Inspiring use of maths in Biology

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Developing understanding through communicating the mathematical principles of biological research to school pupils – Snapdragons, Nanogeometry and Coding

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Project: Royal Society Summer Science Exhibition 2009 - Genetics of Snapdragons

John Innes Centre scientists and the BBSRC presented their research on snapdragons.

In association with
Mathematics Promotion unit.

Snapdragons

"Genes guide the formation of shapes and give the snapdragon flower its fascinating symmetry," Prof Coen.

The commonplace snapdragon flower helps scientists understand how complex biological shapes like hearts or flowers emerge.

In association with Mathematics Promotion unit.

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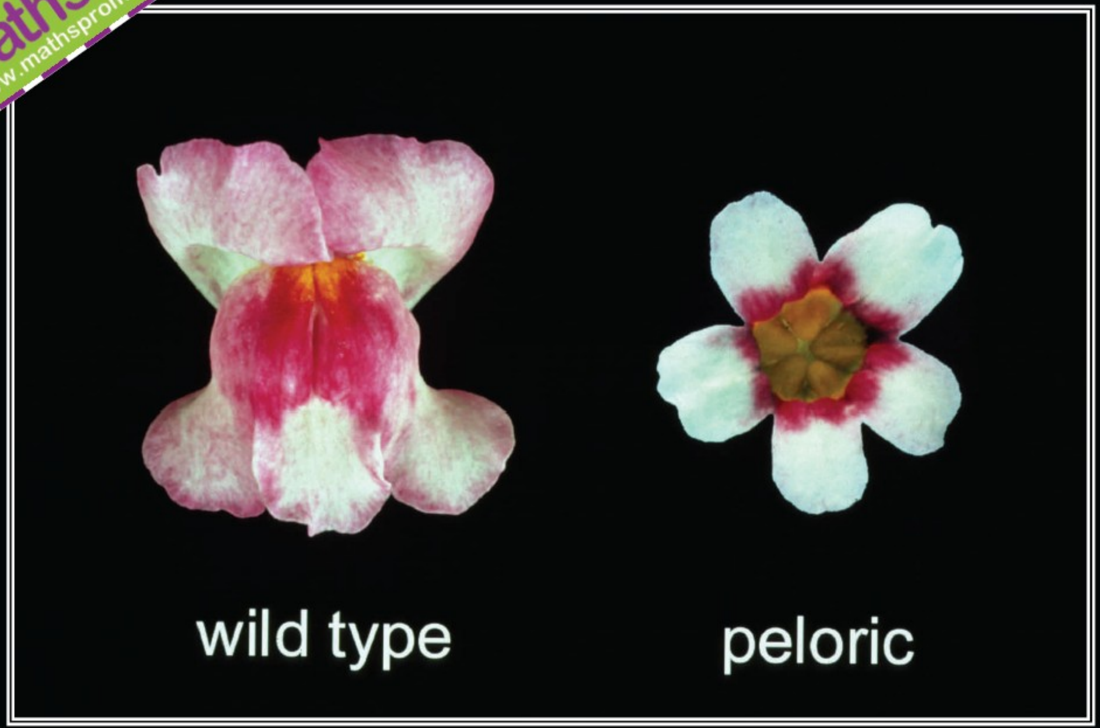

The Maths Inside project aim is to draw attention to the wealth of mathematical tools and concepts that scientists use in their research. The project is a way to bring out the mathematics powering the sciences: how simple mathematical concepts can power some quite sophisticated science and make research possible.

[The Mathematics Promotion unit is a collaboration between the London Mathematical Society and the Institute of Mathematics and its Applications]

Snapdragons

Background Science:

Cell and Developmental Biology department at the John Innes Centre

Prof Coen's lab work on Plant Development and Evolution

*"We wish to understand how diverse biological forms develop and evolve. A combination of molecular, genetic, imaging and modelling approaches are being used to understand how genes and growth interact to create specific shapes during development and how this is related to patterns of evolutionary diversity. We exploit **Antirrhinum (Snapdragons)** and Arabidopsis as model systems to study problems such as flower shape and asymmetry, leaf shape and plant architecture. Expertise includes genetics, transposon-tagging, in situ hybridisation, 3D imaging, image analysis and computer modelling of shape and growth."*

