

## Lederberg 3: Trinity

My co-first authors are Dunning and Kruger.

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1. Eckart et al discovered highly polarized flares with a period of about 20 minutes from this object that disproved hypotheses that they could be caused by boson or fermion balls. Andrea Ghez's career has been dedicated to the study of this object, around which she discovered an associated object named S0-102. The HESS array collaboration published the alphabetical Aharonian et al paper showing that gamma rays from this object had a power law spectrum with index negative 2.2, which substantially differed from the CANGAROO collaboration measurements. By definition this object is located at (\*) coordinates  $b = 0$  and  $l = 0$ . A press conference on April 10th is expected to announce that V·L·B·I conducted by the E·H·T has created an image of this object, the first of its kind to be imaged. This object was first observed as an excess in radio by Karl Jansky when pointing at the galactic plane. For 10 points, name this supermassive black hole at the center of our galaxy, named for the zodiac constellation in which it is visible, the archer.

ANSWER: Sagittarius A\* [pronounced 'A - Star'; also accept Sgr A\*; prompt on Supermassive black holes; prompt on "the black hole at the center of the Milky Way" or similar descriptions]

<Astronomy, James Lasker>

2. Hein and Mackay observed that the sub-epithelial region of the lymphoid tissue of these organisms are rich in gamma/delta T cells, which comprise somewhere between 15-60% of total lymphocytes in them. Because these organisms have a low M·R/G·C ratio, they rely on the production of V·F·As for energy. These organisms can suffer from Johne's disease, in which their Peyer's ("PIE-urz") patches are infected with M·A·C. Selenomonas ("sell-uh-MOAN-us") bacteria are found in the gut of these organisms and allow these organisms to break down inositol ("in-OSS-it-all") hexa-phosphate with (\*) phytases ("FIGHT-aces"). These organisms contain an organ with compartments called the reticulum, the omasum ("oh-MAY-sum") and the abomasum ("AH-bo-may-sum"). These organisms, which perform foregut fermentation, contain flora in the hindgut which allow them to break down cellulose. For 10 points, name these organisms with four-compartment stomachs.

ANSWER: ruminants [or Ruminantia, prompt on herbivores, prompt on mammals or Mammalia, prompt on farm animals, anti-prompt on specific ruminants like ungulates, Ungulata, cattle, cows, bovines, deer, sheep]

<Biology, Geoffrey Chen>

3. The amount of computation needed for these quantities is cut in half when re-expressing them in terms of modified star integrals; that is the Ree-Hoover resummation. When considering particles in a Tonks gas, these quantities are expressed as the principal Lambert W function. Supplementing a hard sphere potential with a square well makes one of these quantities temperature dependent, while for an unmodified hard sphere potential that one of these quantities is athermal and simply equals "four times the particle volume." These quantities are interpreted as sums over weighted 2-connected graphs when expressed in terms of (\*) Mayer f-functions. Attractive and repulsive forces in non-ideal gases balance out when the second of these coefficients is zero, which occurs at the Boyle temperature. For 10 points, name these quantities that multiply powers of molar density in an expansion of the compressibility factor.

ANSWER: virial coefficients [accept things like coefficients in the virial expansion, accept more specific answers like second virial coefficient]

<Physics, Jonathen Settle>

4. A mixture of salts called Tacsimate (“TACK-suh-mate”) is used for this task, which can also use M·P·D and 2-propanol. Pi sampling, grid screens and sparse-matrix screens are used to find optimum conditions for this task. One method of doing this task involves sealing a siliconized coverslip with an adherent drop of water over a clear poly-styrene well containing reservoir solution. It’s not dialysis, but Cambridge buttons are used in the microdialysis method of performing this task. A 1-1 mixture of paraffin oil and silicon oil is used in a microbatch-under-oil method for performing this task, which is also done via (\*) hanging drop vapor diffusion. Spontaneous resolution separates enantiomers using this process. Impurities are removed using a hot solvent, then subsequent slow cooling, in a procedure called “re-” *this*. This process, which requires a seed for nucleation, is used to prepare proteins for X-ray diffraction. For 10 points, name this process of creating an ordered solid.

