

Science Monstrosity II: Science of the Lambs

Jerry Vinokurov - editor packet 5

July 9, 2004

Tossups

1. When it occurs in one dimension with equal probabilities it is an example of a martingale. According to Polya's theorem, it will never return to the origin if it occurs in greater than two dimensions, and if it occurs on a lattice, the probability of reaching any point is one as time goes to infinity. The simple type is an example of a Markov chain, and in both one and two dimensions, the root mean square displacement after n iterations is proportional to the square root of n . The mathematical basis for such processes as diffusion and Brownian motion, FTP, identify this process in which every iteration consists of taking a step in some direction with some probability, often illustrated with a drunken sailor.

Answer: **random walk**

2. The most common calculation of this effect in hydrogen is expanded to three terms, and the third correction is known as the Darwin term. The eigenstates resulting from the addition of its second term can be found using the Clebsch-Gordan coefficients, and the second term vanishes for states of 0 orbital angular momentum. The first term of this effect is the result of relativistic corrections to the hydrogen atom and like the other two terms is proportional to the square of the charge times its namesake constant. FTP, identify this energy splitting in hydrogen which takes its name from its proportionality to a constant approximately equal to one over 137.

Answer: **fine structure**

3. Pronunciation note: pronounce NdYAG and GdYAG as "en-dee-yag" and "gee-dee-yag" The Lande equation for the gyromagnetic ratio works best for these elements. They are used in lasers, where such minerals as NdYAG and GdYAG replace rubies as lasing mediums. One member, samarium, can be combined with cobalt to form permanent magnets due to its high magnetic anisotropy, while another member, thorium, can be used together with lead in radioactive dating. All of them have electronic configurations that fill the 5s and 6p level and their principal ore is monazite. Comprising scandium, yttrium, lanthanum, and the 14 lanthanides that fill the 4f orbital, FTP, identify these metals, misleadingly named since cerium is the 25th most common element in the crust.

Answer: **rare earth(s)** metals

4. This term can be applied to glycine and aluminum hydroxide can exhibit this behavior depending on what kind of solution it is in. Surfactants of this type are used in shampoos and soaps because of their mildness to the skin and because their zwitterionic characteristics make them compatible with both anionic and cationic surfactants. Metals exhibiting this effect include lead, tin, and aluminum, and water is often incorrectly classified in this group even though it cannot donate and accept hydroxide ions, only protons. FTP, what is this name, given to compounds which behave as both an acid and a base?

Answer: **amphoteric**

5. The design of its RBMK had a positive void coefficient, which meant that in the absence of coolant power output would increase. The power increase due to steam voids combined with a farther-than-normal retraction of the rods contributed to a 30 gigawatt power spike. The retraction itself occurred when electrical power supplies failed, plunging power to 30 megawatts and causing a buildup of xenon-135. The bursting of the steam vessel then blew the top off the reactor, sparking a graphite fire. Discovered only after Swedish workers discovered radioactive particles on their clothes, FTP, identify this most famous nuclear accident which occurred near its namesake Ukrainian city in 1986.

Answer: Chernobyl accident (the writer of this question was 4 years old and living only a couple hundred kilometers from the event when it occurred)

6. One of its practical applications is the mass flow meter, which can be used with non-Newtonian fluids. An analog of this effect is present in molecules and can lead to mixing between the rotational and the vibrational energy states. It causes geostrophic wind, in which all effects other than this one and the pressure gradient force are ignored and in stellar dynamics it affects the rotational direction of sunspots. Failure to account for it can result in inaccurate artillery fire, and in the northern hemisphere, it will cause a falling object to land east of where it would land without this effect. Responsible for the rotational direction of cyclones, FTP, what is this non-inertial force proportional to the cross product of the velocity and the frequency of rotation of the coordinate system.