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Nanogeometry

2008 Royal Society exhibition

The Institute for Animal Health (IAH) collaborated with Rothamsted Research and the University of Cambridge on the topic:

"

Are epidemics inevitable? Disease prevention and control in changing landscapes

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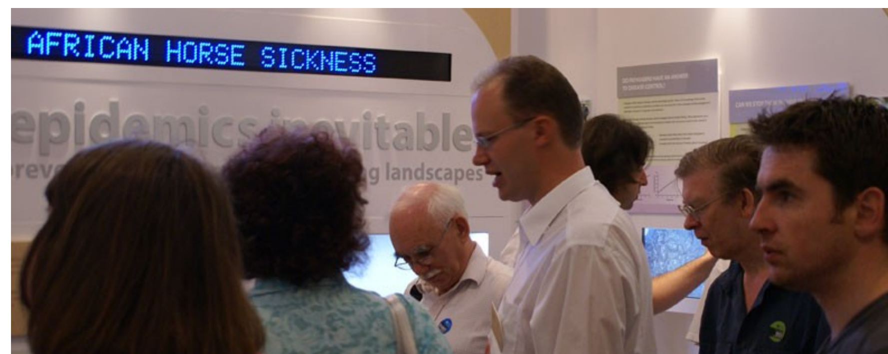

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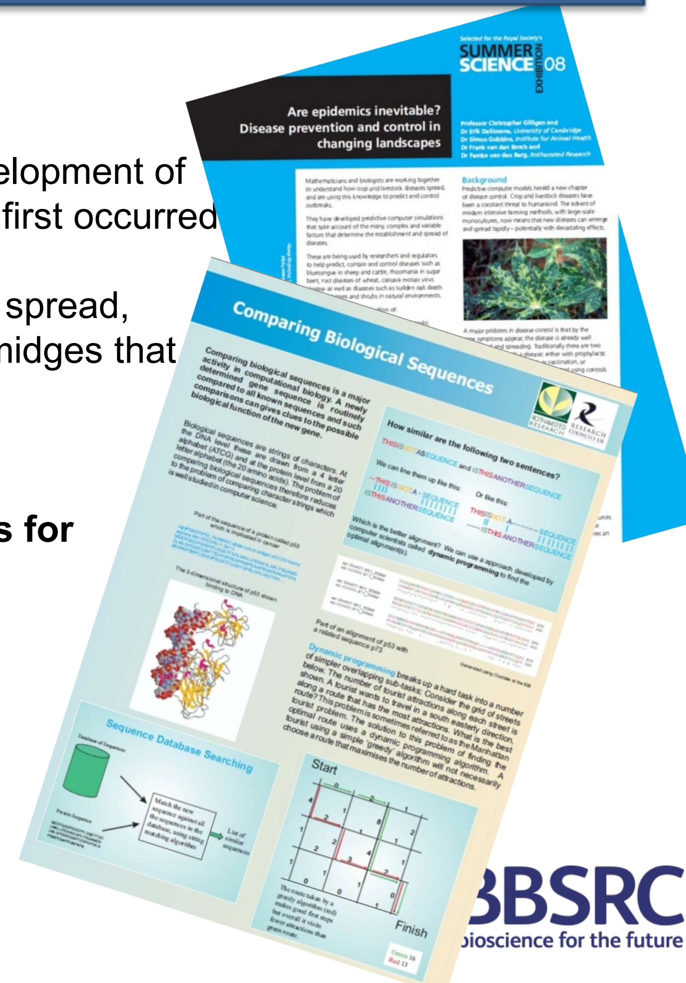
Nanogeometry

Background science:

Mathematical modelers, biologists (entomologists, virologists) and meteorologists in the IAH are working together to predict likely development of outbreaks of infectious diseases. These include bluetongue, which first occurred in the UK in 2007.

Mathematical models are used to predict disease occurrence and spread, taking into account such factors as weather, and biting rate of the midges that spread bluetongue virus.



Scientists at Rothamsted Research have developed workshops for A-level pupils on:

Computer Simulations in Biology

Comparing Biological Sequences

Nanogeometry

At the John Innes Centre Professor Dave Evans uses origami viruses to explain nanoscience

In March 2010 for the first time, scientists succeeded in growing empty particles derived from a plant virus and made them carry useful chemicals.