ANSWER: crystallization [accept fractional crystallization, accept recrystallization; accept any answer related to making crystals; prompt on precipitation]

<Chemistry, Eric Mukherjee>

5. A version of this algorithm that minimizes error named for Dormand and Prince is used by default in MATLAB (“MATT-lab”). The stability function of this algorithm is the ratio of two polynomials, and for explicit versions of this algorithm the denominator is a constant; therefore, explicit variations of this algorithm are not A-stable and cannot be applied to “stiff” inputs. Interweaving two orders of this algorithm allows computation of the truncation error in a single step, which is used to adjust the step size in its adaptive variant. Variants of this method have coefficients listed in a Butcher tableau, and this method’s first step is identical to the (\*) Euler method. In this method, the local truncation error goes as the step size to the power of order plus 1. This algorithm’s fourth-order variant is the most popular, and requires calculating coefficients  $k_{sub\ 1}$  to  $k_{sub\ 4}$  in order to calculate  $y_{sub\ n\ minus\ 1}$ . For 10 points, name this numerical method of solving ODEs, named for two Germans.

ANSWER: Runge-Kutta method [anti-prompt on Euler method before mention]

<Data Science/Stats/Applied Math, Eric Mukherjee>

6. A major success of I·A·D·I models of this substance was a 2003 analysis of the Edwards-Trinity system. Conductivity equations which govern the movement of this substance are solved using finite-difference methods by the MODFLOW program; other methods reduce those equations to two dimensions via the Dupuit-Forchheimer (“doo-PWEE FORK-hai-mur”) assumption. One method of modelling its transport uses a polynomial with negative one times the Euler-Mascheroni constant as the constant term to calculate the drawdown; that method is the transient (\*) Theis solution. A book on modeling this substance by Anderson and Woessner includes guidelines for dealing with areal recharge. It is found at atmospheric pressure in the phreatic zone. Like petroleum, the movement of this substance is often described using Darcy’s law, which models how it infiltrates systems such as the Ogallala. For 10 points, give this substance which is found in aquifers.

ANSWER: groundwater [accept answers that indicate water which is underground; prompt on water or H2O or dihydrogen monoxide by asking “where is the water?”]

<Earth Science, Will Alston>

7. This operation can be conducted via the component design technique using gadgets. The jump operator moves between equivalence classes defined by this operation; those equivalence classes are also called degrees. One type of this operation is equivalent to a function computable by an oracle machine for the result. This operation is symbolized using a less-than-or-equals sign with a subscript. Applying one version of this technique to a problem usually expressed using propositional logic is used to prove the (\*) Cook-Levin theorem. Karp applied that theorem to his list of 21 problems by repeatedly using this technique, which is often applied to the halting problem to prove that a decision problem is undecidable. For 10 points, name this technique that, if it can be performed in polynomial time on a problem in  $N \cdot P$  to another  $N \cdot P$ -hard problem  $m$ , shows that  $m$  is  $N \cdot P$ -complete.

ANSWER: reduction [accept more specific answers like Turing reduction or truth table reduction or many-one reduction or parsimonious reduction or Karp reduction or polynomial reduction]

<Computer Science, Steven Silverman>

8. A common example of these systems forms a c-4-by-2 superlattice. Cyclic voltammetry is applied to binary examples of these systems with ferrocene (“FAIR-uh-seen”)-terminated substituents to determine their heterogeneity. A form of these created using mesoporous ceramic oxides can be used to sequester mercury, lanthanides, or actinides. Kumar and Whitesides used a P·D·M·S stamp, followed by selective etching, to create these systems in the first application of microcontact printing. One example of these systems begins with constituents in a “flat” orientation, which then changes to a (\*) thirty-degree orientation with increasing occupancy. N-alkane·thiols on gold-111 and porphyrins on graphite are common examples of these systems, which are created when molecules with a functionalized tail group use their head groups to adsorb to a solid support. For 10 points, name these spontaneously-forming one-molecule thick sheets that are used in nanotechnology applications.

