOUNDS INVOLVED IN THE CALVIN CYCLE	THIS WAS A GREAT CLASS...BUT ANOTHER ADVENTURE BEGINS....GENETICS
R389	Yes	Ms Amy	Roos Hall	Review of photosynthesis	Calvin cycle	Cam and C4 photosynthesis	no
R390	No	None	Thuto 1-2 / Thuto 1-2	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R391	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	Revision of C4 and CAM plants and a general overview of photosynthesis. An example of the application of genetics was also demonstrated and explained.	C4 and CAM plants. She explained it twice using two different methods: Drawing and using a pointer and diagram.	None.	<Unanswered>
R392	Yes	Ms Amy	Roos Hall	(photosynthesis) CAM	<Unanswered>	<Unanswered>	<Unanswered>
R393	Yes	Ms Amy	Roos Hall	C4 and CAM photosynthesis	C4 and CAM photosynthesis	no part was confusing as the lecturer explained it a few times	well explained lecture
R394	No	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>

Number	Did you attend class today? /	Which lecturer's class did you attend?	In which venue was your lecture today?	Which sections were covered in class today?	Which part/aspect of this section did the lecturer explain exceptionally well? Why did it work for you?	Which part/aspect of this section do you still find confusing or unclear? Why?	Any other comments about today's class?
Number	Did you attend class today? /	Which lecturer's class did you attend?	In which venue was your lecture today?	Which sections were covered in class today?	Which part/aspect of this section did the lecturer explain exceptionally well? Why did it work for you?	Which part/aspect of this section do you still find confusing or unclear? Why?	Any other comments about today's class?
R395	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	c4 photosynthesis	the difference between c4 photosynthesis and CAM photosynthesis	none	none
R396	Yes	Ms Amy	Roos Hall	C4 PHOTOSYNTHESIS AND CAM PHOTOSYNTHESIS	Everything. When she compared them by drawing diagrams of the processes side by side for us I finally understood them	none	<Unanswered>
R397	Yes	Ms Amy	Roos Hall	She Finished off Photosynthesis C4 plants and CAM-plants	Comparison of chemiosmosis in a Chloroplast and Mitochondrion. By explaining it more than once so that we truly understand.	None	The genetics anthem; was interesting
R398	Yes	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R399	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	<Unanswered>	<Unanswered>	<Unanswered>	<Unanswered>
R400	Yes	<Unanswered>	Roos Hall	she explained the rest of the cam	she explained all the sections well	none	no comment
R401	Yes	Ms Amy	Roos Hall	Photosynthesis was completed	i found it all rather confusing	I feel that if a concept is misunderstood Ms Amy just explains it again, in the exact same way. I didn't understand the way she had explained it the first time round, so merely repeating the explanation was a futile attempt. She should consider trying to explain difficult concepts	Nothing, that hasn't already been mentioned.

Number	**Did you attend class today? /**	**Which lecturer's class did you attend?**	**In which venue was your lecture today?**	**Which sections were covered in class today?**	**Which part/aspect of this section did the lecturer explain exceptionally well? Why did it work for you?**	**Which part/aspect of this section do you still find confusing or unclear? Why?**	**Any other comments about today's class?**
						in different ways and she should maybe simplify it, i find it to be muddled up and if she could be more blatant in explaining certain aspects i feel i would understand it a lot better. This is especially true for the different cycles and parts of respiration and photosynthesis.	
R402	Yes	Ms Amy	Roos Hall	She basically explained yesterday's lectures	c4 and CAM Photosynthesis	none	class was interesting
Number	**Did you attend class today? /**	**Which lecturer's class did you attend?**	**In which venue was your lecture today?**	**Which sections were covered in class today?**	**Which part/aspect of this section did the lecturer explain exceptionally well? Why did it work for you?**	**Which part/aspect of this section do you still find confusing or unclear? Why?**	**Any other comments about today's class?**
R403	Yes	Ms Amy	Roos Hall	Recap of the entire photosynthesis processes	what we need to know for test purposes	linking photosynthesis to cellular respiration	a video to wrap the entire photosynthesis process would have been awesome
R404	Yes	Ms Amy	Roos Hall	she wrapped up photosynthesis	Everything.	Nothing, just need a bit more self-study and I'll be done.	She taught photosynthesis exceptionally well and she explained concepts very well too.
R405	Yes	Ms Amy	Roos Hall	Revision	Photo respiration	<Unanswered>	<Unanswered>
R406	Yes	Ms Amy	Roos Hall	an overview on how the plant uses light energy for glucose production	photorespiration	how the plant uses oxygen	interactive
R407	Yes	Ms Amy	Roos Hall	Finalised photosynthesis.	N/A	I find most of the work is self-study!	N/A
R408	Yes	Ms Amy	Roos Hall	A review of the entire theme of photosynthesis	C4 photosynthesis and CAM photosynthesis	The differences between respiration and photosynthesis	No further comments
R409	Yes	Ms Amy	Roos Hall	photosynthesis	comparing photosynthesis with cellular respiration	none	best lecture ever
R410	Yes	Ms Amy	Roos Hall	we had reviewed the last few aspects of photosynthesis again	the lecture explained all of the sections really well and she	none	it was an enjoyable class and very productive

Number	Did you attend class today? /	Which lecturer's class did you attend?	In which venue was your lecture today?	Which sections were covered in class today?	Which part/aspect of this section did the lecturer explain exceptionally well? Why did it work for you?	Which part/aspect of this section do you still find confusing or unclear? Why?	Any other comments about today's class?
					repeatedly if we needed further explanation		
R411	Yes	Ms Amy	Roos Hall	C4 photosynthesis and CAM photosynthesis.	I felt that both sections were explained very well. We did them yesterday, so today was just a further explanation. I found the final summary of photosynthesis to be quite beneficial too; it summed everything up and brought the topic to a close. The mini-test at the end also helped me to establish what I know and what I need to study a bit more.	There are no parts that are unclear. All sections have been explained multiple times in a variety of different ways.	I'm a bit sad that it's over, but excited to start with genetics. As a result of the explanations in class I feel confident about this section for the upcoming semester test and exam.
Number	**Did you attend class today? /**	**Which lecturer's class did you attend?**	**In which venue was your lecture today?**	**Which sections were covered in class today?**	**Which part/aspect of this section did the lecturer explain exceptionally well? Why did it work for you?**	**Which part/aspect of this section do you still find confusing or unclear? Why?**	**Any other comments about today's class?**
R412	Yes	Ms Amy	Thuto 1-2 / Thuto 1-2	1. Photosynthetic Respiration 2. Revision on the C4 and CAM cycle 3. An overview on how aerobic respiration and photosynthesis relate	The relationship between aerobic respiration and photosynthesis. This worked well for me because i was able to see clearly how the two are so similar and yet so different at the same time.	I found that the way the lecturer explained the C4 cycle as well as the CAM cycle in a more confusing manner than yesterday. This may be because the lecturer drew the cycles on the board and I find it is better if I am given an image to visualise the process.	None.
R413	Yes	Ms Amy	Roos Hall	C3, C4 and CAM photosynthesis was revised.	Ms Amy drew a comparative of C4 and CAM photosynthesis and it really clarified the similarities and differences as well as cemented what happens where.	<Unanswered>	<Unanswered>
R414	Yes	Ms Amy	Roos Hall	THE WHOLE OF PHOTOSYNTHESIS.	PHOSPHO RELATION,I WAS PAYING ATTENTION	NONE	IT WAS AWESOME
R415	Yes	Ms Amy	Roos Hall	photorespiration, integration between photosynthesis and respiration, CA,	the explanation of the structure of where photosynthesis occurs and	how the 3 phases works of the TCA works	no other comments

Number	Did you attend class today? /	Which lecturer's class did you attend?	In which venue was your lecture today?	Which sections were covered in class today?	Which part/aspect of this section did the lecturer explain exceptionally well? Why did it work for you?	Which part/aspect of this section do you still find confusing or unclear? Why?	Any other comments about today's class?
					how it occurs, i went through it a day before		
R416	Yes	Ms Amy	Roos Hall	C3, C4 and CAM photosynthesis. Calvin cycle, rubisco. Differentiating between the three types of photosynthesis. Definition of rubisco. Distinguished between respiration and photosynthesis.	Three types of photosynthesis... because now I know C3 and C4 are the same processes except that C4 has an additional step, and also that Calvin cycle always takes place in plants.	How the proton gradient is established across thylakoid membrane. I don't know how it moves from where to where and how it is generated but I need to do more self-studying.	Lecturers should post the practice questions they always have in class on click-up for test practice.
R417	Yes	Ms Amy	Roos Hall	c4 and CAM photosynthesis and a general review of photosynthesis	The differences between CAM and C4 photosynthesis were explained multiple time	<Unanswered>	<Unanswered>

Appendix 3: Evidence of TSPCK in the BL's class

	Student prior knowledge	**Curricular Saliency**	**What makes this topic difficult**	**Representations**	**Teaching Strategies**
lesson 1	00:01:03 • respiration	00:01:29 • need to know reactions • redox reactions • what happens where and why	00:09:04 • photo synthesis is extremely complex We only do the tip of the iceberg	00:01:00 • picture of photo synthesis	00:00:06 • show how many people works on photosynthesis to illustrate difficulty
	00:13: 30 • e transport chain of respiration	00:6:16 • non Sulphur purple Bacteria that is needed in microbiology	00:26: 45 Mg in chlorophyll molecule	00:02:29 • Tablet → write to show what is important	00:11:22 • show video to show basic steps at what happens in the plant cell
	00:16:01 • Wave lengths explained earlier by EL	00:11:00 • also only basic steps now rest in 3rd and 4 the year	00:16:29 • Liberated 0_2 Comes from H_20 NOT CO_2	00:07:38 • metabolic chart; show relationship	00:35: 00 • Explains photo systems again
	00:17:42 • physics knowledge on wavelengths		00:22: 20 • Don't refer to dark phase	00:11:21 • show video → basic steps	
	00:21:56 • refer to physics of light photons & chemistry		00:24: 00 • NAD → respiration • NADPH → photosynthesis	00:18: 00 • analogy of wavelengths & energy by referring to a trampoline	
	00:29:.00 • The plant cell		00:25:28 • specify type of phosphor Italian	00:25: 50 • picture of electron acceptor & light reaction	
	00:30: 20 • refer to what happens in plants		00:30:30 • photo system 2 works before Photosystems 1	00:30:45 • Ask students questions	

	Student prior knowledge	**Curricular Saliency**	**What makes this topic difficult**	**Representations**	**Teaching Strategies**
	00:14:15 • Refer to photosynthesis as the opposite of respiration			00:36:00 • Carotenoids; orange like carrots	
Lesson 2	00:14: 58 • redox reactions that is opposite to respiration • knowledge of chemistry			00:06:30 • sketch + pointer	
	00:24:43 • Substrate level phosphorylation • oxidative phosphorylation			00:10:30 • explain wavelengths where photosynthesis takes place with experiment	
				00:13:00 • Explain by writing on the slide	
				00:27:00 • Draw a photo system	
				00:40:18 • Use Writing an diagram and the pointer (on requests) to explain photo systems	
Lesson 3	00:0l: 10 • non-cyclic electron transport done the previous day		00:16:25 • Difficult to remember e^- transport chains were drawn &	00:06:00 • draw reaction as Noncyclic electron transport sketch	00:16:25 • Drawing is a good way of learning the e^- transport chain

	Student prior knowledge	**Curricular Saliency**	**What makes this topic difficult**	**Representations**	**Teaching Strategies**
	00:25: 30 • Refer to respiration		00:16:53 • light doesn't split the water it is catalyzed by on enzyme	00:09:30 • repeat explanation with laser pointer (on request)	
			00:34:00 • Confuse respiration & photosynthesis study Separately	00:14:52 • Tell students to read about the analogy in the textbook	
				00:17:50 • Drawing of Cyclic e^- transport	
				00:22: 28 • Repeat explanation • Same method	
				00:30: 32 • Re explain with pointer proton gradient	
				00:36: 00 Multiple choice questions for revision	
Lesson 4	00:03:50 • Cyclic electron transport only ATP no Oxygen forms		00:03:12 • Get confused between Carbon fixation and the Krebs cycle from respiration	00:01:22 • Compare chemiosmoses in photosynthesis & respiration with sketches → see Use different Province	
			00:0 4:19 • Anabolic → build up	00:09:04 • Schematic diagrams NO structures only names	00:08:04 • Draw because it slows talking down

	Student prior knowledge	**Curricular Saliency**	**What makes this topic difficult**	**Representations**	**Teaching Strategies**
			00:04: 39 • NADPH and not NADH	00:14:04 • only do diagram up to G3P • no details on regeneration phase	
			00:06:28 • Effect of temp on Calvin cycle in Botany	00:16:29 • Repeat explanation of Calvin cycle using a slide of the cycle.	
				00:36: 12 • Structure of CAM plants	
Lesson 5			00:06:52 • Extra step in ↳ plants; different enzyme ; combine CO_2 and 4C Compound • C4 Calvin cycle.	00:05:16 • Anatomy of C3 & C4 plant; pictures	Repeat photorespiration
			00:09:54 • Only cyclic electron transport in C4	00:12:50 • Drawing to compare C4 & CAM	
			00:11:17 • special separation in cells		
			00:12: 17 • Time separation in CAM plants		
			00:28: 30 • NADPH not NADH		

Appendix 4 Evidence of TSPCK in the EL's class

	Student prior knowledge	**Curricular Saliency**	**What makes this topic difficult**	**Representations**	**Teaching Strategies**
Lesson 1	00:00:54 • Respiration is the reverse of photosynthesis		00:02:40 • Confuse Krebs & Calvin cycles • Calvin is reverse of Krebs	00:03: 15 • show difference between respiration and photosynthesis	00:11:40 Song to emphasize importance
	00:04:20 • Similarities between respiration & photosynthesis		00:25: 30 • Drawing atom of Mg to explain electron transport	00:06:14 • Song: photosynthesis	
	00:27: 57 • electron transport chain			00:12: 30 • Analogy of Heterotrophy	
	• 00:36:00 Mitochondrion in respirator			00:20:00 • Electromagnetic Spectrum	
	00:35:00 • Respiration • Plant structure			00:36: 20 • structure of the plant	
				00:40: 20 • Analogy of carotenoid	
Lesson	00:04 : 38 • Reduction & oxidation		00:07:20 • Oxygen are from water, not CO_2	00:19:4 7 • Analogy: Popeye use spinach for energy → ATP supply energy	00:17:50 • Say to remember difference between P 700 & P 680
	00:05: 38 • Endorgonic reaction		00:10:40 • C fixation not dark phase → happens in daylight	00:25:24 • Analogy → golf whole in one the hole is P1	00:32:40 • sing to remember system

	Student prior knowledge	**Curricular Saliency**	**What makes this topic difficult**	**Representations**	**Teaching Strategies**
	00:12:00 • Thylakoid membrane		00:15:15 • photo system 2 takes place before photo system 1	00:27:21 • Analogy picture of light reactions	
				00:33:20 • Photosynthesis song	
Lesson 3	00:10: 30. ' • Glycolysis → oxidize aldehyde to acid.	00:20:22 • Calvin cycle structures in 2nd year Biochemistry	00:12:48 • Glycerin: acid reduced to aldehyde	00:23:16 • Analogy: Compare energy to toll fees	00:07:59 • new figure for C-fixation
	00:20:13 • Reverse of glycolysis forms glucose		00:20: 50 • use NADPH not NADH for anabolic reactions	00:25-23 • Song: regeneration of Calvin cycle	00:27: 45 • If you can sing it, you can remember it
	•		00:24: 24 • Energy calculations	00:38:02 • Song	00:33:39 • Photorespiration diagram
			00:31:15 • Competitive inhibitions		
Lesson	00:18: 42 • Respiration, reaction → anabolic		00:16:28 • only cyclic electron transport in C4 plants	00:10: 19 • Picture of C4, plant	
			00:20:67 • Extra ATP needed in C fixation	00:15: 20 • Analogy: energy compared to investments	

	Student prior knowledge	**Curricular Saliency**	**What makes this topic difficult**	**Representations**	**Teaching Strategies**
			00:28: 34 • difference between cyclic and non-cyclic electron transport	00:23:24 • repeat C4 reaction	
			00:30:12 • Difference between C3 & C4	00:29: 50 • C3 analogy: palisades around homes → look similar in C3 plants	
			00:32:32 • where Calvin cycle takes place in C4	00:30:38 • sketch to compare C4 & CAM	
			00:33:10 • C4 2 different cells for Calvin & C Fixation	00:38.04 • Analogy: speed of reaction in C4 & CAM→ Hare and tortoise	
			00:34: 20 • Cam: C fixation at night • Calvin cycle in day		
Lesson 5	00:04:06 • Respirations → make oxygen			00:01:08 • Schematic representation of photosynthesis	00:01:08 • Questions: test understanding
	00:08:50 → • Glycolysis			00:04:30 • Difference between hydrogen gradient in respiration and photosynthesis	

Appendix 5: Information letters to students

Dear 1st year student,

I am currently busy with my Masters degree in Science Education. The focus of my research is the teaching orientations of different lecturers in first year molecular and cell biology. To be able to do this research I need the voluntary input of first year students.

If you agree to participate you will have to complete a questionnaire on clickUP after every photosynthesis lecture. This means that I need 15 min of your time for 1 week.

Please note that your daily journal entries will be handled confidentially and will not be used for any other purpose than the research.

Thank you for your co-operation.

Hester Kriel

MSc Student

University of Pretoria

Brief aan die Student

Geagte 1ste jaar student,

Ek is tans besig met my Meesters graad in Science Education. Die fokus van my navorsing is die onderwys oriëntasies van verskillende lektore in eerste jaar molekulêre en sel biologie. Om my studie te kan voltooi het ek die vrywillige deelname en insette van eerste jaar studente nodig.

Indien jy instem om deel te neem moet jy na elke fotosintese lesing ‘n vraelys op clickUP gaan voltooi. Dit beteken dat ek 15 min van jou tyd vir 1 week nodig het.

Neem asseblief kennis dat jou joernaal inskrywings op clikUP kondfidensiëel hanteer sal word en vir geen ander doel as die navorsing aangewend sal word nie.

Dankie vir jou samewerking.

Hester Kriel

MSc Student

University of Pretoria

Appendix 6: Consent form of students

Consent Form

I understand that

- The purpose of this study is to investigate how student learning is influenced by the teaching orientation of different MLB 111 lecturers

- Any personal information about me that is collected during the study will be held in the strictest confidence and will not form part of my permanent record at the university.