The external surface of these nano containers could be decorated with molecules that guide them to where they are needed in the body, before the chemical load is discharged to exert its effect on diseased cells. The containers are particles of the *Cowpea mosaic* virus, which is ideally suited for designing biomaterial at the nanoscale.

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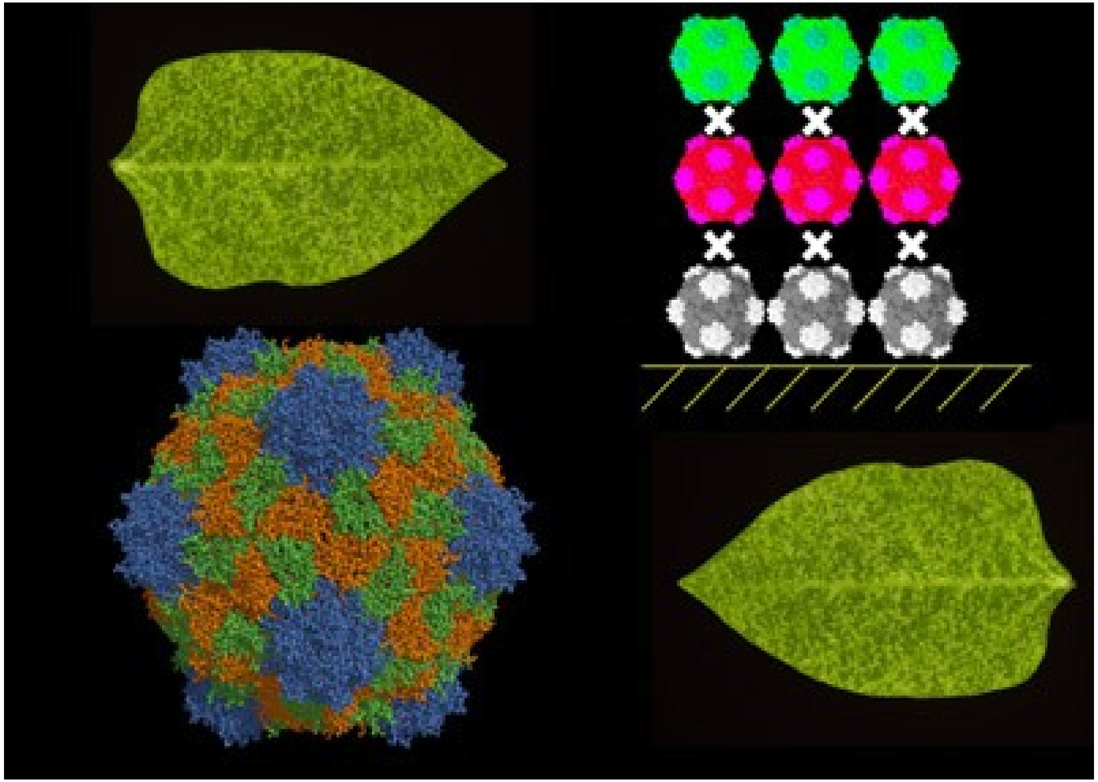
Nanogeometry



Prof Evans lab discovered they could assemble empty particles from precursors in plants, extract them and then insert chemicals of interest

They had previously managed to decorate the surface of virus particles with useful molecules.

Such particles have not been available before.

One application could be in cancer treatment. This would mean the particles seek out cancer cells to the exclusion of healthy cells. Once bound to the cancer cell, the virus particle would release an anti-cancer agent that has been carried as an internal cargo.

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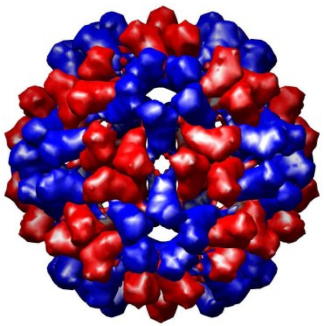
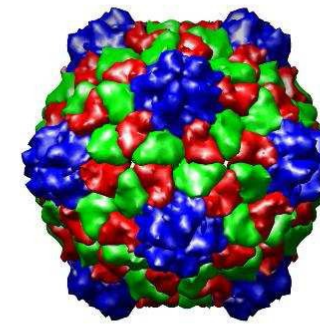
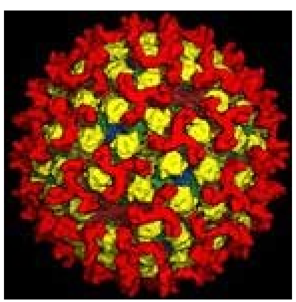
Nanogeometry



