Learn Chemistry

Chemistry's Interfaces: The Reality of Nutrition

Student Guide

Developed by Dr. Dylan Williams and Dr. Sarah Gretton, University of Leicester

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National HE STEM Programme

RSC | Advancing the Chemical Sciences

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Facilitation Session Guide

Suggested Texts:

Berg, J.M., Tymoczko, J.L. & Stryer, L., ***Biochemistry***. Palgrave.

Atkins, P. & de Paula, J., ***Atkins' Physical Chemistry***. Oxford University Press.

Session 1 (60-90 minutes)

Pre-Session Preparation

You should be prepared to discuss the following topics in the facilitation session:

- Proteins
- Enzymes
- Enzyme Kinetics

We recommend reading the following topics in *Biochemistry* (Berg *et al*):

- Sections 1.1-1.3 (possibly 1.4)
- Sections 2.1-2.6
- Sections 8.1-8.5
- Sections 23.1 and 23.2 (possibly 23.5)

Intended Learning Outcomes

By the end of this problem you should be able to:

- explain how amino acids form proteins
- explain how amino acid side chains affect the properties of a protein
- describe the meaning of Primary, Secondary, Tertiary and Quaternary protein structure,
- explain the roles of proteins in cells and how their structure affects their function
- describe the mechanism of protein catabolism and its importance
- understand the role of enzymes in terms of chemical thermodynamics and kinetics
- explain the general mechanism by which enzymes catalyse biochemical processes
- calculate kinetic parameters related to enzyme catalysed processes in terms of the Michaelis-Menten model
- work in a small group to analyse and critique a scientific article based on both the style of writing and the scientific content
- decide on the best course of action based on a group discussion
- communicate with scientific colleagues at a professional level

Student Introduction

You are working for the National Academy of Science as part of a team of graduate interns. The Academy publishes a monthly magazine called 'Nutrition and Health' which is aimed at professionals working in this area as well as at interested members of the public.

From: Chief Editor [chiefeditor@nutritionandhealth.com]

To: Graduate Interns

Cc:

Subject: Nature and Health – the Diet Issue

Dear Intern team,

I have a small project for you to work on for the next week or so. I would like you to work as sub-editors for the next issue of Nutrition and Health. I am afraid I will be away at a conference so won't be able to put the issue together myself. This should be an easy task as you only really need to do one thing – Dr Sally will be acting as guest editor and I would like you to make sure that the content that she submits meets our usual rigorous standards (please see the bullet point summary below). I'm sure it will be fine and this will turn out to be an easy assignment.

Dr Sally has also provided some kinetic data from a study that her research group conducted into a digestive enzyme. Dr Sally thought we might want to include a summary of this (her research group isn't sure how to interpret the data) – please take a look at this and use it as you see most appropriate.

Best wishes,

Dr Livid,

Chief Editor of Nutrition and Health

- All articles must be written in proper English. The use of correct spelling and grammar is essential.
- All articles must be based on our current understanding of scientific concepts. Where possible this must be supported by examples from research literature.
- All 'Nutrition and Health' articles must be written in a format which makes them interesting and accessible to as wide an audience as possible. Our subscribers range from A-level students to lifelong practitioners of nutritional science so it is essential that the articles are written at an appropriate level.
- All references to the work of others must be fully cited.
- Only copyright free images can be used.

Nutrition and Health

Volume 16, edition 4 – The Diet Issue

Editorial: Dr Sally

"I am honoured to be acting as the guest editor of this month's edition of Nutrition and Health. Thanks to the internet we find ourselves living in a generation of information overload so it is very important that we become skilled in evaluating the quality of the information that we encounter. Our understanding of nutrition is becoming increasingly sophisticated and it is the scientific community's responsibility to ensure this information is disseminated in a way that will ensure everyone can benefit from the latest findings.

A number of challenges remain for the nutritional sciences. My research team is working on uncovering the scientific basis of the metabolism of food in order to help improve our understanding of what constitutes a healthy diet. We know that proteins play an important role in this process but the details of what they do remain unclear. We consume a lot of protein in the form of meat, poultry, fish, nuts and eggs so it's vital that we know what they do, how they do it and how we can maximise their effect by managing our protein intake. Proteins form a range of diverse structures but we don't know very much about what causes them to adopt these structures and how the three dimensional structures relates to their chemical properties but we do know that certain types of proteins, known as enzymes, can speed up reactions. Our understanding of how these proteins are synthesised from the food we consume is limited. We are hoping that our current research will allow us to develop an understanding of the underlying physical basis of enzyme catalysed process that will potentially allow us to measure (and even predict) the rates of enzyme catalysed processes.

