Departments of Biology, Chemistry, Computer Science, Electronics, Mathematics, Physics and HYMS

WELLCOME TRUST CIDCATS PROGRAMME 2015

Section 1 BIOLOGY CHECK-LIST

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Section 2 CHEMISTRY CHECK-LIST

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Section 3 COMPUTER PROGRAMMING CHECK-LIST

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BIOLOGY CHECK-LIST

Please ensure you familiarise yourself with the following terms and concepts, and if not clear, you take questions to the week 0 checkup session! Most can be derived from introductory chapters of undergraduate Biology books and some good websites. This will allow us to build upon a common knowledge level, which you will need to understand the background we will provide for the group project. If you are a biologist, we hope you will attend the session to provide support!

- Human body: key organs and function for concepts of infectious disease and immunology (skin, spleen, liver, lymph system and lymph nodes).
- Concept of innate immunity and adaptive immunity: cytokines, antibodies, major components/cells of immune system, blood and roles.
- Eukaryotic cell vs prokaryotic cell vs virus: major differences.
- Cell biology - main cell organelles and roles: nucleus, mitochondrion, membrane(s), endoplasmic reticulum.
- Genes, Chromosomes; homozygous, heterozygous.
- Nucleic acids, DNA, mRNA, tRNA, transcription , translation. (coordinate with biochem).
- Gene expression: Transcription factor, RNA polymerase, regulatory RNAs.
- Proteins and amino acids.

Read the chapter on Infection from Garland. This will further help you identify terminology that you need to find clarification for/ ask about once you are here. There will be plenty of chance to discuss the concepts presented in this and the other chapters during term 1.

You can access the chapter on VLE: log in with York user name and password at https://vle.york.ac.uk/ then go to 2014/15 CIDCATS, and look under Resources.

Marjan Van der Woude

CHEMISTRY CHECK-LIST

We will expect that you are familiar with the basic concepts listed below. These are covered in undergraduate Chemistry & Biochemistry textbooks. We encourage you to discuss any questions that you may have during the checkup session, where further reading will be recommended; additional training sessions can be arranged if required.

- pH, how to prepare a buffer solution, pKa.
- Thermodynamics: First and Second Laws, Gibbs free energy.
- Interactions between chemical groups that stabilize the structure of biological macromolecules: covalent bonds, ionic interactions, van der Waals forces, hydrophobic interactions.
- Proteins: properties of amino acids, peptide bond, polypeptide chain conformation, Ramachandran plot, different levels of structural organisation (primary, secondary, tertiary and quaternary).
- Nucleic acids: acid-base chemistry, tautomerism, base pairs, conformation. Differences between DNA and RNA.
- Enzyme catalysis: Michaelis-Menten kinetics, Vmax, *k*cat, *K*M, induced fit, transition state.
- Role of metals in biological molecules: Na, K, Mg, Ca, Mn, Cu, Zn, Co, Fe and in the interaction of small molecules with these metal centres (e.g. O2 and CO).
- Use of synthetic chemistry in the lead therapeutic discovery process (basic chemical reactions, e.g. Suzuki couplings, esterifications, amide bond formations).
- Isolating biological molecules: solubility, affinity and size exclusion chromatography, electrophoresis and isoelectric focusing.
- Characterisation of macromolecules by mass-spectrometry, CD spectroscopy, fluorescence, analytical ultracentrifugation.
- 3-D structure determination: electron microscopy, NMR, X-ray crystallography. Advantages and limitations of each method.

Fred Anston and Ian Fairlamb

COMPUTER PROGRAMMING CHECK SHEET

Before starting the course in October, we recommend that you spend a little time, if you have any, starting to look at computer programming. Some of you will have extensive experience programming, whereas some will never have coded before. Don't worry either way! You will all attend classes in programming once you start, so don't worry if you feel under-prepared, but if you do have some time to make a head start, then please do.

This sheet is intended to act as a guide to basic concepts in programming, concepts that you may come to rely on during your PhD. You will be taught a language called Python and a good guide to this language can be found at http://www.greenteapress.com/thinkpython/thinkpython.pdf We recommend that you use this book as a reference guide to get you started. It has some good introductory chapters on the basic concepts of programming and is a good, gentle introduction to the Python programming language. We don't expect to read through the whole book, but try and look at the following chapters: 1, 2, 3, 5, 6, 7 and 8 (chapter 4 is not really needed at this stage). These chapters cover the following issues:

Basic programming concepts
Declaring variables
Assignment
Comparison operators
Conditional statements
Iteration
Functions

You should aim to be familiar with these concepts at least. Anything over and above this is not needed at this stage, but of course if you enjoy the programming experience and want to explore further, then do go ahead.

For those of you with Mac or Linux machines, you should already have Python installed, so you can immediately begin tinkering with code. For those of you using PCs, we suggest downloading Portable Python 2.7 from portablepython.com

In the first week we will also be meeting with you for an hour during which time we can further explain core concepts and answer any questions that arose during your reading.