Cowpea mosaic virus (CPMV) particles are 28 nm in diameter.
It is a pentakis-dodecahedron (or truncated icosahedron) as is buckminsterfullerene $C*_{60}$(Ih), (a, b) = (1, 1), T = 3





Blue tongue virus (BTV) has 2-3 cores and 70nm diameter
It is a polyhedra – formed by addition of hexagons to a rhombicosidodecahedron with an icosahedron core of 120 subunits
(a, b) = (3, 1), T = 13 *laevo*
13 x 60 subunits organized into capsomers

The largest structure determined to atomic resolution!

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Geometry of the structure of Viruses, *Michel Deza, Ecole Normale, Superieure, Paris and JAIST, Ishikawa*

Nanogeometry

Use of origami in communicating nano science and viruses as well as flower shape and genetics is used by a number of researchers at IAH, JIC and TGAC.

- The Snapdragon Tale used origami to communicate the concept of developmental biology, geometry and folding of tissues.

- Scientists at the Institute for Animal Health have used origami virus models as part of their Royal Society Exhibition

- Professor Dave Evans of the John Innes Centre uses origami virus models to explain to gifted and talented secondary pupils about the development of nano-luggage from cow pea mosaic virus for delivery of therapeutics

- Scientists at The Genome Analysis Centre use DNA origami models to explain their work

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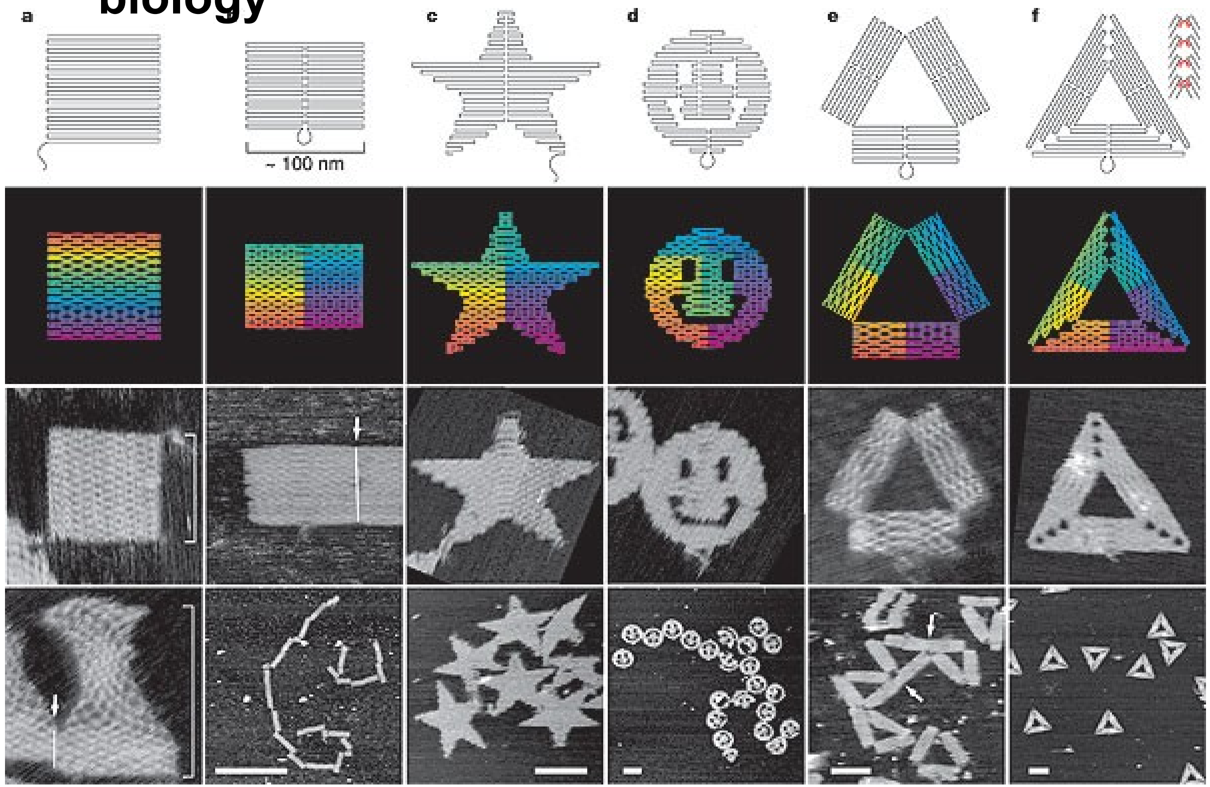
DNA origami and computational biology