- I give permission that my journal entries and the videos may be reported provided that my identity is not disclosed

- I am not waiving any human or legal rights by agreeing to participate in this study

- My participation in this study is voluntary.

Signature ____________________________ Date: ____________________

Toestemmings Vorm

Ek ____ (naam),

Studente nommer____

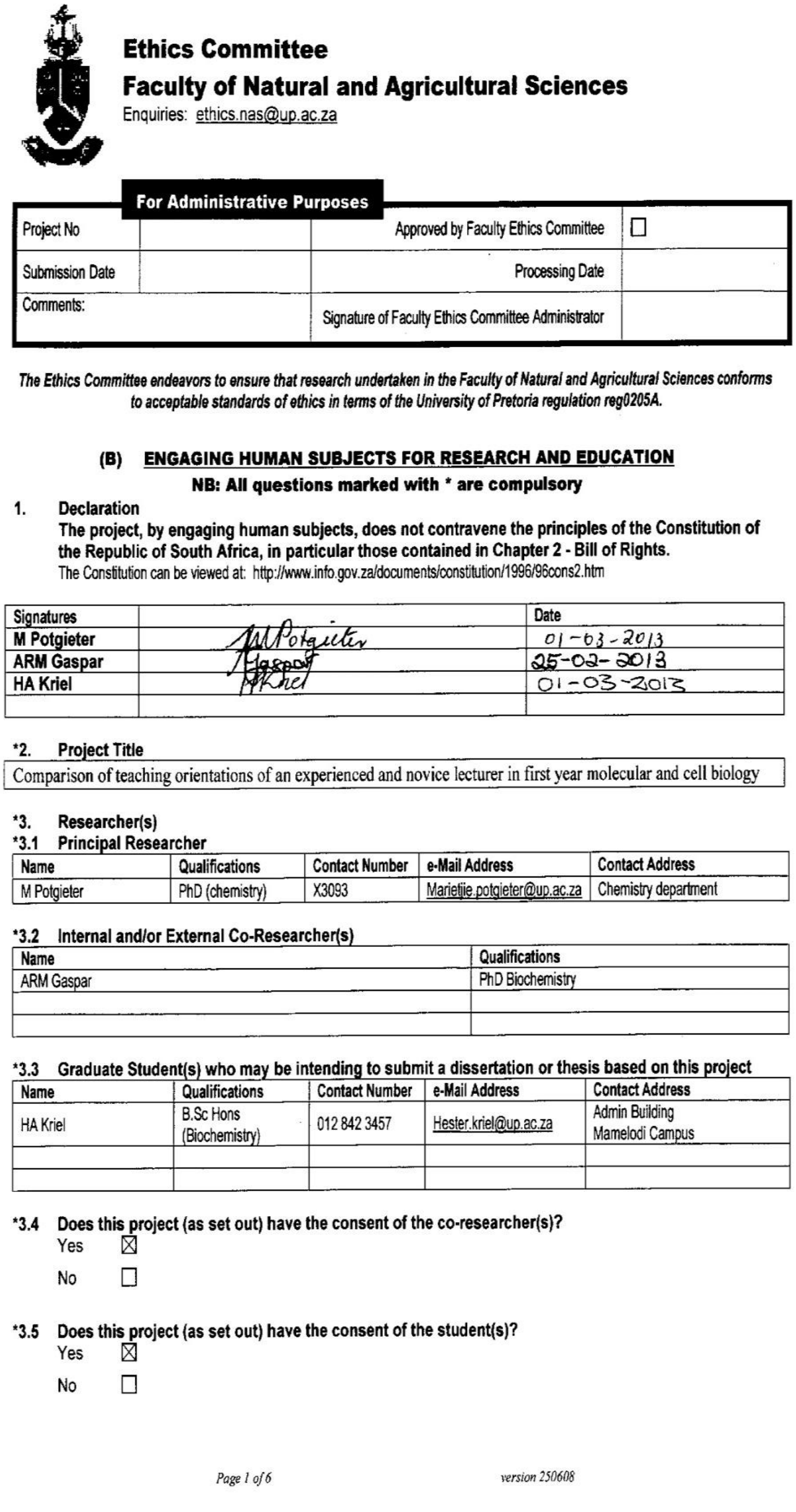
Verstaan dat

- Die doel van die studie is om na te vors hoe student leer beïnvloed word deur die onderwys oriëntasie van die verskillende lektore in MLB
- Alle persoonlike inligting sal streng vertroulik hanteer word en sal glad nie deel word van my akademiese rekord by die universiteit nie.
- Ek gee toestemming dat my joernaal inskrywings in verslae gebruik kan word op voorwaarde dat my identiteit nie openbaar gemaak word nie.
- My menseregte sal nie aangetas word as ek tot hierdie studie instem nie.
- My deelname in die studie is vrywillig

Handtekening__________________

Datum _______________

Appendix 7: Ethical clearance



Ethics Committee
Faculty of Natural and Agricultural Sciences
Enquiries: ethics.nas@up.ac.za

For Administrative Purposes

Project No		Approved by Faculty Ethics Committee	☐
Submission Date		Processing Date	
Comments:		Signature of Faculty Ethics Committee Administrator	

The Ethics Committee endeavors to ensure that research undertaken in the Faculty of Natural and Agricultural Sciences conforms to acceptable standards of ethics in terms of the University of Pretoria regulation reg0205A.

(B) ENGAGING HUMAN SUBJECTS FOR RESEARCH AND EDUCATION

NB: All questions marked with * are compulsory

1. Declaration
The project, by engaging human subjects, does not contravene the principles of the Constitution of the Republic of South Africa, in particular those contained in Chapter 2 - Bill of Rights.
The Constitution can be viewed at: http://www.info.gov.za/documents/constitution/1996/96cons2.htm

Signatures		Date
M Potgieter	MPotgieter	01-03-2013
ARM Gaspar	Gaspar	25-02-2013
HA Kriel	HKriel	01-03-2013

***2. Project Title**

Comparison of teaching orientations of an experienced and novice lecturer in first year molecular and cell biology

***3. Researcher(s)**
***3.1 Principal Researcher**

Name	Qualifications	Contact Number	e-Mail Address	Contact Address
M Potgieter	PhD (chemistry)	X3093	Marietjie.potgieter@up.ac.za	Chemistry department

***3.2 Internal and/or External Co-Researcher(s)**

Name	Qualifications
ARM Gaspar	PhD Biochemistry

***3.3 Graduate Student(s) who may be intending to submit a dissertation or thesis based on this project**

Name	Qualifications	Contact Number	e-Mail Address	Contact Address
HA Kriel	B.Sc Hons (Biochemistry)	012 842 3457	Hester.kriel@up.ac.za	Admin Building Mamelodi Campus

***3.4 Does this project (as set out) have the consent of the co-researcher(s)?**
Yes ☒
No ☐

***3.5 Does this project (as set out) have the consent of the student(s)?**
Yes ☒
No ☐

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3.6 Student Assistantship(s)

Name	Qualifications
N/A	

3.7 Specialised Services Used

(e.g. Statistician, Analyst, etc.)

Name	Qualifications
Voice and image recording, ClickUP journals completed by students	

*4. Intended degree

X Degree: *(Please Specify)*

☐Honours

☒Masters

☐Doctorate

☐**Non degree:**

*4. Funding

***4.1 Is this project fully funded?**

☐Yes

☒No

***4.1.1 If yes, please provide the contact details of the funding body**

Name	Contact Details

***4.2 Does the funding of the project depend on the project being approved by the Ethics Committee?**

☐Yes

☐No

☒N/A

*5. Data

***5.1 The use of external data derived from procedures using animals - provide the source of external data**

(Example: ARC, XYZ bank)

N/A

***5.2 Recording and archiving data**

In terms of the University regulation Policy for the Preservation and Retention of Research Data (Rt 306/07), researchers must indicate the manner in which the accummulated from this research trial or obtained from an external source is to be archived. This is to avoid disputes over authenticity and intellectual property.

5.2.1 Recording data at the point of measurement:

Laboratory book ☒

Logged electronically ☒

Voice recorded ☒

Other forms

(Please describe)

Videos

5.2.2 Archiving data

Written / printed ☐

Electronically ☒

Other forms

(Please describe)

CX

***6. Intellectual property: Declare the interests in the intellectual property of this research project by the participating institutions (university or research, financial or other institution), or persons (project supervisor, research leader, student or other persons).**

Examples: a: Data provided by FNB to study poverty in Gauteng. FNB relinquishes all IP to the UP. b: Prof XYZ is the project supervisor, while Mr. J is the PhD candidate analysing the data with the assistance of the IT Dept. The participants agree that the IP resides equally with all persons, and that the PhD candidate has the first option to be principal author of research papers.

a. Institutions

University of Pretoria

b. Persons

The IP resides equally with all co-researchers

***8. Aim of the Project**

(This is the main question(s) being posed)

First year Molecular and Cell Biology (MLB111) students at the University of Pretoria tend to struggle to understand and explain photosynthesis. The question arises whether the process itself is conceptually challenging or whether understanding is hampered by the way the lecturer explains the concept. We have decided to investigate the situation from two different angles: the experience of the students in class with the emphasis on problems that they may still encounter at the end of the class (this will link to the teaching styles of the different lecturers) and the difference in teaching styles of lecturers explaining the concept. The different teaching approaches and the way an experienced and a novice lecturer plan and present the lesson may also affect learning differently. This leads to the following research questions:

How does the teaching orientation of a novice lecturer differ from that of an experienced lecturer?

How do students experience the different the teaching orientations of a novice and experienced lecturer, respectively?

The findings of this study will be shared with the lecturers involved to enrich their teaching in future.

***9. Scientific justification to use human subjects supported by relevant scientific literature**

Vidoes of class sessions and student and lecturer feedback are the primary sources of data.

***10. Materials and Methods**

(Detail procedures required - supported by references that validate procedures)

Questionnaires will be completed by the lecturers and the students. A video will be taken of all the classes in this particular section. The video will be analysed and discussed with the lecturers involved. Interviews will be conducted with the lecturers and possibly with some of the students.

The analysis of teaching orientations of lecturers will be informed by theory on pedagogical content knowledge (PCK) because classroom instructional design is expected to reveal the different domains of teacher knowledge and its manifestation as described in this theoretical framework (Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu, 2008). The study is situated within the constructivist paradigm in recognition of the fact that students have to integrate new knowledge into existing schema in order to construct their own meaning (Fosnot, Perry, 2005), a process which is complicated by the presence of scientifically unacceptable alternative conceptions, also called misconceptions. A random sample of students will be recruited (10% of the population) to keep a journal of the classes that they attend and to answer a questionnaire after every class. The data will be subjected to thematic analysis subsequently. An experienced and a novice lecturer volunteered to be part of the study. A comparison will be drawn between the way they introduce and explain photosynthesis to the first year students. It is suggested in the literature that experienced lecturers tend to take it for granted that students have very good pre-knowledge of certain concepts. As participant observers we would like to test this suggestion. Video footage will be collected (3 lecture groups, 5 lectures each). Lecturers will be asked to record their planning before each class and their planned outcomes and interviews will be conducted after the topic is completed to analyse the lessons and to see if they met their own criteria. If necessary we will also conduct interviews with some of the students. The videos, questionnaires and interview data from class observations will be analysed for evidence of PCK, i.e. evidence of content knowledge; general pedagogical knowledge; curricular knowledge; knowledge of learners (their characteristics, cognition, motivation, and development); knowledge of educational contexts; knowledge of educational aims, goals, and purposes (Shulman, 1987). The members of the research committee will be involved in the validation of the interpretation of data.

***10.1 Full Description of Human Subjects to be used**

First year MLB 111 students. *The student sample will be chosen from the Tuesday morning practical groups. That will EXCLUDE the medical students from the sample. This will ensure that students from all ethnic groups and languages and gender will be included, but the sample will not be skewed by the stronger performing medical students. We will ask 196 English speaking students and 114 Afrikaans speaking students to take part in the study, the ratio is similar to the ration in the whole group.*

10.2 Where and how are subjects selected?

Tutors will select groups of students *from their Tuesday morning groups.*

10.3 If subjects are asked to volunteer, who are being asked to volunteer and how are they selected?

Students will not be asked to volunteer but will be recruited *to fill in five questionnaires, one for each day of attending lectures on photosynthesis. Students will be reminded daily by bulk sms to complete their questionnaires on ClickUP (see 10.4). It is expected that not all students will complete questionnaires on a daily basis (5 days in total), but only complete data sets will be used for analysis.*

10.4 If subjects are to be recruited, what inducement is to be offered?

No inducement but possibly reward after completion of the journal entries.

10.5 If subjects' records are to be used, specify the nature of these records and indicate how they will be selected.

Students are promised anonymity but there contributions will be captured with student numbers. There comments may be sighted in the dissertation, but without revealing their identity. *Students will also not be videoed. The video will concentrate on the lecturer and the notes.*

10.6 Has permission been obtained to study and report on these records?

Yes ☐
No ☒Permission will be requested by means of a letter of consent. (see attached)
Not applicable ☐

If *Yes*, attach letters

10.7 Salient Characteristics of Subjects

Number 120
Age 18-24
Male ☒ Female ☒
Racial Group All

10.8 Estimation of Literacy Level

None ☐
Very low ☐
Low ☐
Medium ☐
High ☒

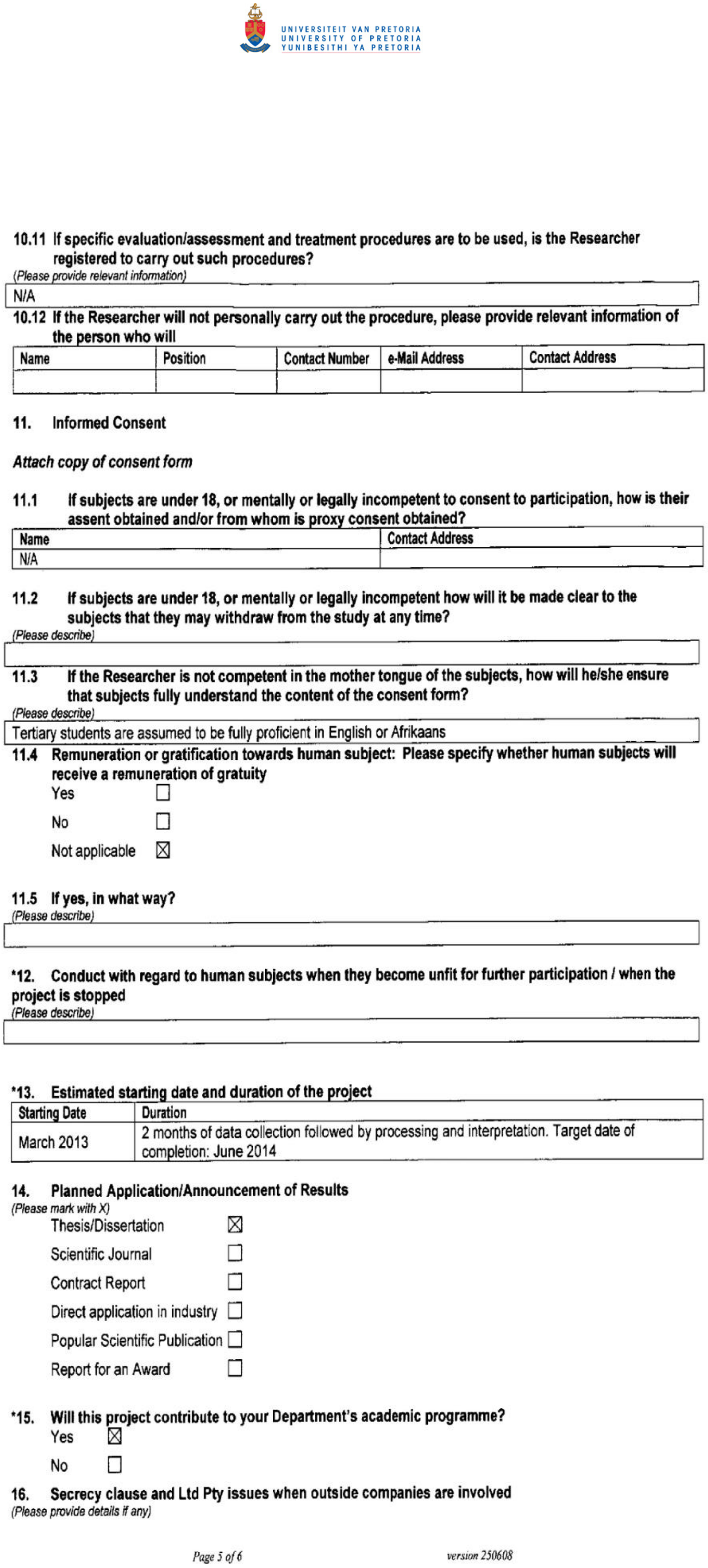
10.9 Describe if permission of relevant authorities (e.g. School, Hospital, Clinic) has been obtained?

Yes ☐
No ☐
Not applicable ☒

If *Yes*, attach letters

10.10 List proposed procedures to be carried out with subjects to obtain data required

Record voice ☒
Interview ☒ *Attach*
Questionnaire ☒ *Attach, if available. If not, submit at a later stage, together with initial approval of Ethics Committee*
Procedures ☐ *e.g. therapy - Please describe*
Photograph ☐ *Attach*
Other ☒ *Please describe* Video recording of the lectures



10.11 If specific evaluation/assessment and treatment procedures are to be used, is the Researcher registered to carry out such procedures?
(Please provide relevant information)

N/A

10.12 If the Researcher will not personally carry out the procedure, please provide relevant information of the person who will

Name	Position	Contact Number	e-Mail Address	Contact Address

11. Informed Consent

Attach copy of consent form

11.1 If subjects are under 18, or mentally or legally incompetent to consent to participation, how is their assent obtained and/or from whom is proxy consent obtained?