Answer: Coriolis force or effect

7. In mammals, the suprachiasmatic nuclei located here allow it to function as a biological clock. It also receives input from the circumventricular organs, which monitor substances in the blood, and leptin, a hormone that increases metabolism, is believed to act on it. Besides the input it receives from these sensors and the limbic system, this area of the brain also possesses thermoreceptors and osmoreceptors, allowing it to maintain ionic balance and keep the body at a constant temperature. Operating by sending neural signals to the autonomic nervous system and endocrine signals to the pituitary, FTP, identify this region of the brain, so named because it lies beneath another brain area.

Answer: hypothalamus

8. A template algorithm bearing this name enables the use of non-numerical weights, and its adaptive type calculates frequencies dynamically and is related to the LZ family. It is most efficient if the probability of occurrence of each input symbol is a power of two and it works by combining the trees for each symbol until one complete tree has been constructed containing all the symbols. It is the most efficient method of compression that results in a prefix-free code, and it improves on Shannon-Fano coding by building the tree from the bottom up instead of from the top down. Developed by its namesake while a Ph.D. student under Robert Fano, FTP, identify this entropy encoding algorithm.

Answer: Huffman coding

9. The destruction of the anchor cell in it leads to the failure of the vulva to develop and the precursor cells are absorbed into the epidermis. Throughout the course of its development, apoptosis occurs in it exactly 131 times and it possesses both a male and a hermaphroditic sex, which lays the eggs after being inseminated by the male. Specimens of this organism survived the explosion of the Columbia shuttle, and it is attractive to researchers because it is multicellular, eukaryotic, and possesses a nervous system. Often used as a model organism, FTP, identify this small nematode, the first organism to have its genome completely sequenced.

Answer: Caenorhabditis elegans

10. These cosmic objects generally have a mass several times that of the sun, and their distinctive features result from their location in the instability strip on the Hertzsprung-Russell diagram. Stars with a

lower mass than the sun that fall into this category are called W Virginis. Their distinguishing feature is caused by the opacity of ionized helium, which then holds in radiation, causing the star to expand. As the star expands, it cools, becomes less luminous, and the helium ions recombine with free electrons, increasing luminosity. The source of calibration for the standard candle, FTP, identify this class of variable stars, named after the delta star of the King constellation.

Answer: Cepheid variables

11. In control theory, a system is said to possess one of these if any eigenvalues of the state matrix have real parts greater than zero. A two-stream one may develop when a particle beam has a velocity distribution that peaks far away from the peak of the distribution of the medium through which the beam is passing. The sausage type arises during attempts to pinch a plasma, and the Rayleigh Taylor type is the exponential growth of waves in a heavy fluid supported by a light one. All these phenomena are types of, FTP, what general behavior, characterized by boundless growth of perturbations within a system?

Answer: instability

12. Herman Weyl first developed this technique in his attempts to unify relativity and electromagnetism. The first theory to make use of it in its general form addressed the effect of an electromagnetic field on a charged particle. For a principal bundle whose base space is spacetime and structure group is a Lie group, the space of smooth sections of this bundle form a group of these, and in Yang-Mills theory, the Wilson loop is invariable under them. Taking its name from acting on a degree of freedom whose change does not influence physical observable, FTP, identify this operation, whose best-known application is in picking the divergence of the vector potential.

Answer: gauge transformation (prompt on "gauge")

13. Ernst Mayr proposed one of the mechanisms by which this process takes place, and in angiosperms, this process often takes place through hybridization and is accompanied by polyploidy. It can also occur, as in the case of Darwin's finches, by means of adaptive radiation, and in the case of the yellowthroat, geographic separation brings about this event. Another version of it was found to occur in turtles in British Columbia, where several evolutionary branches spawned from one ancestor in one location. Existing in allopatric, sympatric, and parapatric forms, FTP, identify this process by which the most specific evolutionary branches divide until they are no longer able to reproduce with each other.

Answer: speciation

14. The first system to use it was the CDC 6600 supercomputer designed in 1964 by Seymour Cray. One example illustrating the inefficiency of its counterpart was VAX's index routine, which ran slower than a loop designed to do the same thing. Because this design has fewer transistors dedicated to the core logic, it allows for such additional features as larger caches and an increased register set. The MIPS design is one example of this architecture, and the only surviving desktop example of it is the PowerPC. Based on the philosophy of fewer, shorter commands, FTP, identify this computer architecture, the opposite of a complex instruction set computer.