Rothemund P. *et al*, Folding DNA to create nanoscale shapes and patterns Nature, **440**, 297-302, 2006.

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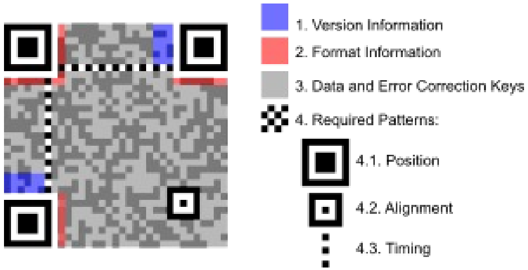
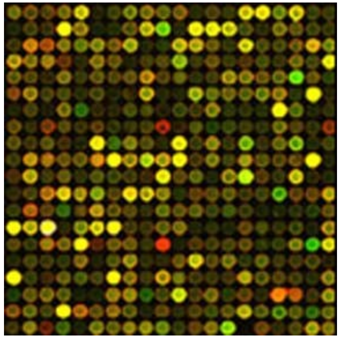
	DNA		QR codes		Microarrays	
Code	Nucleic Acids (ATCG)	Chemical code	Alphanumeric text	Binary coding	Red, Yellow, Green, Black	Chromatic coding
Encoded information	Protein structure	genes	Online content	Website links	cDNA/mRNA	Gene expression
Positioning	Relative positioning	Chromosome localisation	4.1	Position	Automated spotting	Robotic
Alignment	Sense/ antisense	Protein binding	4.2	Alignment	Software based	Computer controlled
Timing	S phase	Cell cycle	4.3	Timing	Flourescence emission time	Scan speed
Version	Thymine vs Uracil	DNA/RNA	1	Version	oligonucleotide	PCR products
Format	Introns/ exons	chromosome	2	Format	Flourescent labelled RNA/DNA	Glass slide
Error correction	Multiple codons for some amino	DNA repair enzymes	3	Data and error correction keys	Mathematical equalisation of intensities	Data centring
Code reader	es		phone	camera	microscope	ers or HD Digital

Coding





If you have been amused by my moustache during this presentation please feel free to log onto the Movember website http://uk.movember.com/ and donate money to help prevent prostate cancer.

MOVEMBER.COM

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Further reading

E. Coen, A.-G. Rolland-Lagan, M. Matthews, A. Bangham, P. Prusinkiewicz: (2004)The genetics of geometry. *Proceedings of the National Academy of Sciences* 101 (14), pp. 4728-4735.

Aljabali A. A. A., Sainsbury F., Lomonossoff G., Evans D. J. (2010) Cowpea mosaic virus unmodified empty viruslike particles can be loaded with metal and metal oxide. *Small* 6 818-821

M. Grimes *et al.*D.I. Stuart, The atomic structure of the bluetongue virus core. *Nature* **395** (1998), pp. 470–478.

Sanderson K. Bioengineering: What to make with DNA origami. *Nature.* 2010 Mar 11;**464(**7286):158-9.

7 Things You Should *Know About QR Codes* http://net.educause.edu/ir/library/pdf/ELI7046.pdf

Links and resources

3D Virus origami templates and lessons:
http://www.rcsb.org/pdb/education_discussion/educational_resources/virus-shape-structure.pdf

http://www.rcsb.org/pdb/education_discussion/educational_resources/life-cycle-dengue.pdf

http://www.rcsb.org/pdb/education_discussion/educational_resources/dengue_virus_3Dmodel.pdf

http://www.yourgenome.org/teachers/origami.shtml

http://www.bluetonguevirus.org/images/video/btv-assembly.avi/at_download/file

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