Name	Contact Address
N/A	

11.2 If subjects are under 18, or mentally or legally incompetent how will it be made clear to the subjects that they may withdraw from the study at any time?
(Please describe)

11.3 If the Researcher is not competent in the mother tongue of the subjects, how will he/she ensure that subjects fully understand the content of the consent form?
(Please describe)

Tertiary students are assumed to be fully proficient in English or Afrikaans

11.4 Remuneration or gratification towards human subject: Please specify whether human subjects will receive a remuneration of gratuity

Yes ☐

No ☐

Not applicable ☒

11.5 If yes, in what way?
(Please describe)

***12. Conduct with regard to human subjects when they become unfit for further participation / when the project is stopped**
(Please describe)

***13. Estimated starting date and duration of the project**

Starting Date	Duration
March 2013	2 months of data collection followed by processing and interpretation. Target date of completion: June 2014

14. Planned Application/Announcement of Results
(Please mark with X)

Thesis/Dissertation ☒

Scientific Journal ☐

Contract Report ☐

Direct application in industry ☐

Popular Scientific Publication ☐

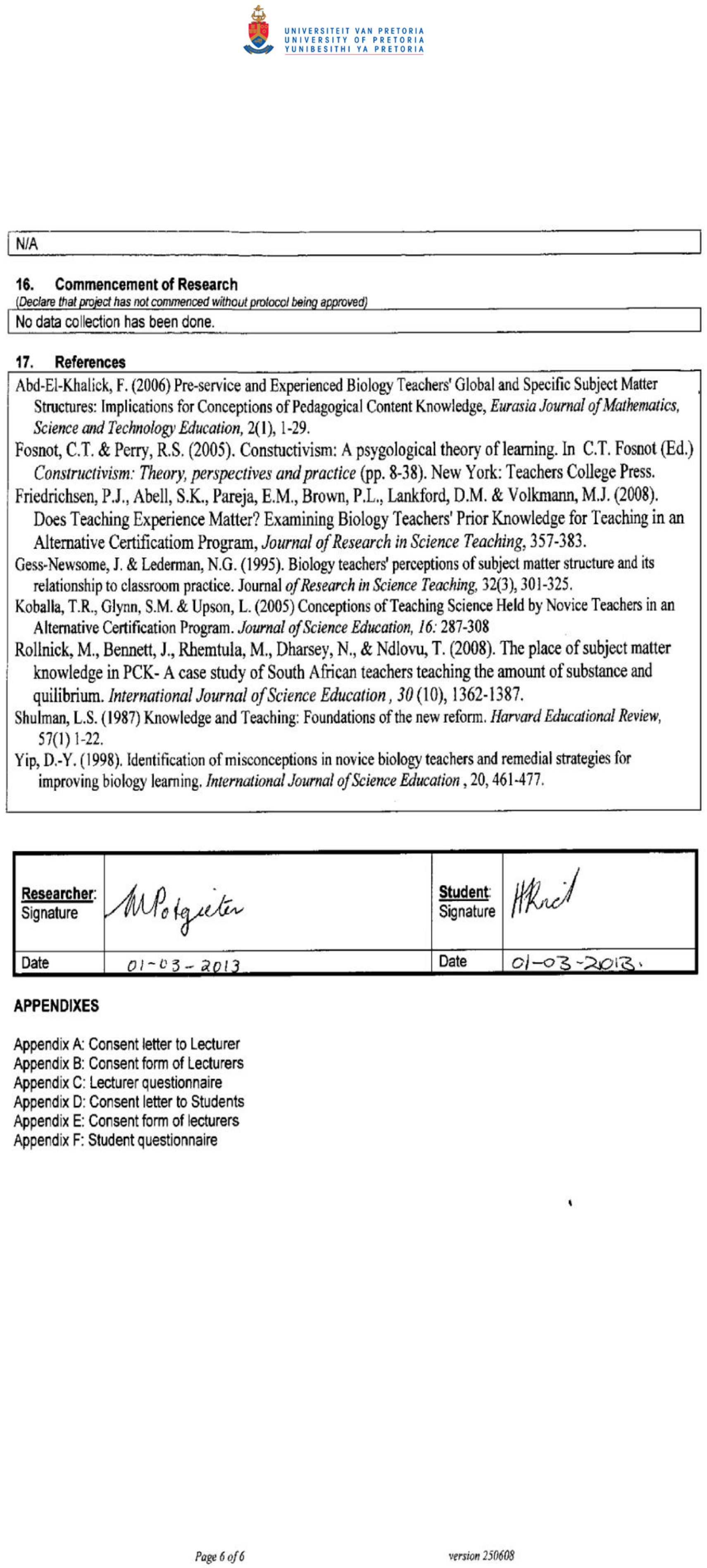
Report for an Award ☐

***15. Will this project contribute to your Department's academic programme?**

Yes ☒

No ☐

16. Secrecy clause and Ltd Pty issues when outside companies are involved
(Please provide details if any)



N/A

16. Commencement of Research

(Declare that project has not commenced without protocol being approved)

No data collection has been done.

17. References

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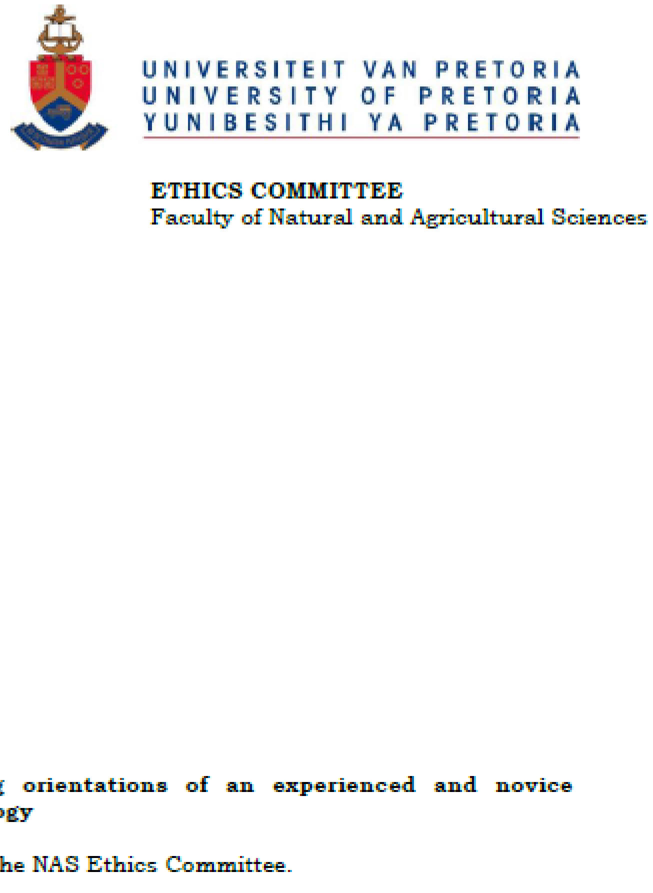
Yip, D.-Y. (1998). Identification of misconceptions in novice biology teachers and remedial strategies for improving biology learning. *International Journal of Science Education*, 20, 461-477.

Researcher: Signature	MPotgieter	**Student**: Signature	
Date	01-03-2013	Date	01-03-2013.

APPENDIXES

Appendix A: Consent letter to Lecturer
Appendix B: Consent form of Lecturers
Appendix C: Lecturer questionnaire
Appendix D: Consent letter to Students
Appendix E: Consent form of lecturers
Appendix F: Student questionnaire

Appendix 8: Ethical clearance letter



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

ETHICS COMMITTEE
Faculty of Natural and Agricultural Sciences

9 April 2013
Prof Marietjie Potgieter
Deputy dean: NAS Faculty
University of Pretoria
Pretoria
0002

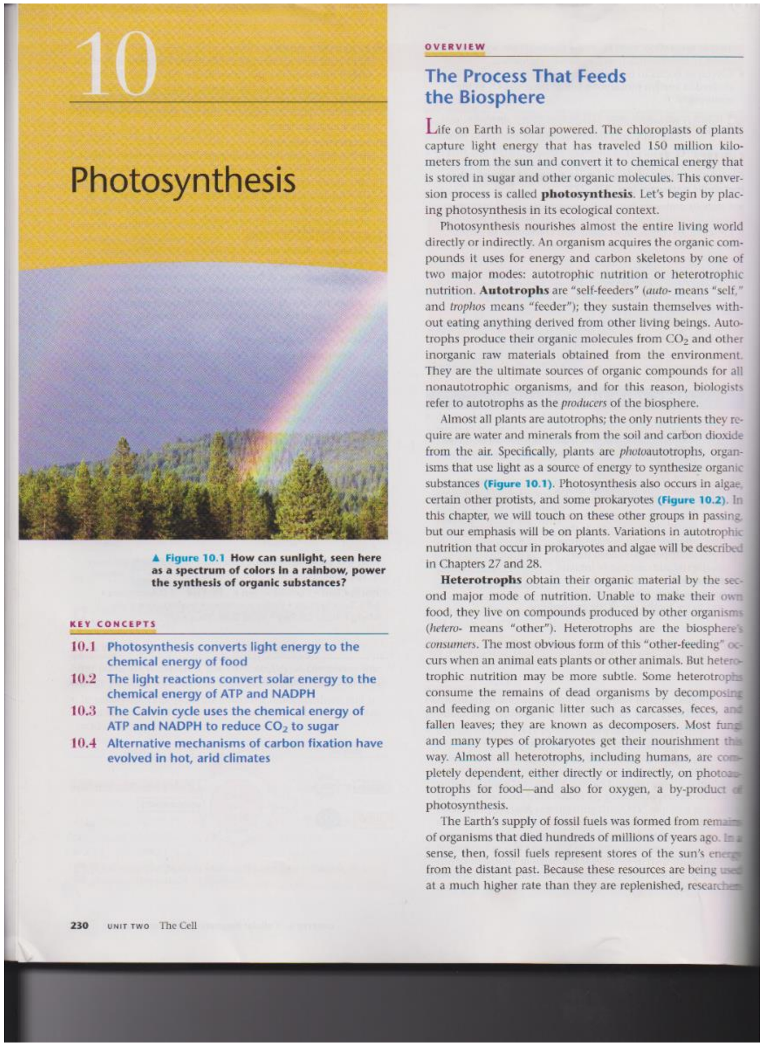
Dear Prof Potgieter

EC1301147-002: Comparisons of teaching orientations of an experienced and novice lecturer in first year molecular and cell biology

This protocol conforms to the requirements of the NAS Ethics Committee.

Kind regards

Appendix 9:



10

Photosynthesis

▲ **Figure 10.1 How can sunlight, seen here as a spectrum of colors in a rainbow, power the synthesis of organic substances?**

KEY CONCEPTS

- 10.1 Photosynthesis converts light energy to the chemical energy of food
- 10.2 The light reactions convert solar energy to the chemical energy of ATP and NADPH
- 10.3 The Calvin cycle uses the chemical energy of ATP and NADPH to reduce CO_2 to sugar
- 10.4 Alternative mechanisms of carbon fixation have evolved in hot, arid climates

OVERVIEW

The Process That Feeds the Biosphere

Life on Earth is solar powered. The chloroplasts of plants capture light energy that has traveled 150 million kilometers from the sun and convert it to chemical energy that is stored in sugar and other organic molecules. This conversion process is called **photosynthesis**. Let's begin by placing photosynthesis in its ecological context.

Photosynthesis nourishes almost the entire living world directly or indirectly. An organism acquires the organic compounds it uses for energy and carbon skeletons by one of two major modes: autotrophic nutrition or heterotrophic nutrition. **Autotrophs** are "self-feeders" (*auto-* means "self," and *trophos* means "feeder"); they sustain themselves without eating anything derived from other living beings. Autotrophs produce their organic molecules from CO_2 and other inorganic raw materials obtained from the environment. They are the ultimate sources of organic compounds for all nonautotrophic organisms, and for this reason, biologists refer to autotrophs as the *producers* of the biosphere.

Almost all plants are autotrophs; the only nutrients they require are water and minerals from the soil and carbon dioxide from the air. Specifically, plants are *photo*autotrophs, organisms that use light as a source of energy to synthesize organic substances **(Figure 10.1)**. Photosynthesis also occurs in algae, certain other protists, and some prokaryotes **(Figure 10.2)**. In this chapter, we will touch on these other groups in passing, but our emphasis will be on plants. Variations in autotrophic nutrition that occur in prokaryotes and algae will be described in Chapters 27 and 28.

Heterotrophs obtain their organic material by the second major mode of nutrition. Unable to make their own food, they live on compounds produced by other organisms (*hetero-* means "other"). Heterotrophs are the biosphere's *consumers*. The most obvious form of this "other-feeding" occurs when an animal eats plants or other animals. But heterotrophic nutrition may be more subtle. Some heterotrophs consume the remains of dead organisms by decomposing and feeding on organic litter such as carcasses, feces, and fallen leaves; they are known as decomposers. Most fungi and many types of prokaryotes get their nourishment this way. Almost all heterotrophs, including humans, are completely dependent, either directly or indirectly, on photoautotrophs for food—and also for oxygen, a by-product of photosynthesis.

The Earth's supply of fossil fuels was formed from remains of organisms that died hundreds of millions of years ago. In a sense, then, fossil fuels represent stores of the sun's energy from the distant past. Because these resources are being used at a much higher rate than they are replenished, researchers are exploring methods of capitalizing on the photosynthetic process to provide alternative fuels **(Figure 10.3)**.

In this chapter, you will learn how photosynthesis works. After a discussion of the general principles of photosynthesis, we will consider the two stages of photosynthesis: the light reactions, in which solar energy is captured and transformed into chemical energy; and the Calvin cycle, in which the chemical energy is used to make organic molecules of food. Finally, we will consider a few aspects of photosynthesis from an evolutionary perspective.

Figure 10.2 Photoautotrophs. These organisms use light
nergy to drive the synthesis of organic molecules from carbon dioxide
nd (in most cases) water. They feed themselves and the entire living
orld. **(a)** On land, plants are the predominant producers of food.
aquatic environments, photoautotrophs include unicellular and
b) multicellular algae, such as this kelp; **(c)** some non-algal unicellular
rotists, such as *Euglena*; **(d)** the prokaryotes called cyanobacteria; and
e) other photosynthetic prokaryotes, such as these purple sulfur bacteria,
hich produce sulfur (the yellow globules within the cells) (c–e, LMs).

▼ Figure 10.3

IMPACT

Alternative Fuels from Plants and Algae

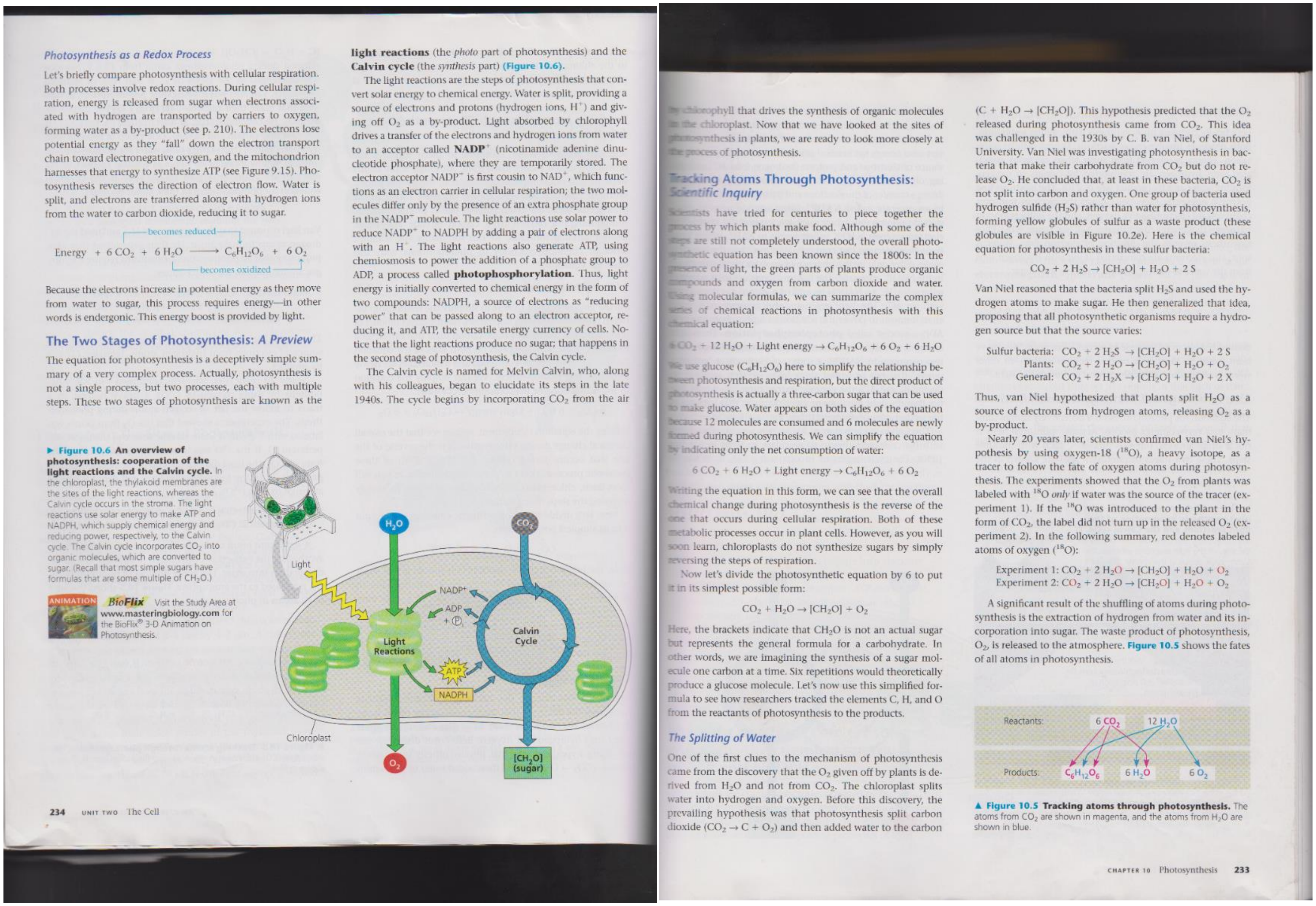
Biofuels from crops such as corn, soybeans, and cassava have been proposed as a supplement or even replacement for fossil fuels. To produce "bioethanol," the starch made naturally by the plants is simply converted to glucose and then fermented to ethanol by microorganisms. Alternatively, a simple chemical process can yield "biodiesel" from plant oils. Either product can be mixed with gasoline or used alone to power vehicles. Some species of unicellular algae are especially prolific oil producers, and they can be easily cultured in containers such as the tubular plastic bags shown below.

WHY IT MATTERS The rate of fossil fuel use by humans far outpaces its formation in the earth: Fossil fuels are a nonrenewable source of energy. Tapping the power of sunlight by using products of photosynthesis to generate energy is a sustainable alternative if cost-effective techniques can be developed. It is generally agreed that using algae is preferable to growing crops for this purpose because this use of cropland diminishes the food supply and drives up food prices.

FURTHER READING A. L. Haag, Algae bloom again, *Nature* 447:520–521 (2007).