Answer: Reduced Instruction Set Computer or RISC

15. One type of this material is called an ionomer, which are copolymers in which a small number of the repeat units have attached ionic pendant groups. Another type of this material is a block copolymer, such as SBS rubber in which polybutadiene links are joined together by polystyrene clusters. More famous compounds that fit this description are PVC and polyethylene, and polypropylene can be made one by interspersing blocks of varying tacticity. All of them exhibit their unique properties when heated, as they undergo a de-linkage but do not change their chemical structure. FTP, identify this group of compounds comprising plastics that can be melted down and recast.

Answer: thermoplastics

16. The study of these objects in the 1930s led to a precise determination of the sun's position in the Milky Way. M87 is believed to contain as many as 15 thousand of them, and exotic star types such as blue stragglers and millisecond pulsars are more common in them. Structurally, these objects are similar to the bugles in spiral galaxies, but are confined to only a few parsecs. They typically contain relatively large numbers of RR Lyrae stars, and their HR diagrams typically have short main sequences and prominent horizontal branches, indicating very old stars. FTP, what are these dense collections of stars held together by gravity?

Answer: globular clusters

17. Sulfonation is the only reversible substitution reaction acting on this class of compounds. In these hydrocarbons, the carbon atoms have sp² hybridization and a planar structure, while the carbon-hydrogen ratio is very small. The simplest polycyclic one is pentalene, while naphthalene and phenol also belong in this category. According to Huckle's rule, if the number of delocalized electrons is equal to 4n plus two, where n is a nonnegative integer, a compound is said to be this. Undergoing electrophilic rather than nucleophilic substitution reactions, FTP, identify these opposites of aliphatic compounds which contain their namesake carbon rings and whose name suggests olfactory pleasantness.

Answer: aromatic compounds

18. Evidence from the geologic record suggests that this phenomenon can take as little as 100 years, and it was first detected by analyzing lava flows from the Massif Central. Brad Clement of Florida International University has used the sedimentary record to calculate an average figure of 7,000 years for this to occur, though he believes it happens with different frequency at low and high altitudes. It last occurred roughly 780,000 years ago, when it was termed the Brunhes-Matuyama event, and the evidence for it is provided by magnetic domains frozen in ancient rock. Viewing earth as a giant magnet, FTP, identify this event, during which the magnet is flipped 180 degrees.

Answer: reversal of Earth's magnetic field (accept logical equivalents)

19. In the first Brillouin zone, their allowed frequencies have an optical and an acoustical branch, and one way of determining their dispersion relation is through inelastic neutron scattering. They behave as though they have a momentum equal to h-bar times their wavenumber, but actually don't carry any momentum at all. The application of Planck statistics to them allows the derivation of the Debye model of heat capacity, and effects involving three of these, such as the umklapp process, result from third-order anisotropies in the lattice geometry. FTP, identify these particles which represent the quantization of elastic waves in solids.

Answer: phonons

20. The beginning of this process involves the degradation of the extra-cellular matrix, and when it occurs in the mouth, it generally spreads to the lymph nodes. The complexity of this process has recently led scientists to speculate that it occurs through the hijacking of existing cellular processes, such as activating the Twist protein in mice that allows breast cells to separate from each other and travel to other areas of the body. In some cases of melanoma, no primary tumor is found even on autopsy, despite the occurrence of this process. Proceeding by the limbic and blood circulatory systems, FTP, what is this process by which cancerous cells spread to other areas of the body?

Answer: metastasis

Bonuses

1. Answer some questions about primitive organisms FTPE.

[10 points] Rhizopods, actinopods, and foraminiferans all move and feed by means of this cellular extension.

Answer: **pseudopodia**

[10 points] Divided into plasmodial and cellular varieties, these organisms resemble fungi in appearance but are closer to amoeboid protists with regards to cellular organization and reproduction.

Answer: **slime molds**

[10 points] These creatures have glasslike walls consisting of hydrated silica and divided into two halves. They reproduce asexually by mitotic division with each offspring receiving half of the original's cell wall.