ANSWER: **SAM** [or **self-assembled monolayer**; prompt on monolayer; accept word forms of “assembled” in place of “assembled”]

<Chemistry, Eric Mukherjee>

9. Solutions to this equation on a boundary can be reconstructed within the boundary using Poincare’s (“pwan-cuh-RAYZ”) balayage (“bah-lee-YAZH”) method. The limit of monotone sequences of solutions to this equation is either finite or infinite at every point in a domain according to Harnack’s inequality. If a potential satisfies this equation, then the energy becomes minimal according to Thomson’s theorem, which forms the basis of some finite element methods. The value of a solution to this equation at the center of a sphere is equal to the mean of that solution on the surface of the sphere. A potential which satisfies this equation on the boundary of a region R uniquely determines that potential throughout R if the (\*) charge density is zero. Earnshaw’s theorem results from the fact that all stationary points of a scalar field that satisfies this equation must be saddle points. Harmonic functions satisfy this equation, which is a special case of Poisson’s equation without a source term. For 10 points, name this equation which sets del-squared of a function equal to zero.

ANSWER: **Laplace**’s equation [prompt on Poisson equation before “Poisson”, prompt on Helmholtz equation]

<Physics, Will Alston>

10. In yeast, this process is finished by a Mus·81·M·m·s·4 hetero·dimer. Factories for this process can be identified by staining for D·m·c·1. The search phase of this process may occur through inter·segmental contact sampling, followed by kinetic discrimination. Chi sites have increased frequency of this process. One model of this process has stages of invasion, branch migration, and resolution, which can produce either “splice” or “patch” products. R·u·v·A·B·C mediates the final stages of this process. In yeast, the protein H·O catalyzes an instance of this process at the M·A·T locus to switch (\*) mating types. In another setting, a complex containing S·p·o·11, M·r·e·11, and R·a·d·50 mediates this process, which usually occurs through a four-armed intermediate called a Holliday junction. The synaptonemal (“sin-AP-toe-NEE-mul”) complex mediates this process during prophase I, where it forms chiasmata (“ki-az-MAH-tuh”). For 10 points, name this process which swaps D·N·A between chromosomes.

ANSWER: **homologous recombination** [or **crossing over** or **meiotic crossover**; prompt on recombination, DNA repair, double-strand break repair, double-strand break formation, or DSB formation, or DSB repair]

<Biology, Akshay Govindan>

11. Joseph H. Silverman used this statement to prove that there are infinitely many primes that do not satisfy the Wieferich (“VEE-fer-ich”) criterion. Noam Elkies applied the Riemann-Hurwitz formula and Belyi’s theorem to show that an effective form of this result implies Mordell’s conjecture. This statement is equivalent to the Szpiro (“SPEAR-oh”) conjecture for elliptic curves. Originally formulated concurrently by Oesterlé (“oy-STER-lee”) and Masser, this conjecture gives a simple proof of (\*) Fermat’s last theorem that hinges on the fact that z to the quantity six minus k is not greater than one for any integer k larger than 5. The equivalent of this statement for polynomials is the Mason-Stothers theorem. RIMS controversially published a series of exceedingly opaque papers purporting to prove this result by Shinichi Mochizuki using his Inter-universal Teichmüller theory. For 10 points, what conjecture bounds the number of distinct prime factors of the product of three coprime numbers?

ANSWER: **abc** conjecture

<Math, Jonathen Settle>

12. **H·T·A-1 is an unusually temperature-stable one of these compounds that contains a meth·ani·minium core. One family of these compounds contains N-spiro-bi-naphthyl moieties and was developed by Marouka for alkylation of amino acids. Brandstrom and Montanari name a modification of a mechanism that governs these compounds that requires the formation of a mobile ion pair; that extractive mechanism is named for Starks. Makosza's ("muh-CO-shuz") interfacial mechanism can govern these compounds. Shiori et al developed a (\*) cinchona ("sin-CO-nuh") alkaloid derivative used as one of these compounds for use with the Darzens' reaction. The reaction between sodium cyanide and 1-chloro-octane is facilitated by having a quaternary ammonium salt act as one of these compounds. For 10 points, name these catalysts that move reactants between immiscible solvents.**

ANSWER: **phase-transfer catalysts** [or **PTC**; prompt on catalyst or asymmetric catalyst or enantioselective catalyst or stereoselective catalyst; before "quaternary ammonium salt": either accept **quaternary ammonium salt** or prompt on partial answer since a bunch of the clues apply specifically to them]