WHAT IF? The main product of fossil fuel combustion is CO_2, and this combustion is the source of the increase in atmospheric CO_2 concentration. Scientists have proposed strategically situating containers of these algae near industrial plants, as shown above, or near highly congested city streets. Why does this arrangement make sense?

Photosynthesis Chapter 10



Photosynthesis as a Redox Process

Let's briefly compare photosynthesis with cellular respiration. Both processes involve redox reactions. During cellular respiration, energy is released from sugar when electrons associated with hydrogen are transported by carriers to oxygen, forming water as a by-product (see p. 210). The electrons lose potential energy as they "fall" down the electron transport chain toward electronegative oxygen, and the mitochondrion harnesses that energy to synthesize ATP (see Figure 9.15). Photosynthesis reverses the direction of electron flow. Water is split, and electrons are transferred along with hydrogen ions from the water to carbon dioxide, reducing it to sugar.

becomes reduced

$$\text{Energy} + 6\,CO_2 + 6\,H_2O \longrightarrow C_6H_{12}O_6 + 6\,O_2$$

becomes oxidized

Because the electrons increase in potential energy as they move from water to sugar, this process requires energy—in other words is endergonic. This energy boost is provided by light.

The Two Stages of Photosynthesis: *A Preview*

The equation for photosynthesis is a deceptively simple summary of a very complex process. Actually, photosynthesis is not a single process, but two processes, each with multiple steps. These two stages of photosynthesis are known as the **light reactions** (the *photo* part of photosynthesis) and the **Calvin cycle** (the *synthesis* part) **(Figure 10.6)**.

The light reactions are the steps of photosynthesis that convert solar energy to chemical energy. Water is split, providing a source of electrons and protons (hydrogen ions, H^+) and giving off O_2 as a by-product. Light absorbed by chlorophyll drives a transfer of the electrons and hydrogen ions from water to an acceptor called **$NADP^+$** (nicotinamide adenine dinucleotide phosphate), where they are temporarily stored. The electron acceptor $NADP^+$ is first cousin to NAD^+, which functions as an electron carrier in cellular respiration; the two molecules differ only by the presence of an extra phosphate group in the $NADP^+$ molecule. The light reactions use solar power to reduce $NADP^+$ to NADPH by adding a pair of electrons along with an H^+. The light reactions also generate ATP, using chemiosmosis to power the addition of a phosphate group to ADP, a process called **photophosphorylation**. Thus, light energy is initially converted to chemical energy in the form of two compounds: NADPH, a source of electrons as "reducing power" that can be passed along to an electron acceptor, reducing it, and ATP, the versatile energy currency of cells. Notice that the light reactions produce no sugar; that happens in the second stage of photosynthesis, the Calvin cycle.

The Calvin cycle is named for Melvin Calvin, who, along with his colleagues, began to elucidate its steps in the late 1940s. The cycle begins by incorporating CO_2 from the air

▶ **Figure 10.6 An overview of photosynthesis: cooperation of the light reactions and the Calvin cycle.** In the chloroplast, the thylakoid membranes are the sites of the light reactions, whereas the Calvin cycle occurs in the stroma. The light reactions use solar energy to make ATP and NADPH, which supply chemical energy and reducing power, respectively, to the Calvin cycle. The Calvin cycle incorporates CO_2 into organic molecules, which are converted to sugar. (Recall that most simple sugars have formulas that are some multiple of CH_2O.)

ANIMATION **BioFlix** Visit the Study Area at **www.masteringbiology.com** for the BioFlix® 3-D Animation on Photosynthesis.

by chlorophyll that drives the synthesis of organic molecules in the chloroplast. Now that we have looked at the sites of photosynthesis in plants, we are ready to look more closely at the process of photosynthesis.

Tracking Atoms Through Photosynthesis: *Scientific Inquiry*

Scientists have tried for centuries to piece together the process by which plants make food. Although some of the steps are still not completely understood, the overall photosynthetic equation has been known since the 1800s: In the presence of light, the green parts of plants produce organic compounds and oxygen from carbon dioxide and water. Using molecular formulas, we can summarize the complex series of chemical reactions in photosynthesis with this chemical equation:

$$6\,CO_2 + 12\,H_2O + \text{Light energy} \rightarrow C_6H_{12}O_6 + 6\,O_2 + 6\,H_2O$$

We use glucose ($C_6H_{12}O_6$) here to simplify the relationship between photosynthesis and respiration, but the direct product of photosynthesis is actually a three-carbon sugar that can be used to make glucose. Water appears on both sides of the equation because 12 molecules are consumed and 6 molecules are newly formed during photosynthesis. We can simplify the equation by indicating only the net consumption of water:

$$6\,CO_2 + 6\,H_2O + \text{Light energy} \rightarrow C_6H_{12}O_6 + 6\,O_2$$

Writing the equation in this form, we can see that the overall chemical change during photosynthesis is the reverse of the one that occurs during cellular respiration. Both of these metabolic processes occur in plant cells. However, as you will soon learn, chloroplasts do not synthesize sugars by simply reversing the steps of respiration.

Now let's divide the photosynthetic equation by 6 to put it in its simplest possible form:

$$CO_2 + H_2O \rightarrow [CH_2O] + O_2$$

Here, the brackets indicate that CH_2O is not an actual sugar but represents the general formula for a carbohydrate. In other words, we are imagining the synthesis of a sugar molecule one carbon at a time. Six repetitions would theoretically produce a glucose molecule. Let's now use this simplified formula to see how researchers tracked the elements C, H, and O from the reactants of photosynthesis to the products.

The Splitting of Water

One of the first clues to the mechanism of photosynthesis came from the discovery that the O_2 given off by plants is derived from H_2O and not from CO_2. The chloroplast splits water into hydrogen and oxygen. Before this discovery, the prevailing hypothesis was that photosynthesis split carbon dioxide ($CO_2 \rightarrow C + O_2$) and then added water to the carbon ($C + H_2O \rightarrow [CH_2O]$). This hypothesis predicted that the O_2 released during photosynthesis came from CO_2. This idea was challenged in the 1930s by C. B. van Niel, of Stanford University. Van Niel was investigating photosynthesis in bacteria that make their carbohydrate from CO_2 but do not release O_2. He concluded that, at least in these bacteria, CO_2 is not split into carbon and oxygen. One group of bacteria used hydrogen sulfide (H_2S) rather than water for photosynthesis, forming yellow globules of sulfur as a waste product (these globules are visible in Figure 10.2e). Here is the chemical equation for photosynthesis in these sulfur bacteria:

$$CO_2 + 2\,H_2S \rightarrow [CH_2O] + H_2O + 2\,S$$

Van Niel reasoned that the bacteria split H_2S and used the hydrogen atoms to make sugar. He then generalized that idea, proposing that all photosynthetic organisms require a hydrogen source but that the source varies:

Sulfur bacteria: $CO_2 + 2\,H_2S \rightarrow [CH_2O] + H_2O + 2\,S$
Plants: $CO_2 + 2\,H_2O \rightarrow [CH_2O] + H_2O + O_2$
General: $CO_2 + 2\,H_2X \rightarrow [CH_2O] + H_2O + 2\,X$

Thus, van Niel hypothesized that plants split H_2O as a source of electrons from hydrogen atoms, releasing O_2 as a by-product.

Nearly 20 years later, scientists confirmed van Niel's hypothesis by using oxygen-18 (^{18}O), a heavy isotope, as a tracer to follow the fate of oxygen atoms during photosynthesis. The experiments showed that the O_2 from plants was labeled with ^{18}O *only* if water was the source of the tracer (experiment 1). If the ^{18}O was introduced to the plant in the form of CO_2, the label did not turn up in the released O_2 (experiment 2). In the following summary, red denotes labeled atoms of oxygen (^{18}O):

Experiment 1: $CO_2 + 2\,H_2O \rightarrow [CH_2O] + H_2O + O_2$
Experiment 2: $CO_2 + 2\,H_2O \rightarrow [CH_2O] + H_2O + O_2$

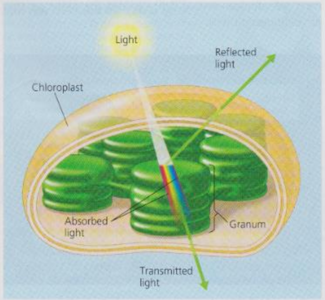
A significant result of the shuffling of atoms during photosynthesis is the extraction of hydrogen from water and its incorporation into sugar. The waste product of photosynthesis, O_2, is released to the atmosphere. **Figure 10.5** shows the fates of all atoms in photosynthesis.

▲ **Figure 10.5 Tracking atoms through photosynthesis.** The atoms from CO_2 are shown in magenta, and the atoms from H_2O are shown in blue.

Photosynthetic Pigments: The Light Receptors

When light meets matter, it may be reflected, transmitted, or absorbed. Substances that absorb visible light are known as *pigments*. Different pigments absorb light of different wavelengths, and the wavelengths that are absorbed disappear. If a pigment is illuminated with white light, the color we see is the color most reflected or transmitted by the pigment. (If a pigment absorbs all wavelengths, it appears black.) We see green when we look at a leaf because chlorophyll absorbs violet-blue and red light while transmitting and reflecting green light **(Figure 10.8)**. The ability of a pigment to absorb various wavelengths of light can be measured with an instrument called a **spectrophotometer**. This machine directs beams of light of different wavelengths through a solution of the pigment and measures the fraction of the light transmitted at each wavelength. A graph plotting a pigment's light absorption versus wavelength is called an **absorption spectrum** **(Figure 10.9)**.

The absorption spectra of chloroplast pigments provide clues to the relative effectiveness of different wavelengths for driving photosynthesis, since light can perform work in chloroplasts only if it is absorbed. **Figure 10.10a** shows the absorption spectra of three types of pigments in chloroplasts: **chlorophyll *a***, which participates directly in the light reactions; the accessory pigment *chlorophyll b*; and a group of accessory pigments called carotenoids. The spectrum of chlorophyll *a* suggests that violet-blue and red light work best for photosynthesis, since they are absorbed, while green is the least effective color. This is confirmed by an **action spectrum** for photosynthesis **(Figure 10.10b)**, which profiles the relative effectiveness of different wavelengths of radiation in driving the process. An action spectrum is prepared by illuminating chloroplasts with light of different colors and then plotting wavelength against some measure of photosynthetic rate, such as CO_2 consumption or O_2 release. The action spectrum for photosynthesis was first demonstrated by Theodor W. Engelmann, a German botanist, in 1883. Before equipment for measuring O_2 levels had even been invented, Engelmann performed a clever experiment in which he used bacteria to measure rates of photosynthesis in filamentous algae **(Figure 10.10c)**. His results are a striking match to the modern action spectrum shown in Figure 10.10b.



▲ **Figure 10.8 Why leaves are green: interaction of light with chloroplasts.** The chlorophyll molecules of chloroplasts absorb violet-blue and red light (the colors most effective in driving photosynthesis) and reflect or transmit green light. This is why leaves appear green.

▼ **Figure 10.9** RESEARCH METHOD

Determining an Absorption Spectrum

APPLICATION An absorption spectrum is a visual representation of how well a particular pigment absorbs different wavelengths of visible light. Absorption spectra of various chloroplast pigments help scientists decipher each pigment's role in a plant.

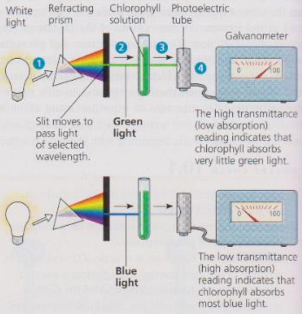
TECHNIQUE A spectrophotometer measures the relative amounts of light of different wavelengths absorbed and transmitted by a pigment solution.

① White light is separated into colors (wavelengths) by a prism.

② One by one, the different colors of light are passed through the sample (chlorophyll in this example). Green light and blue light are shown here.

③ The transmitted light strikes a photoelectric tube, which converts the light energy to electricity.

④ The electric current is measured by a galvanometer. The meter indicates the fraction of light transmitted through the sample, from which we can determine the amount of light absorbed.



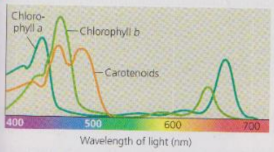
RESULTS See Figure 10.10a for absorption spectra of three types of chloroplast pigments.

ure 10.10 INQUIRY

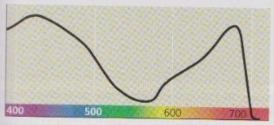
ch wavelengths of light are most effective riving photosynthesis?

IMENT Absorption and action spectra, along with a classic ex-
nt by Theodor W. Engelmann, reveal which wavelengths of light
tosynthetically important.

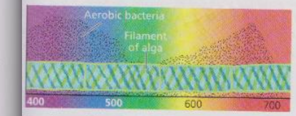
TS



orption spectra. The three curves show the wavelengths of light
absorbed by three types of chloroplast pigments.



on spectrum. This graph plots the rate of photosynthesis
s wavelength. The resulting action spectrum resembles the
ption spectrum for chlorophyll a but does not match exactly
part a). This is partly due to the absorption of light by accessory
ents such as chlorophyll *b* and carotenoids.



lmann's experiment. In 1883, Theodor W. Engelmann
nated a filamentous alga with light that had been passed
gh a prism, exposing different segments of the alga to different
engths. He used aerobic bacteria, which concentrate near an
n source, to determine which segments of the alga were
ing the most O_2 and thus photosynthesizing most. Bacteria
egated in greatest numbers around the parts of the alga
nated with violet-blue or red light.

SION Light in the violet-blue and red portions of the spec-
ost effective in driving photosynthesis.

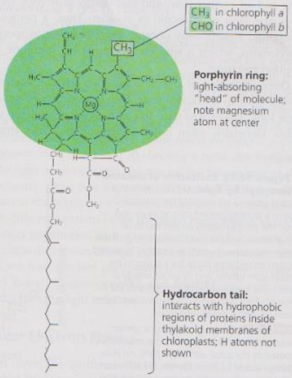
T. W. Engelmann, *Bacterium photometricum*. Ein Betrag zur ver-
en Physiologie des Licht- und farbensinnes, *Archiv. für Physiologie*
4 (1883).

he related Experimental Inquiry Tutorial in MasteringBiology.

? If Engelmann had used a filter that allowed only red light
rough, how would the results have differed?

Notice by comparing Figures 10.10a and 10.10b that the action spectrum for photosynthesis does not exactly match the absorption spectrum of chlorophyll *a*. The absorption spectrum of chlorophyll *a* alone underestimates the effectiveness of certain wavelengths in driving photosynthesis. This is partly because accessory pigments with different absorption spectra are also photosynthetically important in chloroplasts and broaden the spectrum of colors that can be used for photosynthesis. **Figure 10.11** shows the structure of chlorophyll *a* compared with that of **chlorophyll *b***. A slight structural difference between them is enough to cause the two pigments to absorb at slightly different wavelengths in the red and blue parts of the spectrum (see Figure 10.10a). As a result, chlorophyll *a* is blue green and chlorophyll *b* is olive green.

Other accessory pigments include **carotenoids**, hydrocarbons that are various shades of yellow and orange because they absorb violet and blue-green light (see Figure 10.10a). Carotenoids may broaden the spectrum of colors that can drive photosynthesis. However, a more important function of at least some carotenoids seems to be *photoprotection*: These



▲ **Figure 10.11 Structure of chlorophyll molecules in chloroplasts of plants.** Chlorophyll a and chlorophyll *b* differ only in one of the functional groups bonded to the porphyrin ring. (Also see the space-filling model of chlorophyll in Figure 1.4, p. 51.)

compounds absorb and dissipate excessive light energy that would otherwise damage chlorophyll or interact with oxygen, forming reactive oxidative molecules that are dangerous to the cell. Interestingly, carotenoids similar to the photoprotective ones in chloroplasts have a photoprotective role in the human eye. These and related molecules, often found in health food products, are valued as "phytochemicals" (from the Greek *phyton*, plant), compounds with antioxidant properties. Plants can synthesize all the antioxidants they require, but humans and other animals must obtain some of them from their diets.

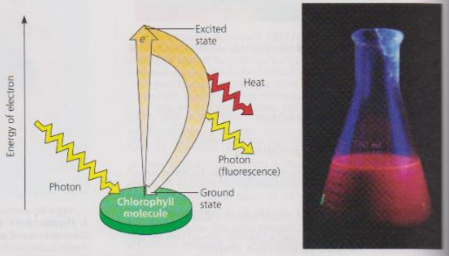
Excitation of Chlorophyll by Light

What exactly happens when chlorophyll and other pigments absorb light? The colors corresponding to the absorbed wavelengths disappear from the spectrum of the transmitted and reflected light, but energy cannot disappear. When a molecule absorbs a photon of light, one of the molecule's electrons is elevated to an orbital where it has more potential energy. When the electron is in its normal orbital, the pigment molecule is said to be in its ground state. Absorption of a photon boosts an electron to an orbital of higher energy, and the pigment molecule is then said to be in an excited state. The only photons absorbed are those whose energy is exactly equal to the energy difference between the ground state and an excited state, and this energy difference varies from one kind of molecule to another. Thus, a particular compound absorbs only photons corresponding to specific wavelengths, which is why each pigment has a unique absorption spectrum.

Once absorption of a photon raises an electron from the ground state to an excited state, the electron cannot remain there long. The excited state, like all high-energy states, is unstable. Generally, when isolated pigment molecules absorb light, their excited electrons drop back down to the ground-state orbital in a billionth of a second, releasing their excess energy as heat. This conversion of light energy to heat is what makes the top of an automobile so hot on a sunny day. (White cars are coolest because their paint reflects all wavelengths of visible light, although it may absorb ultraviolet and other invisible radiation.) In isolation, some pigments, including chlorophyll, emit light as well as heat after absorbing photons. As excited electrons fall back to the ground state, photons are given off. This afterglow is called fluorescence. If a solution of chlorophyll isolated from chloroplasts is illuminated, it will fluoresce in the red-orange part of the spectrum and also give off heat **(Figure 10.12)**.

▶ **Figure 10.12 Excitation of isolated chlorophyll by light. (a)** Absorption of a photon causes a transition of the chlorophyll molecule from its ground state to its excited state. The photon boosts an electron to an orbital where it has more potential energy. If the illuminated molecule exists in isolation, its excited electron immediately drops back down to the ground-state orbital, and its excess energy is given off as heat and fluorescence (light). **(b)** A chlorophyll solution excited with ultraviolet light fluoresces with a red-orange glow.