This is a very exciting time to be researching the nutritional sciences, as society has never depended on us more."

Dr Sally

The Northland Foundation for Nutritional Health

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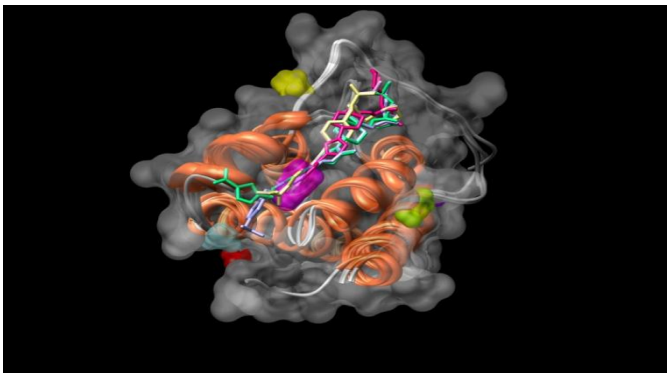
This month's issue:



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Jon Fuller, Image courtesy Centre for Bioscience, the Higher Education Academy, ImageBank

Concentration of substrate (mol dm^{-3})	Amount of product produced (mol min^{-1})
5.00×10^{-6}	3.47×10^{-10}
1.00×10^{-5}	4.75×10^{-10}
2.50×10^{-5}	6.09×10^{-10}
5.00×10^{-5}	6.72×10^{-10}
9.00×10^{-5}	7.05×10^{-10}
5.00×10^{-5}	3.47×10^{-10}

The concentration of enzyme was 12.5 pM.

Facilitation questions

- What happens to protein when we eat it?
- Why do we need protein in the diet?
- What are typical functions of proteins in the body?
- What chemical bonds are present in proteins?
- What are the four levels of protein structure and their significance?
- What is an essential amino acid?
- What is the relationship between amino acids and proteins?
- What factors influence the final structure of a protein?
- Discuss the use of catalysts in chemical processes. How can you modify your simple energy level profile diagrams to show the alternative route taken if the process was catalysed?
- What is meant by the active site of an enzyme?
- Discuss the various mechanisms by which enzymes may catalyse processes in biological systems.
- Discuss the effects of the physical environment (specifically temperature and pH) on the activity of enzymes.
- How may an enzyme be inhibited? Describe the common pathways by which this may be achieved.
- Describe the kinetic model of enzyme catalysed processes in terms of the Michaelis-Menten model. How can the maximal rate of such a process be determined?
- Can we distinguish the different types of inhibition through kinetic studies?
- How can a Lineweaver-Burke plot be used to establish useful kinetic parameters from experimental data?

From: **Chief Editor [chiefeditor@nutritionandhealth.com]**

To: **Graduate Interns**

Cc:

Subject: **FW: Request from Dr Sally**

Dear team,

Please take a look at this e-mail we have received from Dr Sally's legal team. Please draft a Summary of the errors that you spotted in her article and please prepare a two-page spread on the structure and function of proteins (obviously with a specific emphasis on diet). Please make sure this article makes it clear to our guest editor that our changes were based on scientific concerns. Please make sure the article will help our younger subscribers understand these concepts! Perhaps you could include an analysis of that kinetic data - remember to explain what it shows!

Best wishes,

Dr Livid,

Chief Editor of Nutrition and Health

From: **D Rowlands [drowlands@scientificlegal.com]**

To: **Nature and Health [Natureandhealth.com]**

Cc:

Subject: **Request from Dr Sally**

Dear Nature and Health magazine,

I am writing on behalf of my client Dr Sally regarding an article that she wrote for your magazine last month. Dr Sally was invited to write an editorial based on the cutting edge research that is being conducted in her laboratory. Dr Sally was surprised to see that your editorial team have made significant changes to the editorial without notifying her.

Dr Sally is currently considering her options before deciding what the most appropriate course of action is but in the meantime she would like us to inform you that she will be expecting to see a full explanation of these 'errors' in the next edition of your magazine.

Best wishes,

D Rowlands,

Scientific Legal

From: **Chief Editor [chiefeditor@nutritionandhealth.com]**

To: **Graduate Interns**

Cc:

Subject: **FW: Last month's editorial!**

Dear team,

Please take a look at this email we received from one of our readers (see attachment). I am not happy that we agreed to publish an editorial containing a significant number of factual errors. This is embarrassing for all of us and we will need to act fast in order to minimise the damage already done by Dr Sally's editorial. We will need to print an apology in the next issue. I also think it would be useful to run a two-page spread on the structure and function of proteins (obviously with a specific emphasis on diet). Please make sure this article clears up any confusion amongst our readers, our younger subscribers in particular! Perhaps you could include an analysis of that kinetic data - remember to explain what it shows!