<Chemistry, Eric Mukherjee>

13. **The Z·C·H and Miura-Ori patterns are used to achieve unusual values of this quantity in origami structures. Chevrot ("shev-ROW") et al found this quantity to increase with thickness in the Proterozoic ("pro-TEAR-oh-zoh-ick") crust and decrease with thickness in the Phanerozoic ("fan-AIR-oh-zoh-ick") crust. This quantity is equal to  $V \cdot P$  squared minus  $2 \cdot V \cdot S$  squared over two times quantity  $V \cdot P$  squared minus  $V \cdot S$  squared, where  $V \cdot P$  and  $V \cdot S$  are P- and S-wave velocities. This quantity is equal to  $\lambda$  over the quantity 2 times  $\lambda$  plus  $\mu$  in terms of (\*) Lamé (luh-MAY) parameters. This quantity is equal to  $E$  over  $2 \cdot G$  minus 1, or one-half minus one-sixth times  $\kappa E$ . In an isotropic material, this quantity ranges from -1 to  $\frac{1}{2}$ . Foams and honeycombs are examples of auxetic materials, which unusually have a negative quantity for this ratio. For 10 points, name this quantity, often represented as  $\nu$ , the negative ratio of transverse to axial strain.**

ANSWER: **Poisson's ratio**

<Physics, Jaimie Carlson>

14. **A 2018 paper by Liu et al. demonstrates the value of diverse deep supervision in the "category-aware semantic" version of this problem; that paper adds supervision to each step in a stacked activation map. One process for performing this action uses an accumulator array in a parameter space as a voting method. Pratt's figures of merit are used to test algorithms for this task; one such algorithm was improved by Deriche ("duh-REACH") using an infinite impulse response filter, and uses an arctangent function with two arguments in one step. The classical Hough ("Huff") transform performs this task, as does an algorithm which does this task using (\*) blob analysis and hysteresis as its final step to remove weak results; that algorithm was developed by Canny. The Kayyali and Sobel operators are gradient methods for doing this, which can find steps, ramps, or roofs in one dimension. For 10 points, identify this technique of identifying boundaries between objects in an image.**

ANSWER: **edge detection** [accept anything relating to **finding lines** or **edges** in pictures; prompt on blob detection, shape detection, feature detection, feature extraction, image segmentation, segmentation]

<Computer Science, Aakash Patel>

15. One theory about this component was disproved by Bahcall, Flynn, Gould, and Kirhakos using a survey on H·S·T's WFC2 ("whiff-see-2"). Dan Hooper first hypothesized that the isotropic gamma ray background was due to this component. Observations of dwarf galaxies look for gamma rays produced by the self-annihilation of this component. Rho naught over a third order polynomial of the radius divided by the scale radius gives the (\*) Navarro-Frenk-White density profile for this material. One potential type of this material happens to freeze out at exactly the right cross section that supersymmetry predicts for a particle of this type, its namesake "Miracle." Candidates for this material include axions, sterile neutrinos, and WIMPs. Vera Rubin discovered this material when observing galaxy rotation curves. For 10 points name this type of matter which only interacts gravitationally.

ANSWER: **dark matter** [antiprompt on WIMPs, MACHOs, Axions, and Sterile Neutrinos by asking "That is a candidate for what thing?"]

<Astronomy, James Lasker>

16. The spinor ("spinner") map is a surjective homomorphism from S·L (2,C) to a structure named for this scientist. The Levi-Civita ("levy-suh-VEE-tuh") symbol is used to express commutation relations between Hermitian ("her-mission") quantities J and anti-Hermitian quantities K, which are this man's namesake generators. The identity component of a structure named for this man is isomorphic to a structure named for Mobius, an observation that allowed Penrose to derive twistor theory. The set of four connected components of a group named for this scientist is isomorphic to the Klein four-group. A doubly-connected restricted group named for this man consists of elements that are both (\*) proper and ortho-chronous; that group is symbolized S-O-plus-one-comma-three. A series of 4-by-4 matrices which are simplified using the rapidity represent operations named for this man, which are rotations and translations in hyperbolic spacetime. For 10 points, what scientist's namesake transform moves between different inertial reference frames in Minkowski ("min-COW-skee") space?