WHAT IF? *If a leaf containing a similar concentration of chlorophyll as the solution was exposed to the same ultraviolet light, no fluorescence would be seen. Explain the difference in fluorescence emission between the solution and the leaf.*



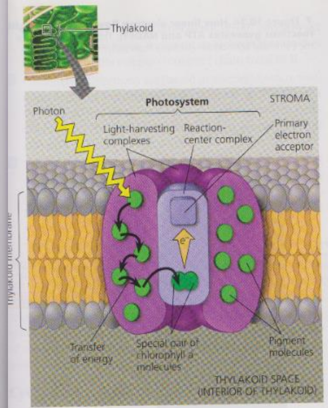
(a) Excitation of isolated chlorophyll molecule

(b) Fluorescence

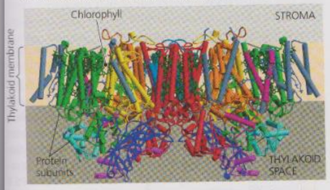
A Photosystem: A Reaction-Center Complex Associated with Light-Harvesting Complexes

Chlorophyll molecules excited by the absorption of light energy produce very different results in an intact chloroplast than they do in isolation (see Figure 10.12). In their native environment of the thylakoid membrane, chlorophyll molecules are organized along with other small organic molecules and proteins into complexes called photosystems.

A **photosystem** is composed of a **reaction-center complex** surrounded by several light-harvesting complexes **(Figure 10.13)**. The reaction-center complex is an organized association of proteins holding a special pair of chlorophyll *a* molecules. Each **light-harvesting complex** consists of various pigment molecules (which may include chlorophyll *a*, chlorophyll *b*, and carotenoids) bound to proteins. The number and variety of pigment molecules enable a photosystem to harvest light over a larger surface area and a larger portion of the spectrum than could any single pigment molecule alone. Together, these light-harvesting complexes act as an antenna for the reaction-center complex. When a pigment molecule absorbs a photon, the energy is transferred from pigment molecule to pigment molecule within a light-harvesting complex, somewhat like a human "wave" at a sports arena, until it is passed into the reaction-center complex. The reaction-center complex also contains a molecule capable of accepting electrons and becoming reduced; this is called the **primary electron acceptor**. The pair of chlorophyll *a* molecules in the reaction-center complex are special because their molecular environment—their location and the other molecules with which they are associated—enables them to use the energy from light not only to boost one of their electrons to a higher energy level, but also to transfer it to a different molecule—the primary electron acceptor.



(a) How a photosystem harvests light. When a photon strikes a pigment molecule in a light-harvesting complex, the energy is passed from molecule to molecule until it reaches the reaction-center complex. Here, an excited electron from the special pair of chlorophyll *a* molecules is transferred to the primary electron acceptor.



(b) Structure of photosystem II. This computer model of photosystem II, based on X-ray crystallography, shows two photosystem complexes side by side. Chlorophyll molecules (small green ball-and-stick models) are interspersed with protein subunits (cylinders and ribbons). For simplicity, photosystem II will be shown as a single complex in the rest of the chapter.

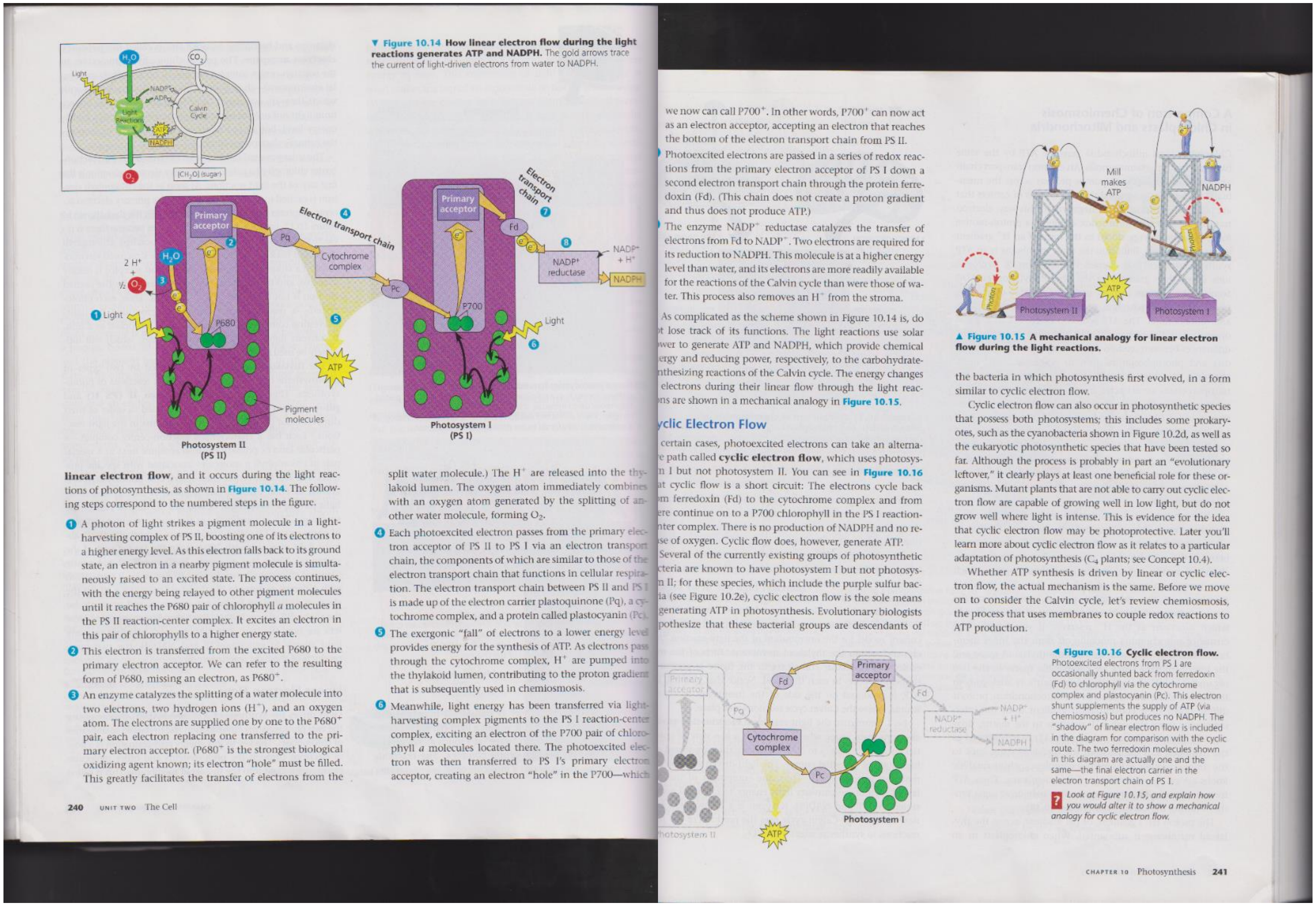
▲ **Figure 10.13 The structure and function of a photosystem.**

The solar-powered transfer of an electron from the reaction-center chlorophyll *a* pair to the primary electron acceptor is the first step of the light reactions. As soon as the chlorophyll electron is excited to a higher energy level, the primary electron acceptor captures it; this is a redox reaction. In the flask shown in Figure 10.12, isolated chlorophyll fluoresces because there is no electron acceptor, so electrons of photoexcited chlorophyll drop right back to the ground state. In the structured environment of a chloroplast, however, an electron acceptor is readily available, and the potential energy represented by the excited electron is not dissipated as light and heat. Thus, each photosystem—a reaction-center complex surrounded by light-harvesting complexes—functions in the chloroplast as a unit. It converts light energy to chemical energy, which will ultimately be used for the synthesis of sugar.

The thylakoid membrane is populated by two types of photosystems that cooperate in the light reactions of photosynthesis. They are called **photosystem II (PS II)** and **photosystem I (PS I)**. (They were named in order of their discovery, but photosystem II functions first in the light reactions.) Each has a characteristic reaction-center complex—a particular kind of primary electron acceptor next to a special pair of chlorophyll *a* molecules associated with specific proteins. The reaction-center chlorophyll *a* of photosystem II is known as P680 because this pigment is best at absorbing light having a wavelength of 680 nm (in the red part of the spectrum). The chlorophyll *a* at the reaction-center complex of photosystem I is called P700 because it most effectively absorbs light of wavelength 700 nm (in the far-red part of the spectrum). These two pigments, P680 and P700, are nearly identical chlorophyll *a* molecules. However, their association with different proteins in the thylakoid membrane affects the electron distribution in the two pigments and accounts for the slight differences in their light-absorbing properties. Now let's see how the two photosystems work together in using light energy to generate ATP and NADPH, the two main products of the light reactions.

Linear Electron Flow

Light drives the synthesis of ATP and NADPH by energizing the two photosystems embedded in the thylakoid membranes of chloroplasts. The key to this energy transformation is a flow of electrons through the photosystems and other molecular components built into the thylakoid membrane. This is called



▼ **Figure 10.14 How linear electron flow during the light reactions generates ATP and NADPH.** The gold arrows trace the current of light-driven electrons from water to NADPH.

linear electron flow, and it occurs during the light reactions of photosynthesis, as shown in **Figure 10.14**. The following steps correspond to the numbered steps in the figure.

① A photon of light strikes a pigment molecule in a light-harvesting complex of PS II, boosting one of its electrons to a higher energy level. As this electron falls back to its ground state, an electron in a nearby pigment molecule is simultaneously raised to an excited state. The process continues, with the energy being relayed to other pigment molecules until it reaches the P680 pair of chlorophyll *a* molecules in the PS II reaction-center complex. It excites an electron in this pair of chlorophylls to a higher energy state.

② This electron is transferred from the excited P680 to the primary electron acceptor. We can refer to the resulting form of P680, missing an electron, as P680$^+$.

③ An enzyme catalyzes the splitting of a water molecule into two electrons, two hydrogen ions (H^+), and an oxygen atom. The electrons are supplied one by one to the P680$^+$ pair, each electron replacing one transferred to the primary electron acceptor. (P680$^+$ is the strongest biological oxidizing agent known; its electron "hole" must be filled. This greatly facilitates the transfer of electrons from the split water molecule.) The H^+ are released into the thylakoid lumen. The oxygen atom immediately combines with an oxygen atom generated by the splitting of another water molecule, forming O_2.

④ Each photoexcited electron passes from the primary electron acceptor of PS II to PS I via an electron transport chain, the components of which are similar to those of the electron transport chain that functions in cellular respiration. The electron transport chain between PS II and PS I is made up of the electron carrier plastoquinone (Pq), a cytochrome complex, and a protein called plastocyanin (Pc).

⑤ The exergonic "fall" of electrons to a lower energy level provides energy for the synthesis of ATP. As electrons pass through the cytochrome complex, H^+ are pumped into the thylakoid lumen, contributing to the proton gradient that is subsequently used in chemiosmosis.

⑥ Meanwhile, light energy has been transferred via light-harvesting complex pigments to the PS I reaction-center complex, exciting an electron of the P700 pair of chlorophyll *a* molecules located there. The photoexcited electron was then transferred to PS I's primary electron acceptor, creating an electron "hole" in the P700—which we now can call P700$^+$. In other words, P700$^+$ can now act as an electron acceptor, accepting an electron that reaches the bottom of the electron transport chain from PS II.

Photoexcited electrons are passed in a series of redox reactions from the primary electron acceptor of PS I down a second electron transport chain through the protein ferredoxin (Fd). (This chain does not create a proton gradient and thus does not produce ATP.)

The enzyme NADP$^+$ reductase catalyzes the transfer of electrons from Fd to NADP$^+$. Two electrons are required for its reduction to NADPH. This molecule is at a higher energy level than water, and its electrons are more readily available for the reactions of the Calvin cycle than were those of water. This process also removes an H^+ from the stroma.

As complicated as the scheme shown in Figure 10.14 is, do t lose track of its functions. The light reactions use solar wer to generate ATP and NADPH, which provide chemical ergy and reducing power, respectively, to the carbohydrate-nthesizing reactions of the Calvin cycle. The energy changes electrons during their linear flow through the light reacns are shown in a mechanical analogy in **Figure 10.15**.

yclic Electron Flow

certain cases, photoexcited electrons can take an alterna-e path called **cyclic electron flow**, which uses photosysn I but not photosystem II. You can see in **Figure 10.16** at cyclic flow is a short circuit: The electrons cycle back m ferredoxin (Fd) to the cytochrome complex and from ere continue on to a P700 chlorophyll in the PS I reaction-nter complex. There is no production of NADPH and no rese of oxygen. Cyclic flow does, however, generate ATP.

Several of the currently existing groups of photosynthetic cteria are known to have photosystem I but not photosysn II; for these species, which include the purple sulfur bacia (see Figure 10.2e), cyclic electron flow is the sole means generating ATP in photosynthesis. Evolutionary biologists pothesize that these bacterial groups are descendants of the bacteria in which photosynthesis first evolved, in a form similar to cyclic electron flow.

Cyclic electron flow can also occur in photosynthetic species that possess both photosystems; this includes some prokaryotes, such as the cyanobacteria shown in Figure 10.2d, as well as the eukaryotic photosynthetic species that have been tested so far. Although the process is probably in part an "evolutionary leftover," it clearly plays at least one beneficial role for these organisms. Mutant plants that are not able to carry out cyclic electron flow are capable of growing well in low light, but do not grow well where light is intense. This is evidence for the idea that cyclic electron flow may be photoprotective. Later you'll learn more about cyclic electron flow as it relates to a particular adaptation of photosynthesis (C_4 plants; see Concept 10.4).

Whether ATP synthesis is driven by linear or cyclic electron flow, the actual mechanism is the same. Before we move on to consider the Calvin cycle, let's review chemiosmosis, the process that uses membranes to couple redox reactions to ATP production.

▲ **Figure 10.15 A mechanical analogy for linear electron flow during the light reactions.**

◀ **Figure 10.16 Cyclic electron flow.** Photoexcited electrons from PS I are occasionally shunted back from ferredoxin (Fd) to chlorophyll via the cytochrome complex and plastocyanin (Pc). This electron shunt supplements the supply of ATP (via chemiosmosis) but produces no NADPH. The "shadow" of linear electron flow is included in the diagram for comparison with the cyclic route. The two ferredoxin molecules shown in this diagram are actually one and the same—the final electron carrier in the electron transport chain of PS I.

? *Look at Figure 10.15, and explain how you would alter it to show a mechanical analogy for cyclic electron flow.*

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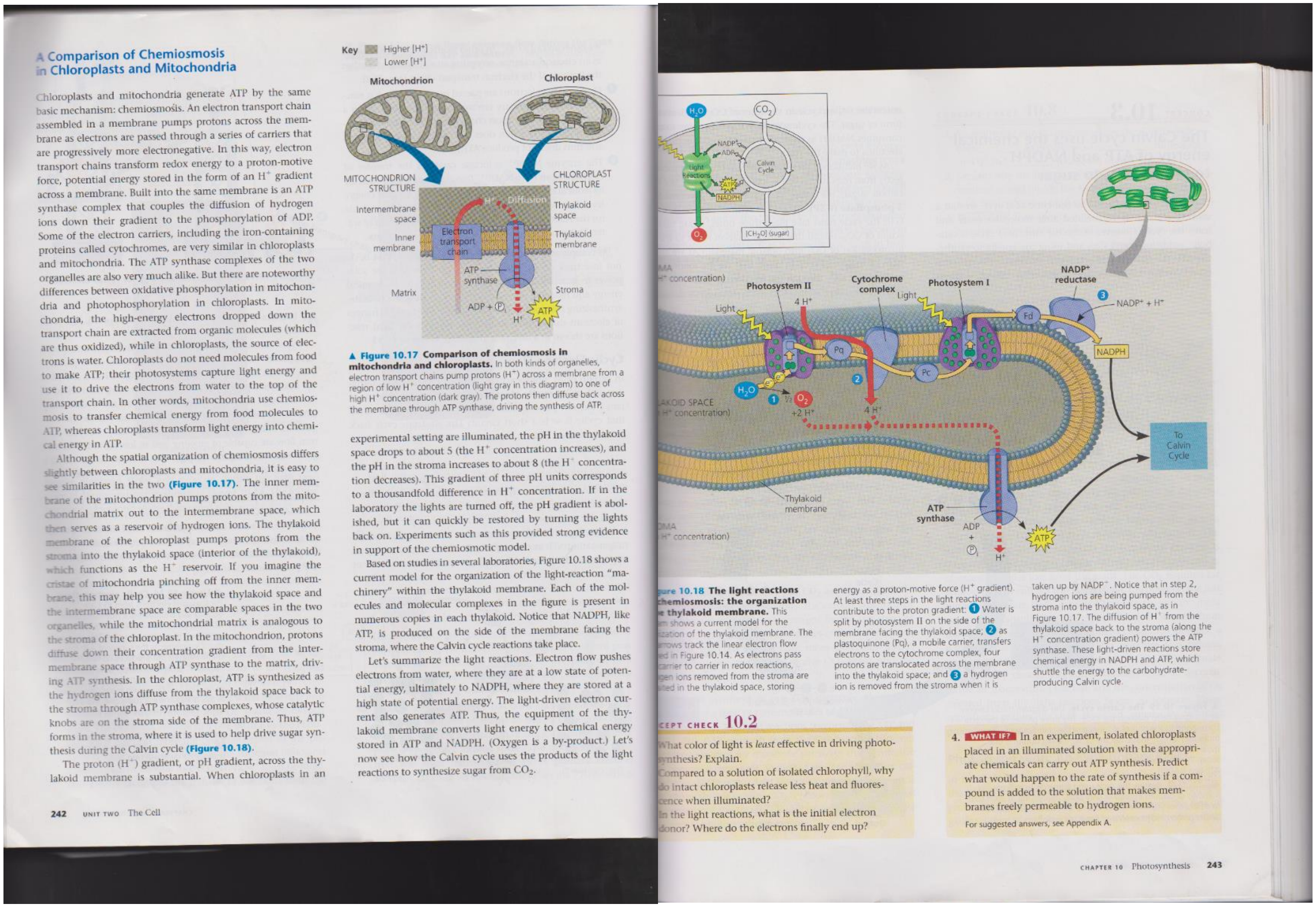
CHAPTER 10 Photosynthesis 241



A Comparison of Chemiosmosis in Chloroplasts and Mitochondria

Chloroplasts and mitochondria generate ATP by the same basic mechanism: chemiosmosis. An electron transport chain assembled in a membrane pumps protons across the membrane as electrons are passed through a series of carriers that are progressively more electronegative. In this way, electron transport chains transform redox energy to a proton-motive force, potential energy stored in the form of an H^+ gradient across a membrane. Built into the same membrane is an ATP synthase complex that couples the diffusion of hydrogen ions down their gradient to the phosphorylation of ADP. Some of the electron carriers, including the iron-containing proteins called cytochromes, are very similar in chloroplasts and mitochondria. The ATP synthase complexes of the two organelles are also very much alike. But there are noteworthy differences between oxidative phosphorylation in mitochondria and photophosphorylation in chloroplasts. In mitochondria, the high-energy electrons dropped down the transport chain are extracted from organic molecules (which are thus oxidized), while in chloroplasts, the source of electrons is water. Chloroplasts do not need molecules from food to make ATP; their photosystems capture light energy and use it to drive the electrons from water to the top of the transport chain. In other words, mitochondria use chemiosmosis to transfer chemical energy from food molecules to ATP, whereas chloroplasts transform light energy into chemical energy in ATP.