Best wishes,

Dr Livid,

Chief Editor of Nutrition and Health

Dear Dr Livid,

Being a graduate of the London College of Nutrition I was very concerned by Dr Sally's editorial in the February issue of Nutrition and Health.

Dr Sally claims that not a lot is known about the structure and function of proteins. May I suggest that Dr Sally consults any introductory textbook – she may find that it makes her current research somewhat redundant!

I was frankly stunned to see that your editor chose not to discuss what we do know about protein structure and function: the four levels of protein structure, the kinetic theories of enzymes (eg. Michaelis Menten) and the catabolism of proteins to name just three areas that were overlooked!

I hope the quality of editorials improves or I may be forced to reconsider my subscription!

Prof Peeved

University of Northland

Group reflection

Review your progress in this session and think about what remains to be done. Construct a brief plan of action – the plan should include a list of the tasks that each group member is expected to do and a timescale for each of these tasks to be done. Remember to include enough time to proof read each other's work before submission. You should briefly present this plan to your tutor before the end of the session.

Session 2: Question Time (60-90 minutes)

Pre-Session Preparation

You should be prepared to discuss the following topics in the facilitation session:

- Nucleic Acids and DNA
- Fatty Acids and Lipids
- Polysaccharides and Carbohydrates

We recommend reading the following topics in *Biochemistry* (Berg *et al*):

- Sections 4.1 and 4.2
- Sections 11.1 and 11.2 (possibly 11.3 and 11.4)
- Sections 12.1 -12.3

Intended Learning Outcomes

By the end of this problem you should be able to:

- draw the typical chemical structure of fats, carbohydrates and nucleic acids
- describe the biochemical role of fats, carbohydrates and nucleic acids
- give an oral presentation to communicate scientific concepts to a diverse audience

Facilitation questions

- The major components of dietary fats are triglycerides (triacylglycerols). What are these?
- How are the components of fat used in cells?
- What is an essential fatty acid? Why is it important?
- What are phospholipids?
- What is a monosaccharide? What is a disaccharide? What is a polysaccharide?
- What happens to carbohydrate after it is eaten?
- Why are sugars needed by cells?
- What is a helix? What is a double helix?
- What makes up the backbone of DNA?
- How are the two strands of DNA connected together?
- What are base pairs and how are they connected to the rest of the DNA molecule?
- What are the differences between DNA and RNA?
- How long are typical strands of DNA?
- What are the functions of nucleic acids in cells?
- What happens to nucleic acids after they are eaten?
- Why aren't nucleic acids or nucleotides essential in the diet?

The Interview

A media interview is another way of communicating scientific ideas; the content discussed in the first two sessions will form the basis of this interview. This interview will be based on a series of questions asked by the presenter of a radio programme on nutrition and health. You will spend most of the interview answering these questions so you will need to think carefully about how to communicate your points at an appropriate level for the audience.

It is important to remember these points:

- This is not a standard oral presentation, the majority of the time you will be answering questions. You should not prepare a PowerPoint presentation!
- Communicate your responses at an appropriate level – the audience won't be experts so it won't be much use to simply quote findings direct from a research paper!
- Critically evaluate Dr Sally's interview and think carefully about the points you would like to get across. Compile a list of possible questions based on this discussion. Put yourselves in the shoes of the press.

From: **Chief Editor [chiefeditor@nutritionandhealth.com]**

To: **Graduate Interns**

Cc:

Subject: **Radio Interview**

Dear team,

Please listen to this recording of a recent radio interview given by Dr. Sally. Given the confusion that I'm sure this interview has caused, I have arranged for you to appear in next week's show – please try to undo some of the damage she has done to our profession! Remember, your responses to the interviewer's questions needed to be grounded in science but you must make sure the audience can understand what you are mean!

Best wishes,

Dr Livid,

Chief Editor of Nutrition and Health

Script of Dr Sally's radio interview:

Clip 1 – Carbohydrates Interview

Interviewer: Good morning and welcome to Health Matters. Today we will be discussing the role of carbohydrates in a healthy diet with our special guest and later in the show we'll be taking some of your health questions so if you have any health issues please get in touch. So first of all I'd like to welcome today's special guest, author of the bestselling book "Dr Sally's Eating for Health", Dr Sally.