ANSWER: Hendrik Antoon **Lorentz** [accept Lorentz group or Lorentz transformation]

<Physics, Eric Mukherjee>

17. Six atoms of this element are present in a room-temperature stable double aromatic compound synthesized by the Saito group. A reagent containing this element linked to benzene and phthalimide is used to derivatize thiols in mass spec. This element is the heaviest in a reagent used to transform carbonyls ("CAR-bun-eelz") to alpha-beta unsaturated carbonyls by using this element to attach to the alpha-position and then forming a five-membered cyclic transition state. An o-nitrophenyl ("oh nitro-FEN-ull") cyanate ("SIGH-uh-nate") of this element is used to transform primary alcohols to alkenes ("AL-keenz") in a thermal syn ("sin") elimination named for (\*) Greico ("greye-co"). Thio·red·oxin reductases, de·iodi·nases, and gluta·thione peroxid·ases all contain this metal in their active site, and it forms the anion of a popular quantum dot with cadmium. For 10 points, name this chalcogen which can replace sulfur in some proteins.

ANSWER: **selenium** [or Se]

<Chemistry, Eric Mukherjee>

18. High-throughput techniques for detecting these phenomena include Stephen Elledge's PLATO and George Church's S·M·I-seq ("seek"). A technique used to validate these phenomena uses a construct with an R·S·I·A·T linker sequence. HI-II-14 ("high-two-fourteen") and Bio·Plex are maps of large numbers of these phenomena. The STRING ("string") database contains networks of these phenomena, which contain "party hubs" and "date hubs". One method of detecting these phenomena has an intermediate step in which tobacco etch virus protease is used to cleave a linker between two domains of a (\*) TAP ("tap") tag. Fluorescence complementation is used to detect these phenomena. A screen used to detect these phenomena can either use Cub and Nub domains or two domains of Gal·4 to turn on a reporter gene; that is a yeast two-hybrid assay. Co-immuno·precipitation is the gold standard for detecting these interactions. For 10 points, name these phenomena in which polypeptides bind to each other.

ANSWER: **protein-protein** interactions [or PPI; accept anything that implies proteins binding to each other, accept **protein complex formation** or equivalents, accept docking, prompt on ligand binding]

<Biology, Eric Mukherjee>

19. Below about 4K, Muller and Burkard showed that one material with this structure displays intrinsic quantum para-electricity. This structure is exhibited by thin films of methyl-ammonium lead tri-iodide spaced with n-butyl-ammonium cations (“CAT-eye-onz”), which are used in solar cells that have surpassed the efficiency of cadmium telluride solar cells. Used to quantify the stability of this structure, the Goldschmidt tolerance factor is equal to the sum of A-cation radius and anion radius over root two times the sum of B-cation radius and anion radius. This structure occurs in P-Z-T and cuprate superconductors like Y-B-C-O. At high pressures, magnesium silicate (\*) transitions from this structure to another structure with greater elastic anisotropy found in minerals that are thought to be the origin of the seismic discontinuity in the D-double-prime layer. Oxides with chemical formula “A-B-O3” are examples of materials with, for 10 points, what crystal structure possessed by calcium titanate, first discovered in the Ural mountains by a Russian mineralogist?

ANSWER: perovskites [do not accept “post-perovskite”]

<Physics, Jonathen Settle>

20. Every separable, infinite-dimensional Fréchet (“FRUH-sheh”) space is homeomorphic to a single space defined using this operation by the Anderson-Kadec theorem. Canonical projection mappings are defined on spaces constructed via this operation. For finite families, the natural topology on spaces defined by this operation is equivalent to the box topology. One motivation for pointless topology is that, unlike in point-set topology, a major theorem regarding spaces defined using this operation can be proven without invoking the (\*) axiom of choice. The Cantor set can be constructed by repeatedly applying this operation to the discrete space with two points. The result of this operation applied to a family of compact spaces must be compact by Tychonoff’s (“TICK-uh-noffs”) theorem. For 10 points, give this operation in which a new space is constructed from ordered pairs of constituent spaces.