If before then you need any help with starting to learn programming or Python, (or even if you'd like some advanced exercises) feel free to contact Jason at any time via email: jc1571@york.ac.uk

Jon Timmis and Jason Cosgrove

Mathematical prerequisites

On this sheet are a series of example problems which cover the basics of things you may need to be aware of - this is essentially the basics of calculus and matrix manipulation which will underpin the theory aspects of this interdisciplinary course. Don't feel like you have to bash through all these, they are there for you to practice if you want to. The important aspect of this is to realise that this is the approximate assumed level of the more mathematical aspects course and many of the ideas spill over into other parts.

Factorising quadratics

Solving arbitrary quadratic equations comes in suprisingly many situations. Guessing the factorising form is a useful skill but many forms you come across cannot be done this way so recourse to the quadratic formula will be essential in many instances.

If

$$ax^2 + bx + c = 0$$

then the two roots $x_\pm$ are

$$x_\pm = -\frac{b}{2a} \pm \frac{\sqrt{b^2 - 4ac}}{2a}$$

if this isn't second nature, write it on your bathroom mirror until it is.

What are the roots of

1.
$$2x^2 + 3x - 1 = 0$$

2.
$$4x^2 - 4x + 1 = 0$$

3.
$$x^2 - \frac{p}{q}x + \frac{p^2}{4} = 0$$

Differentiation and Integration

It will be useful for you to be able to integrate and differentiate simple functions, either in practice or in principle. Some examples below that encompass a variety of techniques.

Differentiate, i.e. find f'(x) for

1.
$$f(x) = \frac{4x-1}{2x+1}$$

2.
$$f(x) = \left(x^2+3x-1\right)^{\left(\frac{3}{2}\right)}$$

3.
$$f(x) = \frac{\sin(2x)}{\cos(3x)}$$

4.
$$f(x) = x\tan(x)e^{-2x}$$

Integrate,

1.
$$\int \sqrt{3x-1}dx$$

2.
$$\int x^2e^{-3x}dx$$

3.
$$\int \frac{1}{x\sqrt{1-x}}dx$$

4.
$$\int_{\frac{\pi}{6}}^{\frac{\pi}{3}} \frac{1}{\sin 2x}dx$$

Differential equations

Differential equations are used to described how the rate of change of something (with respect to something else, often time) depends on other variables. They are often used as a way to describe that information, rather than words, perhaps confusingly. This is an unboundedly difficult subject, and for the purposes of this course it is important that you understand

1. how to solve simple first order equations by separation of variables.
2. that 1st order equations always have a solution, although it may be difficult to algebraically find.
3. that 1st order equations also need one boundary condition to fully solve them
4. that 2nd order and higher equations are hard

Some simple first order ODE's to solve

1.

$$\frac{dx}{dt} = \frac{x(1-t)}{t(2y-1)}, \text{ given that } x = 1 \text{ when } t = 1$$

2.

$$\frac{dy}{dx} = \frac{\cos^2 y}{\sin^2 x}, \text{ given that } y = \pi/4 \text{ when } y = \pi/4$$

Expansions and Taylors Theorem

You should be aware that if we have a small parameter in a function then it is possible to expand it around a known point. This statement can be made mathematically more precise, but it amounts to

$$f(a+h) = f(a) + \frac{h}{1!}f'(a) + \frac{h^2}{2!}f''(a) + \frac{h^3}{3!}f'''(a) + \dots$$

which turns out to be both practical and formally useful.
Expand

1.

$$\ln(1+x) \text{ around 1 for small x}$$

Matrices and Eigenvalues in two dimensions

Matrices invariably will make an appearance. You need to be comfortable working with matrices and in particular, some of the properties of square matrices in particular. Of these the most important are determinants, eigenvalues and eigenvectors. We will consider this here on 2×2 matrices but this is also true for higher dimensions as well (but the algebra is easier on 2×2).

The determinant of a matrix with entries

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix}$$

has determinant $ad - bc$.

To find eigenvalues of Matrix A look at the determinant of the new matrix $A - \lambda I$ where I is the identity matrix and the λ are the unknown values of the eigenvalues.

find the eigenvalues of

1.

$$\begin{pmatrix} 4 & 2 \\ 3 & 3 \end{pmatrix}$$

2.

$$\begin{pmatrix} \alpha & \frac{3}{2} \\ \alpha & 3 \end{pmatrix}$$

Eigenvectors are the vectors along the direction of the eigenvalue. There is some very attractive mathematics here which you can either read about or ask about. In summary, it may be useful to know that matrices by their nature have their own sort of "prefered directions", which we call eigenvectors. Understanding this will help you with other bits of necessary mathematics, such as principle component analysis in statistics, as it can look like black magic if you are not aware of the underlying properties of matrices.

Look for the vectors $\mathbf{v}$ s.t. $A.\mathbf{v} = \lambda_i \mathbf{v}$ for each λ_i you have found.

Find the eigenvalues and eigenvectors of

1.

$$\begin{pmatrix} 1 & 4 \\ 2 & 3 \end{pmatrix}$$