Although the spatial organization of chemiosmosis differs slightly between chloroplasts and mitochondria, it is easy to see similarities in the two **(Figure 10.17)**. The inner membrane of the mitochondrion pumps protons from the mitochondrial matrix out to the intermembrane space, which then serves as a reservoir of hydrogen ions. The thylakoid membrane of the chloroplast pumps protons from the stroma into the thylakoid space (interior of the thylakoid), which functions as the H^+ reservoir. If you imagine the cristae of mitochondria pinching off from the inner membrane, this may help you see how the thylakoid space and the intermembrane space are comparable spaces in the two organelles, while the mitochondrial matrix is analogous to the stroma of the chloroplast. In the mitochondrion, protons diffuse down their concentration gradient from the intermembrane space through ATP synthase to the matrix, driving ATP synthesis. In the chloroplast, ATP is synthesized as the hydrogen ions diffuse from the thylakoid space back to the stroma through ATP synthase complexes, whose catalytic knobs are on the stroma side of the membrane. Thus, ATP forms in the stroma, where it is used to help drive sugar synthesis during the Calvin cycle **(Figure 10.18)**.

The proton (H^+) gradient, or pH gradient, across the thylakoid membrane is substantial. When chloroplasts in an experimental setting are illuminated, the pH in the thylakoid space drops to about 5 (the H^+ concentration increases), and the pH in the stroma increases to about 8 (the H^+ concentration decreases). This gradient of three pH units corresponds to a thousandfold difference in H^+ concentration. If in the laboratory the lights are turned off, the pH gradient is abolished, but it can quickly be restored by turning the lights back on. Experiments such as this provided strong evidence in support of the chemiosmotic model.

Based on studies in several laboratories, Figure 10.18 shows a current model for the organization of the light-reaction "machinery" within the thylakoid membrane. Each of the molecules and molecular complexes in the figure is present in numerous copies in each thylakoid. Notice that NADPH, like ATP, is produced on the side of the membrane facing the stroma, where the Calvin cycle reactions take place.

Let's summarize the light reactions. Electron flow pushes electrons from water, where they are at a low state of potential energy, ultimately to NADPH, where they are stored at a high state of potential energy. The light-driven electron current also generates ATP. Thus, the equipment of the thylakoid membrane converts light energy to chemical energy stored in ATP and NADPH. (Oxygen is a by-product.) Let's now see how the Calvin cycle uses the products of the light reactions to synthesize sugar from CO_2.

▲ **Figure 10.17 Comparison of chemiosmosis in mitochondria and chloroplasts.** In both kinds of organelles, electron transport chains pump protons (H^+) across a membrane from a region of low H^+ concentration (light gray in this diagram) to one of high H^+ concentration (dark gray). The protons then diffuse back across the membrane through ATP synthase, driving the synthesis of ATP.

ure 10.18 **The light reactions hemiosmosis: the organization e thylakoid membrane.** This m shows a current model for the zation of the thylakoid membrane. The rows track the linear electron flow ed in Figure 10.14. As electrons pass rrier to carrier in redox reactions, gen ions removed from the stroma are ted in the thylakoid space, storing energy as a proton-motive force (H^+ gradient). At least three steps in the light reactions contribute to the proton gradient: ① Water is split by photosystem II on the side of the membrane facing the thylakoid space; ② as plastoquinone (Pq), a mobile carrier, transfers electrons to the cytochrome complex, four protons are translocated across the membrane into the thylakoid space; and ③ a hydrogen ion is removed from the stroma when it is taken up by $NADP^+$. Notice that in step 2, hydrogen ions are being pumped from the stroma into the thylakoid space, as in Figure 10.17. The diffusion of H^+ from the thylakoid space back to the stroma (along the H^+ concentration gradient) powers the ATP synthase. These light-driven reactions store chemical energy in NADPH and ATP, which shuttle the energy to the carbohydrate-producing Calvin cycle.

CEPT CHECK 10.2

What color of light is *least* effective in driving photosynthesis? Explain.

Compared to a solution of isolated chlorophyll, why do intact chloroplasts release less heat and fluorescence when illuminated?

In the light reactions, what is the initial electron donor? Where do the electrons finally end up?

4. **WHAT IF?** In an experiment, isolated chloroplasts placed in an illuminated solution with the appropriate chemicals can carry out ATP synthesis. Predict what would happen to the rate of synthesis if a compound is added to the solution that makes membranes freely permeable to hydrogen ions.

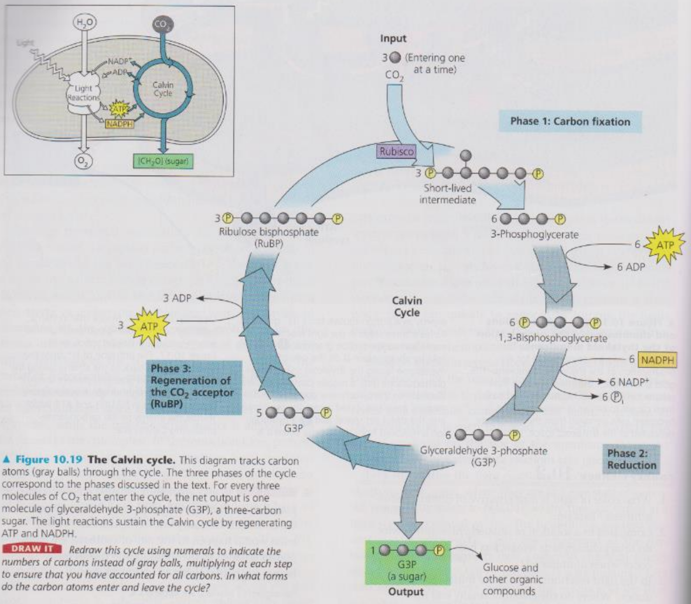
For suggested answers, see Appendix A.

CONCEPT 10.3

The Calvin cycle uses the chemical energy of ATP and NADPH to reduce CO_2 to sugar

The Calvin cycle is similar to the citric acid cycle in that a starting material is regenerated after molecules enter and leave the cycle. However, while the citric acid cycle is catabolic, oxidizing acetyl CoA and using the energy to synthesize ATP, the Calvin cycle is anabolic, building carbohydrates from smaller molecules and consuming energy. Carbon enters the Calvin cycle in the form of CO_2 and leaves in the form of sugar. The cycle spends ATP as an energy source and consumes NADPH as reducing power for adding high-energy electrons to make the sugar.

As we mentioned previously, the carbohydrate produced directly from the Calvin cycle is actually not glucose, but a three-carbon sugar; the name of this sugar is **glyceraldehyde 3-phosphate (G3P)**. For the net synthesis of one molecule of G3P, the cycle must take place three times, fixing three molecules of CO_2. (Recall that carbon fixation refers to the initial incorporation of CO_2 into organic material.) As we trace the steps of the cycle, keep in mind that we are following three molecules of CO_2 through the reactions. **Figure 10.19** divides the Calvin cycle into three phases: carbon fixation, reduction, and regeneration of the CO_2 acceptor.



▲ **Figure 10.19 The Calvin cycle.** This diagram tracks carbon atoms (gray balls) through the cycle. The three phases of the cycle correspond to the phases discussed in the text. For every three molecules of CO_2 that enter the cycle, the net output is one molecule of glyceraldehyde 3-phosphate (G3P), a three-carbon sugar. The light reactions sustain the Calvin cycle by regenerating ATP and NADPH.

DRAW IT *Redraw this cycle using numerals to indicate the numbers of carbons instead of gray balls, multiplying at each step to ensure that you have accounted for all carbons. In what forms do the carbon atoms enter and leave the cycle?*

Phase 1: Carbon fixation. The Calvin cycle incorporates each CO_2 molecule, one at a time, by attaching it to a five-carbon sugar named ribulose bisphosphate (abbreviated RuBP). The enzyme that catalyzes this first step is RuBP carboxylase, or **rubisco**. (This is the most abundant protein in chloroplasts and is also thought to be the most abundant protein on Earth.) The product of the reaction is a six-carbon intermediate so unstable that it immediately splits in half, forming two molecules of 3-phosphoglycerate (for each CO_2 fixed).

Phase 2: Reduction. Each molecule of 3-phosphoglycerate receives an additional phosphate group from ATP, becoming 1,3-bisphosphoglycerate. Next, a pair of electrons donated from NADPH reduces 1,3-bisphosphoglycerate, which also loses a phosphate group, becoming G3P. Specifically, the electrons from NADPH reduce a carboyxl group on 1,3-bisphosphoglycerate to the aldehyde group of G3P, which stores more potential energy. G3P is a sugar—the same three-carbon sugar formed in glycolysis by the splitting of glucose (see Figure 9.9). Notice in Figure 10.19 that for every *three* molecules of CO_2 that enter the cycle, there are *six* molecules of G3P formed. But only one molecule of this three-carbon sugar can be counted as a net gain of carbohydrate. The cycle began with 15 carbons' worth of carbohydrate in the form of three molecules of the five-carbon sugar RuBP. Now there are 18 carbons' worth of carbohydrate in the form of six molecules of G3P. One molecule exits the cycle to be used by the plant cell, but the other five molecules must be recycled to regenerate the three molecules of RuBP.

Phase 3: Regeneration of the CO_2 acceptor (RuBP). In a complex series of reactions, the carbon skeletons of five molecules of G3P are rearranged by the last steps of the Calvin cycle into three molecules of RuBP. To accomplish this, the cycle spends three more molecules of ATP. The RuBP is now prepared to receive CO_2 again, and the cycle continues.

For the net synthesis of one G3P molecule, the Calvin cycle consumes a total of nine molecules of ATP and six molecules of NADPH. The light reactions regenerate the ATP and NADPH. The G3P spun off from the Calvin cycle becomes the starting material for metabolic pathways that synthesize other organic compounds, including glucose and other carbohydrates. Neither the light reactions nor the Calvin cycle alone can make sugar from CO_2. Photosynthesis is an emergent property of the intact chloroplast, which integrates the two stages of photosynthesis.

CONCEPT CHECK 10.3

1. To synthesize one glucose molecule, the Calvin cycle uses ________ molecules of CO_2, ________ molecules of ATP, and ________ molecules of NADPH.
2. Explain why the large numbers of ATP and NADPH molecules used during the Calvin cycle are consistent with the high value of glucose as an energy source.
3. **WHAT IF?** Explain why a poison that inhibits an enzyme of the Calvin cycle will also inhibit the light reactions.
4. **MAKE CONNECTIONS** Review Figures 9.9 (p. 215) and 10.19. Discuss the roles of intermediate and product played by glyceraldehyde 3-phosphate (G3P) in the two processes shown in these figures.

For suggested answers, see Appendix A.

CONCEPT 10.4

Alternative mechanisms of carbon fixation have evolved in hot, arid climates

EVOLUTION Ever since plants first moved onto land about 475 million years ago, they have been adapting to the problems of terrestrial life, particularly the problem of dehydration. In Chapters 29 and 36, we will consider anatomical adaptations that help plants conserve water, while in this chapter we are concerned with metabolic adaptations. The solutions often involve trade-offs. An important example is the compromise between photosynthesis and the prevention of excessive water loss from the plant. The CO_2 required for photosynthesis enters a leaf via stomata, the pores on the leaf surface (see Figure 10.4). However, stomata are also the main avenues of transpiration, the evaporative loss of water from leaves. On a hot, dry day, most plants close their stomata, a response that conserves water. This response also reduces photosynthetic yield by limiting access to CO_2. With stomata even partially closed, CO_2 concentrations begin to decrease in the air spaces within the leaf, and the concentration of O_2 released from the light reactions begins to increase. These conditions within the leaf favor an apparently wasteful process called photorespiration.

Photorespiration: An Evolutionary Relic?

In most plants, initial fixation of carbon occurs via rubisco, the Calvin cycle enzyme that adds CO_2 to ribulose bisphosphate. Such plants are called **C_3 plants** because the first organic product of carbon fixation is a three-carbon compound, 3-phosphoglycerate (see Figure 10.19). Rice, wheat, and soybeans are C_3 plants that are important in agriculture. When their stomata partially close on hot, dry days, C_3 plants produce less sugar because the declining level of CO_2 in the leaf starves the Calvin cycle. In addition, rubisco can bind O_2 in place of CO_2. As CO_2 becomes scarce within the air spaces of the leaf, rubisco adds O_2 to the Calvin cycle instead of CO_2. The product splits, and a two-carbon compound leaves the chloroplast. Peroxisomes and mitochondria rearrange and split this compound, releasing CO_2. The process is called **photorespiration** because it occurs in the light (*photo*) and consumes O_2 while producing CO_2 (*respiration*). However, unlike normal cellular respiration, photorespiration generates no ATP; in fact, photorespiration consumes ATP. And unlike photosynthesis, photorespiration produces no sugar. In fact, photorespiration *decreases* photosynthetic output by siphoning organic material from the Calvin cycle and releasing CO_2 that would otherwise be fixed.

How can we explain the existence of a metabolic process that seems to be counterproductive for the plant? According to one hypothesis, photorespiration is evolutionary baggage—a metabolic relic from a much earlier time when the atmosphere had less O_2 and more CO_2 than it does today. In the ancient atmosphere that prevailed when rubisco first evolved, the inability of the enzyme's active site to exclude O_2 would have made little difference. The hypothesis suggests that modern rubisco retains some of its chance affinity for O_2, which is now so concentrated in the atmosphere that a certain amount of photorespiration is inevitable.

We now know that, at least in some cases, photorespiration plays a protective role in plants. Plants that are impaired in their ability to carry out photorespiration (due to defective genes) are more susceptible to damage induced by excess light. Researchers consider this clear evidence that photorespiration acts to neutralize the otherwise damaging products of the light reactions, which build up when a low CO_2 concentration limits the progress of the Calvin cycle. Whether there are other benefits of photorespiration is still unknown. In many types of plants—including a significant number of crop plants—photorespiration drains away as much as 50% of the carbon fixed by the Calvin cycle. As heterotrophs that depend on carbon fixation in chloroplasts for our food, we naturally view photorespiration as wasteful. Indeed, if photorespiration could be reduced in certain plant species without otherwise affecting photosynthetic productivity, crop yields and food supplies might increase.

In some plant species, alternate modes of carbon fixation have evolved that minimize photorespiration and optimize the Calvin cycle—even in hot, arid climates. The two most important of these photosynthetic adaptations are C_4 photosynthesis and crassulacean acid metabolism (CAM).

C_4 Plants

The **C_4 plants** are so named because they preface the Calvin cycle with an alternate mode of carbon fixation that forms a four-carbon compound as its first product. Several thousand species in at least 19 plant families use the C_4 pathway. Among the C_4 plants important to agriculture are sugarcane and corn, members of the grass family.

A unique leaf anatomy is correlated with the mechanism of C_4 photosynthesis (**Figure 10.20**; compare with Figure 10.4). In C_4 plants, there are two distinct types of photosynthetic cells: bundle-sheath cells and mesophyll cells. **Bundle-sheath cells** are arranged into tightly packed sheaths around the veins of the leaf. Between the bundle sheath and the leaf surface are the more loosely arranged mesophyll cells. The Calvin cycle is confined to the chloroplasts of the bundle-sheath cells. However, the Calvin cycle is preceded by incorporation of CO_2 into organic compounds in the mesophyll cells. See the numbered steps in Figure 10.20, which are also described here:

① The first step is carried out by an enzyme present only in mesophyll cells called **PEP carboxylase**. This enzyme adds CO_2 to phosphoenolpyruvate (PEP), forming the four-carbon product oxaloacetate. PEP carboxylase has a much higher affinity for CO_2 than does rubisco and no affinity for O_2. Therefore, PEP carboxylase can fix carbon efficiently when rubisco cannot—that is, when it is hot and dry and stomata are partially closed, causing CO_2 concentration in the leaf to fall and O_2 concentration to rise.

② After the C_4 plant fixes carbon from CO_2, the mesophyll cells export their four-carbon products (malate in the example shown in Figure 10.20) to bundle-sheath cells through plasmodesmata (see Figure 6.31).

③ Within the bundle-sheath cells, the four-carbon compounds release CO_2, which is reassimilated into organic material by rubisco and the Calvin cycle. The same reaction regenerates pyruvate, which is transported to mesophyll cells. There, ATP is used to convert pyruvate to PEP, allowing the reaction cycle to continue; this ATP can be thought of as the "price" of concentrating CO_2 in the bundle-sheath cells. To generate this extra ATP, bundle-sheath cells carry out cyclic electron flow, the process described earlier in this chapter (see Figure 10.16). In fact, these cells contain PS I but no PS II, so cyclic electron flow is their only photosynthetic mode of generating ATP.

In effect, the mesophyll cells of a C_4 plant pump CO_2 into the bundle sheath, keeping the CO_2 concentration in the bundle-sheath cells high enough for rubisco to bind carbon

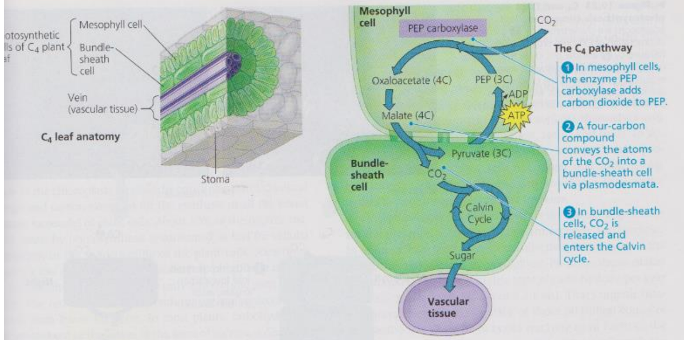


Figure 10.20 C_4 leaf anatomy and the C_4 pathway. The structure and biochemical functions of the aves of C_4 plants are an evolutionary adaptation to hot, dry climates. This adaptation maintains a CO_2 ncentration in the bundle sheath that favors photosynthesis over photorespiration.

ioxide rather than oxygen. The cyclic series of reactions inolving PEP carboxylase and the regeneration of PEP can be hought of as a CO_2-concentrating pump that is powered by TP. In this way, C_4 photosynthesis minimizes photorespiraon and enhances sugar production. This adaptation is espeially advantageous in hot regions with intense sunlight, here stomata partially close during the day, and it is in such nvironments that C_4 plants evolved and thrive today.