Dr Sally: Good morning.

Interviewer: Good morning Dr Sally, a pleasure to have you with us today. So your new book has been another runaway success, congratulations.

Dr Sally: Thank you and thanks to everyone out there who has helped make it a best seller.

Interviewer: Could you please give us a brief summary of "Eating for Health" for the benefit of the one or two people who still haven't bought it?

Dr Sally: Of course Dave. This book is a gift from me to the good people of Northland. I want us to be a fit, healthy nation and it is my responsibility to share my nutritional insight with the public at a reasonable price.

Interviewer: So what insights have you got for the Northland public?

Dr Sally: I don't want to spoil the book but let's think about what's wrong with the nation's diet. I know the answer; the supermarkets know the answer, even the general public know the answer – Carbohydrates.

Interviewer: Carbohydrates?

Dr Sally: Absolutely! Our diets are overloaded with carbohydrates. We need to dramatically reduce our dependence on carbohydrates as a nation. Carbohydrates are essentially incompatible with the human body so we need to cut them out of our diets. It really is no wonder that we lead Europe in terms of obesity – we should be ashamed of ourselves! We need to be teaching our children to cut carbohydrates out of their diets rather than ruining their lives at an early age by force feeding them carbs!

Interviewer: This is clearly something you feel very strongly about.

Dr Sally: It's something that we should all feel very strongly about! As well as causing an alarming rise in national obesity levels, if we persist in allowing people to follow diets which include carbohydrates we will see a massive increase in diabetes levels. The NHS won't be able to cope!

Interviewer: If all of our listeners cut out carbohydrates now what should they eat instead?

Dr Sally: Dietary supplements are an essential part of any healthy diet. My website sells a comprehensive selection of dietary supplements which should be enough to get the country back on track. All of this is in the book – that's why everyone needs to read it!

Interviewer: So from a scientific perspective, what do we know about carbohydrates? Aren't carbohydrates efficient sources of energy? What kind of molecules are they? For instance, do they vary in composition and does this affect how unhealthy there are?

Dr Sally: I really don't want to spoil the book. Remember "Eating for Health" is just £19.95 in all good book shops and supermarkets.

Interviewer: Okay, thanks for now Dr Sally. Dr Sally will be back in ten minutes to answer your questions so get calling now. First we're going to take a look at how to stay healthy in the summer sun…

Clip 2 – Listener Q&A

Interviewer: We're back with Dr Sally now for your questions. We should have Becky from Scunthorpe on the line. Hello Becky?

Becky: Hello Dave.

Interviewer: Becky what's your question for us this morning?

Becky: I'm six months pregnant and I'm rather worried that my child will inherit cystic fiborsis as there is a history of it in my husband's family.

Dr Sally: Good morning Becky this is Dr Sally.

Becky: Good morning Sally.

Dr Sally: Sorry, it's Dr Sally.

Becky: Sorry Dr Sally.

Dr Sally: Becky you don't have anything to worry about here. Inheritance actually has no bearing on health. Health depends entirely on what you eat, not who your parents are.

Presenter: But what about conditions like Huntingdon's disease and haemophilia, are you saying that these conditions are not caused by inherited genes?

Dr Sally: Possibly not. If you want to know more about this I suggest you read my book!

Becky: I'm very confused now – I was sure cystic fibrosis was an inherited condition; I just wanted to know what the chances of my child acquiring the condition were!

Dr Sally: Okay Becky, thanks! Who's up next?

Presenter: Oh, sorry Becky, Dr Sally has accidentally (?!) cut you off. Next we have Jeff in Leyland.

Jeff: Good morning Dave and Dr Sally.

Both: Good morning.

Presenter: Jeff, what would you like to know?

Jeff: I've heard a lot about essential fatty acids but I'm still not sure what makes them so essential – why should I be ensuring I eat them and how I can tell what contains them?

Dr Sally: These fatty acids are called essential because that's exactly what they are, we can't make them in our own bodies so we must consume them as part of our diet.

Presenter: So what do we need to look for on labels?

Dr Sally: Well you should be wary of saturated trans fats – these fats can contribute to heart disease so should be avoided but you should get as much ω-3 and ω-6 oil as possible. ω-3 can be found in fish, soybean and flax oils and ω-6 can be found in sunflower and corn oils.

Presenter: Would you say that it's important that we recognise the importance of some fats in our diets? Fats usually get a very bad press!

Dr Sally: Absolutely. Fats belong to a class of chemical molecules known as lipids. Phospholipids are non-polar lipid molecules which help to form membranes. These phospholipids come together to form little bubbles called micelles in the body, which are important in a number of cellular pathways.