Answer: **diatoms**

2. Answer some questions about fluid mechanics, FTPE.

[10 points] This is the term for fluids in which the curl of the velocity field is zero.

Answer: **irrotational**

[10 points] The presence of rotational effects in fluids limit the application of this equation to movement along streamlines. It relates the pressure to the square of the velocity along a streamline.

Answer: **Bernoulli** equation

[10 points] For an inviscid flow in which all shear stresses are zero, the fluid obeys this set of nonlinear differential equations, which, though simpler than the Navier-Stokes equations are still not solvable exactly.

Answer: **Euler**'s equations of motion

3. Identify these scientists whose work advanced the development of fusion bombs, FTPE.

[10 points] Edward Teller once famously said that he himself deserved 101 percent of the credit, and this Polish mathematician deserved negative one percent. Some of this man's contributions were the Monte-Carlo simulations that showed the viability of the bomb.

Answer: Stanislaw **Ulam**

[10 points] Together with Igor Tamm, this man is generally regarded as the father of the Soviet hydrogen bomb. Later in life he would become a dissident and be placed under house arrest.

Answer: Andrei **Sakharov**

[10 points] Although this German-born scientist claimed that the lack of the hydrogen bomb will not lose the war for America, he nevertheless worked on the project with Teller, all the while advocating peaceful uses of nuclear energy.

Answer: Hans Albrecht **Bethe**

4. Answer some questions about quantum mechanical approximations, FTPE.

[10 points] This approximation is sometimes called the semi-classical approximation and can be applied when the potential is a slowly varying function of position. It is named after its three developers.

Answer: **Wentzel-Kramers-Brillouin** (or **WKB**) approximation

[10 points] This method approximates the eigenenergies of the Hamiltonian by picking trial wavefunctions, changing parameters, and computing the associated energies.

Answer: **variational** method (or **Rayleigh-Ritz** method)

[10 points] For a Hamiltonian that varies very slowly with time, this approximation can be used to expand the wave function in time and calculate the instantaneous energy levels.

Answer: **adiabatic** approximation

5. Answer some questions about the best planet ever, the bringer of jollity, FTSNOPE.

[5 points] This Jovian moon has the highest volcanic activity of any body in the solar system. Voyager I saw 8 volcanic eruptions there during its observation.

Answer: **Io**

[10 points] Jupiter is the only solar-system object besides the sun and Saturn to exhibit this phenomenon, in which different parts of a spinning object move at different angular velocities.

Answer: differential rotation

[5 points] This is Jupiter's most prominent weather feature. It is a storm roughly twice the size of Earth, and it is about half the size today that it was 100 years ago.

Answer: Great Red Spot

[10 points] Io, Europa, and Ganymede exhibit this phenomenon, in which for every four orbits that Io makes around Jupiter, Europa makes two and Ganymede makes one.

Answer: Laplace resonance (or orbital resonance, which is a more general form)

6. Stuff about asteroids, FTPE.

[10 points] The first asteroid to be discovered, it is also the largest in the asteroid belt between Mars and Jupiter.

Answer: Ceres

[10 points] Asteroids larger than Ceres, such as Ixion and Quaoar, have been discovered in this asteroid field which extends from about 30 AU from the sun to about 50 AU.

Answer: Kuiper Belt (or Edgeworth Belt or Edgeworth-Kuiper belt)

[10 points] In the classification scheme devised by Clark Chapman, David Morrison, and Ben Zellner, asteroids are classified according to color, spectral shape, and this property, a measure of a body's reflectivity.

Answer: albedo

7. Chemical bonding, FTPE.

[10 points] This is a non-polar bond in which electrons are delocalized and are shared among the entire lattice.

Answer: metallic bond

[10 points] This term is used to describe molecular orbitals that arise as the result of destructive interference of atomic orbitals. These orbitals have energies higher than the energies the separate atomic orbitals would have if separated.

Answer: antibonding orbitals

[10 points] In valence bond theory, this is a type of bond that is symmetrical around a line between the bonded atoms. Most single bonds fall into this category.