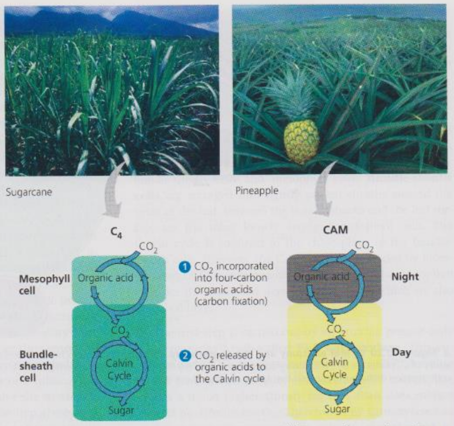
Since the Industrial Revolution began in the 1800s, uman activities such as the burning of fossil fuels have rastically increased the concentration of CO_2 in the atnosphere. The resulting global climate change, including n increase in average temperatures around the planet, nay have far-reaching effects on plant species. Scientists re concerned that increasing CO_2 concentration and temerature may affect C_3 and C_4 plants differently, thus hanging the relative abundance of these species in a given lant community.

Which type of plant would stand to gain more from inreasing CO_2 levels? Recall that in C_3 plants, the binding of O_2 ather than CO_2 by rubisco leads to photorespiration, lowering he efficiency of photosynthesis. C_4 plants overcome this roblem by concentrating CO_2 in the bundle-sheath cells at the cost of ATP. Rising CO_2 levels should benefit C_3 plants by lowering the amount of photorespiration that occurs. At the same time, rising temperatures have the opposite effect, increasing photorespiration. (Other factors such as water availability may also come into play.) In contrast, many C_4 plants could be largely unaffected by increasing CO_2 levels or temperature. In different regions, the particular combination of these two factors is likely to alter the balance of C_3 and C_4 plants in varying ways. The effects of such a widespread and variable change in community structure are unpredictable and thus a cause of legitimate concern.

CAM Plants

A second photosynthetic adaptation to arid conditions has evolved in many succulent (water-storing) plants, numerous cacti, pineapples, and representatives of several other plant families. These plants open their stomata during the night and close them during the day, just the reverse of how other plants behave. Closing stomata during the day helps desert plants conserve water, but it also prevents CO_2 from entering the leaves. During the night, when their stomata are open, these plants take up CO_2 and incorporate it into a variety

Figure 10.21 C_4 and CAM photosynthesis compared. Both adaptations are characterized by ① preliminary incorporation of CO_2 into organic acids, followed by ② transfer of CO_2 to the Calvin cycle. The C_4 and CAM pathways are two evolutionary solutions to the problem of maintaining photosynthesis with stomata partially or completely closed on hot, dry days.



(a) Spatial separation of steps. In C_4 plants, carbon fixation and the Calvin cycle occur in different types of cells.

(b) Temporal separation of steps. In CAM plants, carbon fixation and the Calvin cycle occur in the same cells at different times.

of organic acids. This mode of carbon fixation is called **crassulacean acid metabolism**, or **CAM**, after the plant family Crassulaceae, the succulents in which the process was first discovered. The mesophyll cells of **CAM plants** store the organic acids they make during the night in their vacuoles until morning, when the stomata close. During the day, when the light reactions can supply ATP and NADPH for the Calvin cycle, CO_2 is released from the organic acids made the night before to become incorporated into sugar in the chloroplasts.

Notice in **Figure 10.21** that the CAM pathway is similar to the C_4 pathway in that carbon dioxide is first incorporated into organic intermediates before it enters the Calvin cycle. The difference is that in C_4 plants, the initial steps of carbon fixation are separated structurally from the Calvin cycle, whereas in CAM plants, the two steps occur at separate times but within the same cell. (Keep in mind that CAM, C_4, and C_3 plants all eventually use the Calvin cycle to make sugar from carbon dioxide.)

CONCEPT CHECK 10.4

1. Explain why photorespiration lowers photosynthetic output for plants.
2. The presence of only PS I, not PS II, in the bundle-sheath cells of C_4 plants has an effect on O_2 concentration. What is that effect, and how might that benefit the plant?
3. **MAKE CONNECTIONS** Refer to the discussion of ocean acidification in Concept 3.3 (p. 101). Ocean acidification and changes in the distribution of C_3 and C_4 plants may seem to be two very different problems, but what do they have in common? Explain.
4. **WHAT IF?** How would you expect the relative abundance of C_3 versus C_4 and CAM species to change in a geographic region whose climate becomes much hotter and drier, with no change in CO_2 concentration?

For suggested answers, see Appendix A.

ne Importance of Photosynthesis: *A Review*

this chapter, we have followed photosynthesis from phons to food. The light reactions capture solar energy and use it make ATP and transfer electrons from water to $NADP^+$, rming NADPH. The Calvin cycle uses the ATP and NADPH produce sugar from carbon dioxide. The energy that enters e chloroplasts as sunlight becomes stored as chemical energy organic compounds. See **Figure 10.22** for a review of the ene process.

What are the fates of photosynthetic products? The sugar ade in the chloroplasts supplies the entire plant with chemical ergy and carbon skeletons for the synthesis of all the major ganic molecules of plant cells. About 50% of the organic marial made by photosynthesis is consumed as fuel for cellular spiration in the mitochondria of the plant cells. Sometimes ere is a loss of photosynthetic products to photorespiration.

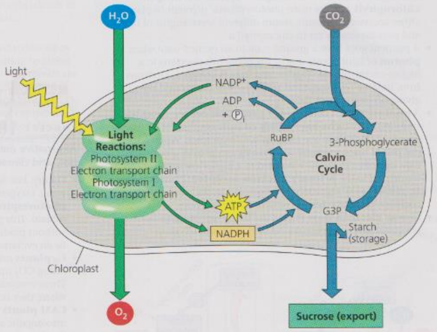
Technically, green cells are the only autotrophic parts of the ant. The rest of the plant depends on organic molecules exrted from leaves via veins. In most plants, carbohydrate is ansported out of the leaves in the form of sucrose, a disacchade. After arriving at nonphotosynthetic cells, the sucrose prodes raw material for cellular respiration and a multitude of abolic pathways that synthesize proteins, lipids, and other oducts. A considerable amount of sugar in the form of glue is linked together to make the polysaccharide cellulose, especially in plant cells that are still growing and maturing. Cellulose, the main ingredient of cell walls, is the most abundant organic molecule in the plant—and probably on the surface of the planet.

Most plants manage to make more organic material each day than they need to use as respiratory fuel and precursors for biosynthesis. They stockpile the extra sugar by synthesizing starch, storing some in the chloroplasts themselves and some in storage cells of roots, tubers, seeds, and fruits. In accounting for the consumption of the food molecules produced by photosynthesis, let's not forget that most plants lose leaves, roots, stems, fruits, and sometimes their entire bodies to heterotrophs, including humans.

On a global scale, photosynthesis is the process responsible for the presence of oxygen in our atmosphere. Furthermore, in terms of food production, the collective productivity of the minuscule chloroplasts is prodigious: Photosynthesis makes an estimated 160 billion metric tons of carbohydrate per year (a metric ton is 1,000 kg, about 1.1 tons). That's organic matter equivalent in mass to a stack of about 60 trillion copies of this textbook—17 stacks of books reaching from Earth to the sun! No other chemical process on the planet can match the output of photosynthesis. And as we mentioned earlier, researchers are seeking ways to capitalize on photosynthetic production to produce alternative fuels. No process is more important than photosynthesis to the welfare of life on Earth.

Figure 10.22 A review of hotosynthesis. This diagram outlines e main reactants and products of the light actions and the Calvin cycle as they occur the chloroplasts of plant cells. The entire dered operation depends on the structural tegrity of the chloroplast and its membranes. nzymes in the chloroplast and cytosol nvert glyceraldehyde 3-phosphate (G3P), e direct product of the Calvin cycle, to any other organic compounds.

MAKE CONNECTIONS *Return to the icrograph in Figure 5.6a, on page 118. bel and describe where the light reactions nd the Calvin cycle take place. Also explain here the starch granules in the micrograph me from.*

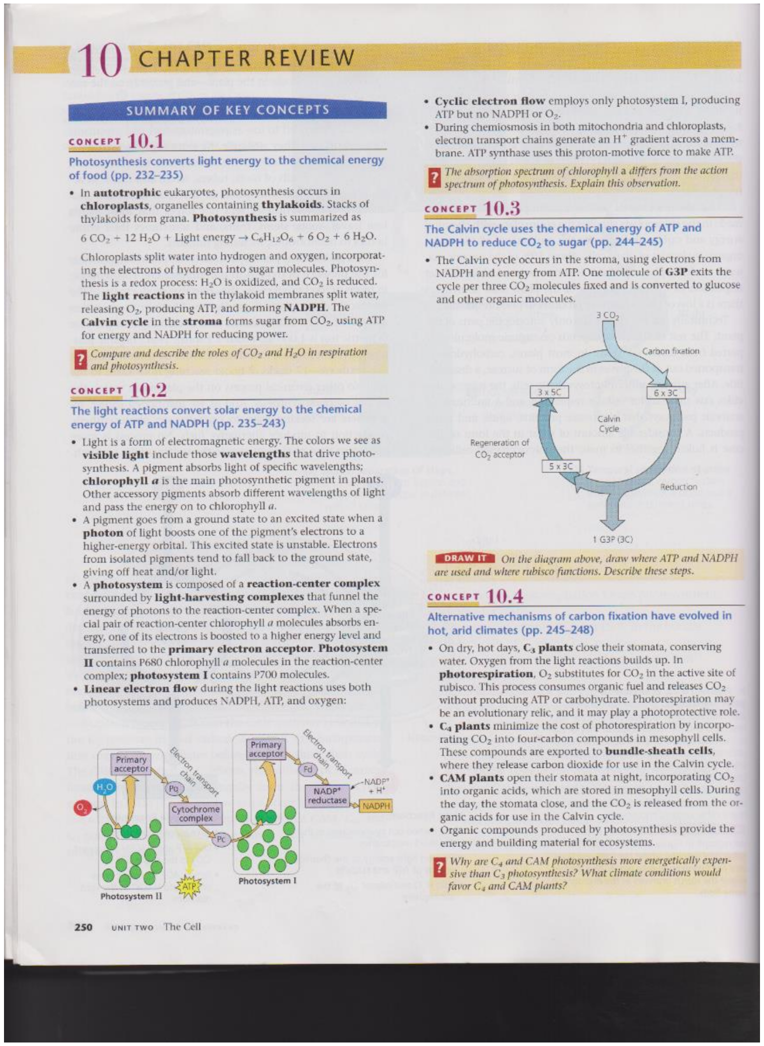


Light Reactions:

- Are carried out by molecules in the thylakoid membranes
- Convert light energy to the chemical energy of ATP and NADPH
- Split H_2O and release O_2 to the atmosphere

Calvin Cycle Reactions:

- Take place in the stroma
- Use ATP and NADPH to convert CO_2 to the sugar G3P
- Return ADP, inorganic phosphate, and $NADP^+$ to the light reactions



10 CHAPTER REVIEW

SUMMARY OF KEY CONCEPTS

CONCEPT 10.1

Photosynthesis converts light energy to the chemical energy of food (pp. 232–235)

- In **autotrophic** eukaryotes, photosynthesis occurs in **chloroplasts**, organelles containing **thylakoids**. Stacks of thylakoids form grana. **Photosynthesis** is summarized as

  $$6\ CO_2 + 12\ H_2O + \text{Light energy} \rightarrow C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O.$$

  Chloroplasts split water into hydrogen and oxygen, incorporating the electrons of hydrogen into sugar molecules. Photosynthesis is a redox process: H_2O is oxidized, and CO_2 is reduced. The **light reactions** in the thylakoid membranes split water, releasing O_2, producing ATP, and forming **NADPH**. The **Calvin cycle** in the **stroma** forms sugar from CO_2, using ATP for energy and NADPH for reducing power.

? *Compare and describe the roles of CO_2 and H_2O in respiration and photosynthesis.*

CONCEPT 10.2

The light reactions convert solar energy to the chemical energy of ATP and NADPH (pp. 235–243)

- Light is a form of electromagnetic energy. The colors we see as **visible light** include those **wavelengths** that drive photosynthesis. A pigment absorbs light of specific wavelengths; **chlorophyll *a*** is the main photosynthetic pigment in plants. Other accessory pigments absorb different wavelengths of light and pass the energy on to chlorophyll *a*.
- A pigment goes from a ground state to an excited state when a **photon** of light boosts one of the pigment's electrons to a higher-energy orbital. This excited state is unstable. Electrons from isolated pigments tend to fall back to the ground state, giving off heat and/or light.
- A **photosystem** is composed of a **reaction-center complex** surrounded by **light-harvesting complexes** that funnel the energy of photons to the reaction-center complex. When a special pair of reaction-center chlorophyll *a* molecules absorbs energy, one of its electrons is boosted to a higher energy level and transferred to the **primary electron acceptor**. **Photosystem II** contains P680 chlorophyll *a* molecules in the reaction-center complex; **photosystem I** contains P700 molecules.
- **Linear electron flow** during the light reactions uses both photosystems and produces NADPH, ATP, and oxygen:

- **Cyclic electron flow** employs only photosystem I, producing ATP but no NADPH or O_2.
- During chemiosmosis in both mitochondria and chloroplasts, electron transport chains generate an H^+ gradient across a membrane. ATP synthase uses this proton-motive force to make ATP.

? *The absorption spectrum of chlorophyll a differs from the action spectrum of photosynthesis. Explain this observation.*

CONCEPT 10.3

The Calvin cycle uses the chemical energy of ATP and NADPH to reduce CO_2 to sugar (pp. 244–245)

- The Calvin cycle occurs in the stroma, using electrons from NADPH and energy from ATP. One molecule of **G3P** exits the cycle per three CO_2 molecules fixed and is converted to glucose and other organic molecules.

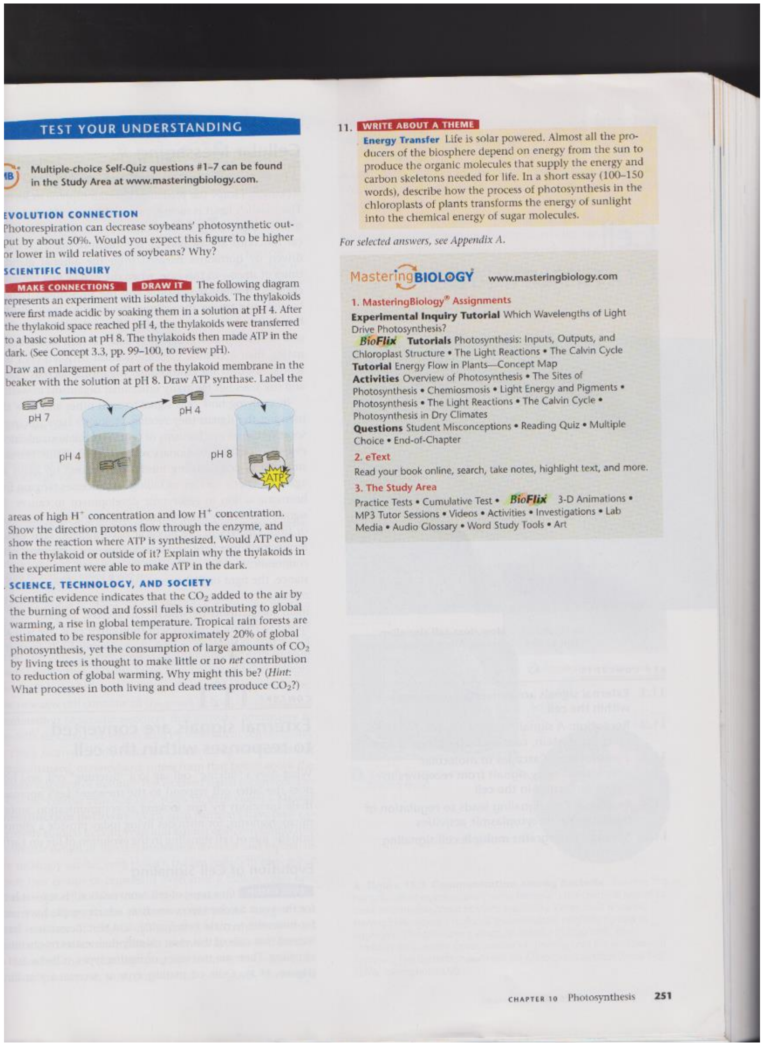
DRAW IT *On the diagram above, draw where ATP and NADPH are used and where rubisco functions. Describe these steps.*

CONCEPT 10.4

Alternative mechanisms of carbon fixation have evolved in hot, arid climates (pp. 245–248)

- On dry, hot days, **C_3 plants** close their stomata, conserving water. Oxygen from the light reactions builds up. In **photorespiration**, O_2 substitutes for CO_2 in the active site of rubisco. This process consumes organic fuel and releases CO_2 without producing ATP or carbohydrate. Photorespiration may be an evolutionary relic, and it may play a photoprotective role.
- **C_4 plants** minimize the cost of photorespiration by incorporating CO_2 into four-carbon compounds in mesophyll cells. These compounds are exported to **bundle-sheath cells**, where they release carbon dioxide for use in the Calvin cycle.
- **CAM plants** open their stomata at night, incorporating CO_2 into organic acids, which are stored in mesophyll cells. During the day, the stomata close, and the CO_2 is released from the organic acids for use in the Calvin cycle.
- Organic compounds produced by photosynthesis provide the energy and building material for ecosystems.

? *Why are C_4 and CAM photosynthesis more energetically expensive than C_3 photosynthesis? What climate conditions would favor C_4 and CAM plants?*



TEST YOUR UNDERSTANDING

Multiple-choice Self-Quiz questions #1–7 can be found in the Study Area at www.masteringbiology.com.