ANSWER: Cartesian product (of topological spaces)

<Math, Justin French>

21. Overexpressing SOX-9 and N-F-I-B transforms i-P-S cells into these cells. The two types of these cells can be distinguished by their expression of A-2-B-5 and R-a-n-2. Tuberos (“TOO-burr-us”) sclerosis causes a subependymal (“sub-uh-PEN-dim-uhl”) giant cell tumor derived from these cells. A secondary tumor that arises from these cells often has a methylated M-G-M-T promoter, is treated with temozolomide (“tem-uh-ZOLL-uh-mide”), and can have a butterfly appearance on radiology. A unipolar type of these cells extend processes to assist with the migration of granule cells in the (\*) cerebellum (“sere-uh-BELL-um”); that type is named for Bergmann. These cells transform into gemistocytes (“juh-MIST-oh-sites”) during injury, and tumors of them include pilocytic (“PILE-oh-SIT-ick”) and anaplastic (“ANN-uh-PLAST-ick”) varieties. Their reactive type form scars in response to tissue damage, and their foot processes comprise the blood-brain barrier. For 10 points, name these glial (“GLEE-uhl”) cells named for their star-shaped appearance.

ANSWER: astrocyte [or astroglia; prompt on glia]

<Biology, Eric Mukherjee>

22. Ames and Kustu developed a method of quantifying periplasmic proteins by treating cells with this substance. Three volumes of water, four volumes of methanol, and one volume of this substance are used in a mixture to precipitate proteins. In the original form of the Keck macro-lacton-ization, a hydroxy-acid is dissolved in an ethanol-free version of this compound, then added to a solution of this compound, D-C-C, D-MAP, and D-MAP-hydro-chloride. This compound is de-protonated, then forms a carbene, in the first steps of the Reimer-Tiemann reaction. Calcium formate and this compound are formed when reacting a precursor with calcium hydroxide, as shown by Liebig. Amylene (“AM-uh-leen”) is used as a stabilizer to prevent the conversion of this compound to (\*) phosgene (“FOS-jeen”). This compound is 48% of a mixture along with isoamyl (“iso-AM-ill”) alcohol and phenol used in D-N-A extraction. For 10 points, name this compound which replaced ether as an anesthetic in the 19<sup>th</sup> century, with formula C-H-C-I-3.

ANSWER: chloroform [accept CHCl3 before mention]

<Chemistry, Eric Mukherjee>

23. Distortion associated with this practice can be measured with the lie factor, whose logarithm is a measure of overstating. One package used for this practice was created by John D. Hunter. Effective implementations of this practice should avoid violating the area principle. One text about this practice praises “small multiples” and lists vibrations and ducks as useless elements of this practice. A Leland Wilkinson book about the “grammar” of this practice inspired a software package named for it that includes “geoms” and “a·e·s”. Six principles of integrity, along with utilizing micro/macro, maximizing the ratio of (\*) ink use, and avoiding junk are among Edward Tufte’s rules for this practice. Software packages for this practice include tidyverse’s ggplot2 for R and matplotlib for Python. For 10 points, name this practice of representing data graphically.

ANSWER: data visualization [accept plotting or graphing or charting or similar until mentioned; prompt on graphics or computer graphics]

<Data Science/Stats/Applied Math, Steven Silverman>

24. One experimental class of inhibitors of these enzymes are called boronic (rhymes with “moronic”) acid transition state inhibitors. A colorimetric (“color-a-metric”) assay for the activity of these enzymes relies on an increase in absorbance at 490 nanometers upon cleavage of nitrocefin (“nitro-CEF-in”). The Verona integron expresses one of these enzymes, which are classified using the Ambler system. T·E·M and S·H·V are two classes of these enzymes. Organisms in the mnemonic “SPICE” or “SPACE” express an inducible one of these enzymes. Those that can act on molecules with an oxy-imino side chain are called “extended-spectrum”, and require the use of (\*) carbapenem (“car-buh-PEN-em”). Vaborbactam (vay-bore-BACK-tam), clavulanate (“clav-yew-LAN-ate”), and tazobactam (“TAY-zo-BACK-tam”) are inhibitors of these enzymes. One of these enzymes was isolated from a Swedish patient with a *Klebsiella* (“kleb-see-ELL-uh”) infection; that one is named for New Delhi. For 10 points, name these enzymes that break down antibiotics in a class including cephalosporins and penicillins.

ANSWER: beta-lactamases [or carbapenemases until “carbapenem”]

<Biology, Abhinav Godavarthi>