Answer: sigma bond

8. Identify these things from number theory, FTPE.

[10 points] Richard Arenstorf has recently published a preprint which purports to prove that there is an infinite number of pairs of these non-composite numbers, in which the second is two greater than the first.

Answer: twin primes

[10 points] Named after the mathematician who proved the first case of Fermat's last theorem for them, these are pairs of numbers such that both p and $2p + 1$ are prime.

Answer: Sophie Germain primes

[10 points] This theorem states that if the Tanayama-Shimura conjecture holds for all semistable elliptic curves, then Fermat's last theorem is true. It was known as the epsilon conjecture before it was proved by the Berkeley professor for whom it's now named.

Answer: Ribet's Theorem

9. Identify these things related to DNA, FTPE.

[10 points] These are pieces of DNA that can move from one location to another in the genome. They are sometimes referred to as jumping genes.

Answer: transposons

[10 points] These are the simplest kinds of transposons, consisting only of the DNA necessary for the transposition. The only gene found in these transposons codes for a transposase and is bracketed by inverted repeats.

Answer: **insertion** sequences

[10 points] This is the term for more complicated transposons. They contain genes sandwiched between insertion sequences and contain an inverted repeat and a directed repeat at each end.

Answer: **composite** or **complex** transposons

10. Answer some questions about the human immune system FTSSNOPE.

[5 points each] These are the two different types of lymphocytes that exist in vertebrates.

Answer: **B and T** lymphocytes

[10 points] Cells are marked as belonging to the body if they possess surface glycoproteins encoded by this family of genes, which is divided into class I and class II.

Answer: **major histocompatibility complex** or **MHC**

[10 points] This type of T-cell possesses receptors that bind to class II MHC molecules.

Answer: **helper** T-cells

11. Identify these things from organic chemistry, FTPE.

[10 points] The first organic compound to be artificially synthesized, Friedrich Woehler created this compound by reacting potassium cyanate with ammonium sulfate.

Answer: **urea**

[10 points] Urea belongs to this general class of organic compounds which result from acids in which a carbon is double bonded to an oxygen and a hydroxyl group when the hydroxyl group is replaced by an amine.

Answer: **amide**

[10 points] This amide with chemical formula $C_8H_9NO_2$ is an analgesic and antipyretic drug and is the main ingredient in Tylenol.

Answer: **acetaminophen** (or paracetamol if you're British)

12. Answer some questions regarding the theory of magnetism, FTPE.

[10 points] Based on the precession of a charged particle in a magnetic field, this diamagnetism formula is a classical calculation of the susceptibility.

Answer: **Langevin** formula

[10 points] In this approximation used in theories of ferromagnetism, each magnetic domain is considered to experience an average B proportional to magnetization.

Answer: **mean field** approximation

[10 points] Below this temperature, the spins of an antiferromagnet are oriented with zero net moment; above it, the material becomes paramagnetic.

Answer: **Neel** point or temperature

13. Answer some questions about parallel computing, FTPE.

[10 points] Invented by Donald Becker and Thomas Sterling, this is a paradigm of parallel computing between massively parallel processors and networks of workstation. It takes its name from an Old English poem.

Answer: **Beowulf**

[10 points] The idea behind Beowulf is to build a computing cluster from relatively cheap storebought workstations. What is the name given to this approach?

Answer: **commodity off the shelf** or **COTS**

[10 points] Back when a processor was too fast for a single Ethernet and switches were expensive, Becker rewrote drivers to support this method, in which data is striped across multiple network cards in each cluster node.

Answer: **channel bonding**

14. Answer some questions about metabolic chemistry FTPE.

[10 points] During starvation, the beta-oxidation of fatty acids by muscle halts the conversion of pyruvate into this.

Answer: **acetyl Coenzyme A** or **acetyl CoA**

[10 points] Prolonged periods of starvation lead to this condition, in which ketone bodies become the brain's major fuel source.