EVOLUTION CONNECTION

Photorespiration can decrease soybeans' photosynthetic output by about 50%. Would you expect this figure to be higher or lower in wild relatives of soybeans? Why?

SCIENTIFIC INQUIRY

MAKE CONNECTIONS **DRAW IT** The following diagram represents an experiment with isolated thylakoids. The thylakoids were first made acidic by soaking them in a solution at pH 4. After the thylakoid space reached pH 4, the thylakoids were transferred to a basic solution at pH 8. The thylakoids then made ATP in the dark. (See Concept 3.3, pp. 99–100, to review pH).

Draw an enlargement of part of the thylakoid membrane in the beaker with the solution at pH 8. Draw ATP synthase. Label the areas of high H^+ concentration and low H^+ concentration. Show the direction protons flow through the enzyme, and show the reaction where ATP is synthesized. Would ATP end up in the thylakoid or outside of it? Explain why the thylakoids in the experiment were able to make ATP in the dark.

SCIENCE, TECHNOLOGY, AND SOCIETY

Scientific evidence indicates that the CO_2 added to the air by the burning of wood and fossil fuels is contributing to global warming, a rise in global temperature. Tropical rain forests are estimated to be responsible for approximately 20% of global photosynthesis, yet the consumption of large amounts of CO_2 by living trees is thought to make little or no *net* contribution to reduction of global warming. Why might this be? (*Hint:* What processes in both living and dead trees produce CO_2?)

11\. **WRITE ABOUT A THEME**

Energy Transfer Life is solar powered. Almost all the producers of the biosphere depend on energy from the sun to produce the organic molecules that supply the energy and carbon skeletons needed for life. In a short essay (100–150 words), describe how the process of photosynthesis in the chloroplasts of plants transforms the energy of sunlight into the chemical energy of sugar molecules.

For selected answers, see Appendix A.

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1\. MasteringBiology® Assignments

Experimental Inquiry Tutorial Which Wavelengths of Light Drive Photosynthesis?

BioFlix **Tutorials** Photosynthesis: Inputs, Outputs, and Chloroplast Structure • The Light Reactions • The Calvin Cycle

Tutorial Energy Flow in Plants—Concept Map

Activities Overview of Photosynthesis • The Sites of Photosynthesis • Chemiosmosis • Light Energy and Pigments • Photosynthesis • The Light Reactions • The Calvin Cycle • Photosynthesis in Dry Climates

Questions Student Misconceptions • Reading Quiz • Multiple Choice • End-of-Chapter

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Practice Tests • Cumulative Test • *BioFlix* 3-D Animations • MP3 Tutor Sessions • Videos • Activities • Investigations • Lab Media • Audio Glossary • Word Study Tools • Art

Appendix 10: Daily journals Student Questionnaire

1. Which lecturer's class did you attend?
2. What section of photosynthesis has been covered?
3. Which part of this section did the lecturer explain exceptionally well?
4. Which part of this section do you still find confusing or unclear?
5. Any other comments about today's class?

Lecturer Questionnaire

Lecturers will be asked to answer the following two questions before teaching the topic:

1. What do you want to achieve in this lecture?

Additional questions will be answered after each session.

Appendix 11: Journal entries about Ms Amy

Quotes of BI's explained exceptionally well

- Photosynthesis converts light energy to chemical energy (BI1)

  ***'….** emphasised certain points and provided examples and analogies that helped me understand what was going on.'*

  'I felt that our lecturer explained the part about the electron transport chain really well.'

  ' the electron transport systems, it worked because she asked if she should explain again, and the second time i got it.'

  'Cyclic electron transport. This section was easy to understand because it is similar to the noncyclic electron transport ……. Ms Amy explained the noncyclic electron transport to us twice ……'

  'The difference between cyclic and non-cyclic electron transport was made clear quite well, she broke down the steps of noncyclic transport and mapped them out which helped'

  'How the electromagnetic spectrum - especially wavelengths as well as light - plays a huge part in photosynthesis. I thought that the analogy of the man on the trampoline was a great way to remember that a wave has a high energy when it is short, and a low energy when it is long. Also I remember the analogy with Carrots - being Carotenoids. How they are associated with an antioxidant and how they reflect orange and yellow light. These worked well for me because I seem to remember something better when I have something real to compare it to.'

  She explained the part about light and chloroplasts well for me because she used images that were easily relatable to the work, like how she said we should think of carrots when we see the word carotenoid, and by this we can remember better. Analogies and images work for me.

  'THE SECTION ABOUT HOW LIGHT IS REFLECTED AND ABSORBED BY DIFFERENT MATERIALS INCLUDING PLANTS OR IN SHORT ELECTROMAGNETIC SPECTRUM. SHE WAS JUST SO CLEAR ABOUT IT, MADE EXAMPLES AND I ACTUALLY LEARNED MLB111 TOGETHER WITH PHYSICS'

  Modes and sources of light and energy tools used by plants. An easy concept well explained by the lecturer.

- The light reactions convert solar energy to the chemical energy of ATP and NADPH. (BI2) *"photosystem II. She not only drew a simplified picture of the process but also explained in detail in simple sentences repeatedly what occurs at this stage of photosynthesis"*

'The light dependent reactions were explained very well, particularly when she drew them as it gave a more simplified view and made it more interactive if you took down the drawings.'

'The two different light systems, because she used examples to explain them.'

'…she explained very well why fd and Atp are the products in the cyclic transport system.'

'I found that the lecturer explained the different photosystems extremely well. I was able to grasp the concepts because she went slowly and gave a detailed explanation of the work. I could follow and understand what was going on.'

'The way in which the electron goes through the photosystems was explained exceptionally well. The lecturer was clear and concise. She elaborated and even asked the group if we needed further explanations.'

'the non-cyclic electron transport because today she was not as fast as she usually is and she kept on repeating the process and we also had additional time so some of us were able to stay behind and understand it the last time ….'

- The Calvin cycle uses chemical energy of ATP and NADPH to reduce CO_2 to sugar. (BI3)

'I really understood the carbon fixation, reduction, etc. (part of the cycle) as we drew diagrams and she explained it slowly and made sure we understood it. As we drew the diagrams I could picture the process happening which helped me a lot'

Ms Amy generally explains complicated concepts twice to make sure that we have a clear understanding of it. I feel that this really helps me and my fellow classmates in fully grasping concepts.

'The actual cycle was explained quite well, I follow better when she draws the cycle out as it makes her go more slowly and I physically map out the steps so I can see what's going on. It makes it more interactive which helps as well.'

'Calvin Cycle: Because she explained it again so we heard 2 times'

'Cyclic Electron Transport. SHE repeated it more than once'

'The Calvin Cycle. She explained it twice using two different methods.'

'The lecturer explained all the cycles extremely well as she went slowly. She continuously asked the class whether we wanted her to repeat herself or if we were understanding.'

- Alternative mechanisms of carbon fixation have evolved in hot, arid climates (BI4)

  '.... drew a comparative of C4 and CAM photosynthesis and it really clarified the similarities and differences as well as cemented what happens where'

  'C4 and CAM plants. She explained it twice using two different methods: Drawing and using a pointer and diagram.'

Quotes on BI's still unclear

Similarly examples of reasons that the respondents gave on why they experienced the different big ideas as still unclear.

- Photosynthesis converts light energy to chemical energy

  No remarks

- The light reactions convert solar energy to the chemical energy of ATP and NADPH.

  I am still unsure about the specifics regarding the noncyclic electron transport

- The Calvin cycle uses chemical energy of ATP and NADPH to reduce CO_2 to sugar.

  'I feel that if a concept is misunderstood Ms Amy just explains it again, in the exact same way. I didn't understand the way she had explained it the first time round, so merely repeating the explanation was a futile attempt. she should consider trying to explain difficult concepts in different ways and she should maybe simplify it, i find it to be muddled up and if she could be more blatant in explaining certain aspects i feel i would understand it a lot better. this is especially true for the different cycles and parts of respiration and photosynthesis.'

- Alternative mechanisms of carbon fixation have evolved in hot, arid climates

  'I found that the way the lecturer explained the C4 cycle as well as the CAM cycle in a more confusing manner than yesterday. This may be because the lecturer drew the cycles on the board and I find it is better if I am given an image to visualise the process.'

Appendix 12: Journal entries about Prof James

Quotes of BI's explained exceptionally well

Examples of reasons that the respondents gave on why they experienced the different big ideas as explained exceptionally well is given below. The Afrikaans responses were translated in Afrikaans for the purpose of this study.

- Photosynthesis converts light energy to chemical energy. (BI1)

  '…. dosent was baie entoesiasties oor hoe die proses verloop, en dit het my laat belangstel. / *lecturer was very enthusiastic about course the process, it made me interested'*

  '…….Dit het goed gewerk omdat dit verduidelik was met behulp van 'n liedjie, waar die woorde in jou kop vas sit en dit bykans onmoontlik is om te vergeet. / *It worked well because it was explained with a song, the words stuck in your head and it is almost impossible to forget....'*

  '…….Die werk is goed en verstaanbaar op die skyfie, wat ook in die klasnotas, is uiteengesit. ....het ook bykomende inligting oor hierdie studie doelwit. / *the work is good and understandable on the slide, it is also in the class notes….. also gave additional information on the study aim.. .'*

- The light reactions convert solar energy to the chemical energy of ATP and NADPH. (BI2)

  '….prof. het die werk eers behandel en daarna weer vir ons 'n lied gesing wat die proses beskryf en dit help my om die werk beter te verstaan en meer te geniet / *prof first explained the work and we then again sang a song that explained the proses and it helped me to understand the work better and enjoy it more'*

  'Song- remember easy'

  '….gebruik verskillende voorbeelde om ons bekend te maak aan wat aan ons verduidelik word en dit stel ons in staat om die werk deeglik te verstaan. / *use different examples to familiarize us with what is explained and it enable us to totally understand the work….'*

  'Die werk is goed en verstaanbaar op die skyfie, wat ook in die klasnotas, is uiteengesit. Prof het ook bykomende inligting oor hierdie studie doelwit. / *The work is good and understandable on the slides`, it is also in the class notes. Prof also gave additional information on this study aim.'*

  'Hy het dit net op so 'n manier verduidelik wat sin gemaak het en verstaanbaar was.. dit was so eenvoudig verduidelik dat ek wat nog altyd daarmee sukkel nou weet wat aangaan. / *he explained it in such a way that it made sense and it was understandable. It was explained in such a simple way that I that always struggled with it now understand it.'*

  '…..die hoof prentjie van fotosintese waar water en koolstofdioksied ingaan om glukose en suurstof te verskaf /…. *the main picture of photosynthesis where water and carbon dioxide* *goes in to supply glucose and oxygen.'*

'Want die siklus is ook meganies voorgestel (in die prentjie) om dit beter te begryp. / *because the cycle is also represented mechanical (in the picture) to understand it better.'*

'werk is baie goed verduidelik, en kan onthou word lank na lesing. / *'work is explained very well and can be remembered long after the lesson.'*

- The Calvin cycle uses chemical energy of ATP and NADPH to reduce CO_2 to sugar. (BI3)

  Calvin siklus, baie in detail verduidelik, en werk goed in a diagram opgesom / *Calvin cycle, explained in detail and the summary in a diagram is good*

  'Die lied oor die tema en dat dit glukolise se inverse is omdat daar 'n prentjie was waarop hy gewys het. / *The song about the theme and that glycolysis is the inverse because there was a picture on which he showed it'*

  'die siklus want hy het dit gesing / *the cycle because he sang it'*

  'Hy het dit interessant gehou en goeie gebruik van sketse en aanwysings gebruik om dit te illustreer, tesame met `n bietjie humor, hou die res van die studente se aandag / *he kept it interesting and made good use of sketches and directions to illustrate it, together with some humor, keep the attention of the rest of the students.*

  'Die vloei diagram help om die werk beter te verstaan en ook redelik makliker te verstaan. */ The flow diagram helps to understand the work better and easier.'*

- Alternative mechanisms of carbon fixation have evolved in hot, arid climates. (BI4)

  'Die manier hoe Prof vir ons verduidelik het hoe om die 3 verskillende soorte plante te onthou. Hy het dit net so verduidelik dat mens logies daar aan kan dink en die 3 verskillendes sal kan onthou en onderskei van mekaar / *The way Prof explained to us how to remember the three different plants. He explained it in such a way that one can think about it logically and will be able to remember the 3 different ones and distinguish them.'*

  'hy het nie hoë woorde probeer gebruik wat mens deur mekaar maak nie. / *he did not try to use complex terminology that will confuse one'*

  'Want hy het baie herhaal en die 2 prentjies wat hy met mekaar kontrasteer het, het dit makliker gemaak om die verskille raak te sien. / *because he repeats a lot and the two pictures that he contrasted with one another, made it easier to see the differences.'*

  'Die verskil tussen die plante en hoe hulle werk is vir my heel duidelik. Dit was logies uiteengesit en ook mooi duidelik verduidelik. Daar was voorbeelde en genoeg tyd om dit self te proseseer. / *The difference between the plants* and how they work is very clear. It is explained logically'

The most frequent reason for work explained exceptionally well give by the students were the songs the Prof James sang after each session. The students also mentioned drawings and examples as reasons. Prof James were right when he said that students learn when they have fun. One of the students wrote an interesting comment, he said that the lecturer is god but nothing was explained exceptionally well. This specific student did not agree with the choice of word in the survey, something that I did not take in consideration.

> ‘ek is van opinie dat niks besonders goed verduidelik is nie. die dosent is wel goed om die inhoud van die werk aan ons deur te gee maar of jy as persoon dit gaan verstaan en onthou hang af hoe hard jy gaan leer en oor die werk nalees / *I am of the opinion that nothing is explained exceptionally well. The lecturer is good to give the content of the work to us, but if you as a person is going to understand and remember it will depend on how hard you are going to study and read about the work.’*

This is a very honest response. I could not use it in the two categories that were created but I wanted to add it. This specific student realised that his results is his own responsibility and does not depend on the performance of the lecturer. It is also interesting that there is not a single topic that s/he found explained exceptionally well or still unclear.

Quotes on BI’s still unclear

Similarly examples of reasons that the respondents gave on why they experienced the different big ideas as still unclear.

- Photosynthesis converts light energy to chemical energy. (BI1)

  > ‘Die fotosisteem I en II. Dit was 'n vreemde konsep en is vinnig behandel. / *the photosystem I and II. Dit is a strange concept and it was covered fast’*

- The light reactions convert solar energy to the chemical energy of ATP and NADPH. (BI2)

  > ‘Die deel van die chloroplaste is effens onduidelik aangesien dit vir my voel hy het dit moeilik verduidelik. Iets wat maklik behoort te wees. / *The part of the chloroplast is a bit unclear if feels he explains something that is supposed to be easy in a difficult way ‘*

- The Calvin cycle uses chemical energy of ATP and NADPH to reduce CO_2 to sugar. (BI3)

  > ‘….want hy verduidelik dit aan die hand van 'n liekie of ruimpies / *…because he explains with sings and rhymes’*
  >
  > ‘Hy gee so klas, dat dit moeilik maak om enigsins notas te maak, hy herhaal nie, - … Meeste van vandag se lesing veral van waar die prosesse plaas vind sal vir my about selfstudie wees. / *He lectures in such a way that it is difficult to take notes, he doesn’t repeat … most of today’s lesson about where the processes take place will be self-study’*

- Alternative mechanisms of carbon fixation have evolved in hot, arid climates. (BI4)

  > ‘Ek is nog heel onseker oor die reaksies in plante, … want daar was heeltyd gespring tussen twee slides, en as mens nog notas moet neem ook. Kan mens nie sien waarna hy verwys en watse slide nie. / *I am not sure about the reactions in plants… he jumps between two slides and if one has to take notes, you can’t see which slide he is referring to…..’*

General comment made by respondents in their journal entries

Ms Amy

> *'It was a very well explained lecture. It seemed Ms Amy is very passionate about this work'*
>
> *'she makes plants interesting, it's not at all boring.'*
>
> *'Appreciate the Lecturer for being patience so that students hear her clearly'*
>
> *'Other than that I really enjoyed the class, especially the fact that Ms Amy asks us if she wants us to have her explain the diagrams again - some lecturers won't'*
>
> *'I enjoyed the class.'*
>
> *'it was exceptionally good'*
>
> *'it was goods because she repeats some of the concepts we don't understand.'*
>
> *'All as she went over it multiple times'*
>
> *'well explained lecture'*
>
> *'no part was confusing as the lecturer explained it a few times'*
>
> *'she taught photosynthesis exceptionally well and she explained concepts very well too.'*
>
> *'it was an enjoyable class and very productive'*
>
> *'The animation made the process easier to understand.'*
>
> *'It was noisy again as usual. Ms Amy really does need to earn the respect of her students'*
>
> *'Please use the laser pointer'*
>
> *'I do not think lecturers fully explain what is in exams and tests and what needs to be more focused on.'*
>
> *'a video to wrap the entire photosynthesis process would have been awesome'*
>
> *'the lecture hall was empty this usually happens when Mrs. A lectures'*
>
> *'just allot of noise'*
>
> *'The overview of the entire photosynthesis process. The accompanying video clearly illustrated her points further and it helped me to develop a better visual idea in my head.'*

Prof James

> 'die dosent was baie entoesiasties oor hoe die proses verloop, en dit het my laat belangstel. */ the lecturer was very enthusiastic about the process, it made me interested'*
>
> 'Hy het dit interessant. Gemaak. / *He made it interesting'*
>
> 'goeie slides / *good slides*'
>
> 'weer vir ons 'n lied gesing wat die proses beskryf en dit help my om die werk beter te verstaan en meer te geniet.../ *sang a song again that explained the process it helped me to understand the work better and made it more enjoyable'*
>
> 'Dit het goed gewerk omdat dit verduidelik was met behulp van 'n liedjie, / *It worked well because it was explained with a song'*
>
> 'Die liedjie het gewerk omdat mens net liedjies beter onthou. / *the song worked because one remember songs better'*

‘hy verduidelik dit aan die hand van 'n liekie of ruimpies / *he explain with songs and rhymes’*

‘die siklus is ook meganies voorgestel (in die prentjie) / *the cycle is presented mechanically (in the picture)‘*

‘ …..deel wat uitgestaan het …… die hoof prentjie van fotosintese / *the ‘part that stood out ….the main picture of photosynthesis’*

‘Hy het dit net op so 'n manier verduidelik wat sin gemaak het en verstaanbaar was. / *He explained it in such a way that made sense and it was understandable’*

‘Die vloei diagram help om die werk beter te verstaan / *the flow diagram helped to understand the work be*