Presenter: Thanks for your call Jeff. I'm afraid that all the time we have for this week. Once again I'd like to thank Dr Sally for joining us today.

Dr Sally: Thank you, it's been a pleasure.

Presenter: Don't forget to join us next week when we'll be learning how the new fitness craze yomba is taking the nation by storm.

Group reflection

Review your progress in this session and think about what remains to be done. Construct a brief plan of action – the plan should include a list of the tasks that each group member is expected to do and a timescale for each of these tasks to be done. Remember to include enough time to proof read each other's work before submission. You should briefly present this plan to your tutor before the end of the session.

Session 3: Question Time – Part 2 (20-30 minutes per group)

In this session you will record your interview

Session 4: Sensors

Intended Learning Outcomes

By the end of this you should be able to:

- Describe the theory behind fluorescent technology and how it can be applied in biological research
- Communicate scientific concepts to a range of audience types by preparing short written reports (news articles in the form of this problem)

From: **D. Carter (Dr) [carterd@nas.nld]**

To: **Graduate Interns**

Cc:

Subject: **Fluorescence**

Attachment: Story from the Northland Gazette

Dear Intern team,

Please read the attached letter recently published in the Northland Gazette. This is another example of the generally poor understanding of important biochemical analytical techniques amongst the general public. We need to raise public awareness of this important analytical technique. If the general public refuse to support the research we are doing we may find it difficult to generate funding in the future.

I have also attached a press release about an innovative biochemical application of fluorescence, please read through this and think about how we can convince the public of the merits of this technique. This should including a simple description of the physical basis of the technique and a description of some interesting applications of the technique in biochemical research.

You should write two articles: one suitable for mainstream (non red-top tabloid) newspapers and another for use in scientific magazines and journals (e.g. Chemistry World and New Scientist)

Best wishes,

Dr Carter,

Biochemical Studies Baffle the Public

Letter from the Northland Gazette

The Northland public is potentially being misled by scientists on a daily basis. Many biochemical studies make use of fluorescence to monitor biochemical processes on the molecular level. Potentially important conclusions about the mechanisms and kinetics of enzyme catalysed processes are being followed by fluorescent techniques but it remains unclear how accurate these techniques are and how they operate. I challenge the scientific community to come up with a suitable explanation of how the technique works and why it is so useful, in language that us non-boffins can understand!

Northland National Academy of Science

Press Release

In order for a protein to have the correct biological function, it is essential that chain of amino acids the protein is composed of folds into the right three-dimensional structure. The misfolding of proteins is responsible for a number of diseases including Alzheimer's and Parkinson's disease. Recent research has shown misfolding is more frequent if the sequence of the amino acids in the neighbouring protein domains is very similar.

Proteins are biological molecules essential for life. In humans, for example, they have a variety of roles including providing the basis for structures such as hair and skin and the function of cells that make up organs with the body. Each protein has unique functions and these functions will be based on its three-dimensional structure, which usually consists of a number of sections, or “domains” It is therefore important that proteins avoid “misfolding processes”. However, this is no easy task since the same molecular interactions that stabilize the correct structure of individual proteins can also bring about interactions between protein molecules, causing them to misfold.

Colleagues from the Universities of Zurich and Cambridge used a technique called single-molecule fluorescence to identify situations in which protein misfolding are more likely to occur. In order to do this the team, headed by Prof. Benjamin Schuler from the University of Zurich, studied the largest protein found in humans, titin. This protein, which is composed of a number of domains, helps the stability and elasticity of the muscle fibres. Individual titin domains unfold when the muscle is heavily exerted to avoid damaging the muscle tissue. When the muscle relaxes again the domains refold; however, there is a danger that these unfolded domains may fold incorrectly.

To investigate how this occurs, the researchers attached small fluorescent molecules to the protein which acted as probes. “Using our laser-spectroscopic method we were able to determine distances on a molecular scale, i.e. down to a few millionths of a millimeter, through the energy transfer between the probes,” explains Prof. Schuler. This enabled the structures of correctly and misfolded proteins to be distinguished and thus the proportion of misfolding determined.

“The study of different titin domains in our experiments revealed that the probability of misfolding increases if neighboring domains are very similar in the sequence of their amino acids,” says Prof. Schuler. This is apparently the reason why neighboring domains in proteins have a limited degree of similarity. “This seems to be a key evolutionary strategy to avoid protein misfolding and thus guarantee their maximum functionality,” says Schuler.