Answer: **ketosis**

[5 points each] These similarly named catecholamine hormones are secreted by the adrenal medulla in response to a low blood glucose level. They stimulate the mobilization of glycogen by triggering the cyclic-AMP-mediated cascade.

Answer: **epinephrine and norepinephrine**

15. Identify some things related to phase transitions, FTPE.

[5 points] This is the point in systems involving liquid and gas phases at which the transition between liquid and solid becomes a second-order transition. The gas phase does not exist above this point.

Answer: **critical point**

[10 points] In the Ehrenfest classification scheme, second-order phase transitions are those which have a discontinuity in the second derivative of this quantity.

Answer: **free energy**

[5 points] This model of nearest-neighbor interactions exhibits no non-trivial phase transitions in one dimension.

Answer: **Ising model**

[10 points] For a critical exponent between minus 1 and 0, the heat capacity at the transition point from the normal to the superfluid state has a kink, leading to it being called this for its resemblance to a Greek letter.

Answer: **lambda** point

16. Come August, the writer of this question is going to Peru, which means he has to be immunized against various nasty diseases. Identify them, FTPE.

[10 points] A mosquito-borne viral disease caused by a zoonotic virus, symptoms of this infection range from flu-like to severe hepatitis and hemorrhagic fever. What fun!

Answer: **yellow fever**

[10 points] Caused by parasites of the *plasmodium* genus, including *falciparum*, *vivax*, and *ovale*, this mosquito-borne disease has an incubation period of about 8 days, during which time the parasites infect the liver, destroying blood cells.

Answer: **malaria**

[10 points] Another fun parasite to catch, this one is a relative of the African variety, which is better known as sleeping sickness.

Answer: **American trypanosomiasis** or **Chagas' disease**

17. Answer some questions about a geological concept, FTPE.

[10 points] This eponymous diagram, consisting of a continuous and a discontinuous branch, shows which minerals are most likely to be formed at a given temperature.

Answer: **Bowen's Reaction Series**

[10 points] The continuous branch describes the evolution of this type of feldspars as they move from being calcium-rich to bein sodium-rich.

Answer: **plagioclase** feldspars

[10 points] This dark-green mineral is located on the discontinuous branch right before the continuous and

discontinuous branches meet, and forms at around 1000 degrees Celsius.

Answer: **biotite mica**

18. Identify these types of transistors FTPE.

[10 points] This first working transistor was built by Walter Brattain and consisted of a gold foil around a plastic tip that hovered on a spring a paper's thickness away from a germanium plate.

Answer: **point-contact** transistor

[10 points] The type of transistor that made Brattain, John Bardeen, and Walter Shockley famous was this type, consisting of two diode junctions and existing in either PNP or NPN flavors.

Answer: **bipolar junction** transistor

[10 points] Consisting of three PN junctions, this device functions like a transistor but remains on once it has been turned on. The only way to turn it off is to cut power to the gate.

Answer: **thyristor**

19. Reaction and equilibrium chemistry, FTSNOPE.

[5 points] This principle states that if a reaction in dynamic equilibrium is disturbed, the concentrations of products and reactants will shift to counteract the change.

Answer: **Le Chatelier's** principle

[10 points] Le Chatelier's principle is exploited in this process, in which atmospheric nitrogen and hydrogen are reacted to produce ammonia.

Answer: **Haber** process

[15 points] The energy form of the Euler equation it states that SdT minus Vdp plus $nd-\mu$ equals 0. One of its namesakes' phase rule may be derived from it.

Answer: **Gibbs-Duhem** equation

20. Identify these expensive scientific installations worldwide, FTPE.

[10 points] With branches in Hanford, Washington, and Livingston, Louisiana, this installation run by Cal-Tech and MIT is searching for gravitational waves.

Answer: **Laser Interferometry Gravitational Wave Observatory** or **LIGO**

[10 points] Located at Culham in England, this fusion installation has operated under combined European directorship until its overtaking by the European Fusion Development Agreement.

Answer: **Joint European Torus** or **JET**

[10 points] So named for the energies to which it is able to accelerate particles, this Fermilab accelerator is currently the most powerful in the world.

Answer: **Tevatron**