

## Lederberg 3: Trinity

Hopefully, we've left you with some good memories. So, until we meet again, stay gold. Preferably colloidal. Bang.

Will Alston<sup>1</sup>, Justin French<sup>2</sup>, Jonathen Settle<sup>3</sup>, Geoffrey Chen<sup>4,5</sup>, Jaimie Carlson<sup>6</sup>, Abhinav Godavarthi<sup>7</sup>, Steven R. Silverman<sup>8</sup>, Akshay Govindan<sup>9</sup>, Paul Chungroh Lee<sup>10</sup>, Julia Zhou<sup>11</sup>, Aakash V. Patel<sup>8</sup>, Fred Zhang<sup>11</sup>, Anson Berns<sup>12</sup>, James Lasker<sup>13, 14\*</sup>, Eric M. Mukherjee<sup>15,16‡</sup>

<sup>1</sup>Emeritus, Dartmouth College, Hanover, NH 03755

<sup>2</sup>University of California, Los Angeles, Los Angeles, CA 90095

<sup>3</sup>Department of Computer and Information Science and Engineering, University of Florida, Gainesville, FL 32611

<sup>4</sup>Wayzata High School, Plymouth, MN 55446

<sup>5</sup>University of Minnesota, Minneapolis, MN 55455

<sup>6</sup>School of Engineering and Applied Science, University of Pennsylvania, Philadelphia, PA 19104

<sup>7</sup>Plano West Senior High School, Plano, TX 75093

<sup>8</sup>Emeritus, Carnegie Mellon University, Pittsburgh, PA 15213

<sup>9</sup>Ladue Horton Watkins High School, St. Louis, MO 63124

<sup>10</sup>College of Arts and Sciences, University of Pennsylvania, Philadelphia, PA 19104

<sup>11</sup>Thomas Jefferson High School for Science and Technology, Alexandria, VA 22312

<sup>12</sup>Montgomery Blair High School, Silver Spring, MD 20901

<sup>13</sup>Department of Astronomy and Astrophysics, University of Chicago, Chicago, IL 60637

<sup>14</sup>Kavli Institute for Cosmological Physics, University of Chicago, Chicago, IL 60637

<sup>15</sup>Emeritus, Medical Scientist Training Program, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, PA 19104

<sup>16</sup>Department of Dermatology, Vanderbilt University Medical Center, Nashville, TN 37232

\*Editor

‡Head Editor and Corresponding Author: [ericmu@penmedicine.upenn.edu](mailto:ericmu@penmedicine.upenn.edu)

**ACKNOWLEDGEMENTS:** The authors would like to thank Ike Jose for valuable input and suggestions, Jason Thompson for negotiating a time to play the tournament at ICT, the players for their generous donations to the Leukemia and Lymphoma Society, and the staffers who made this tournament possible.

1. Staus et al. showed that the sensitivity of these proteins could be explained by three distinct conformations using allosteric nanobodies. Activation of these proteins relies on their forming an H-bonding network between their E/D·R·Y motif on H·3 and residues on H·6 called an “ionic lock”. Kenakin’s cubic ternary complex model is used to model these proteins, which have families A through F. Those involved in adhesion often have an auto·proteo·lytic GAIN domain. Familial hypo·calci·uric hyper·cal·cemia occurs due to a mutation in one of these proteins, which includes frizzled and smoothed. Phosphorylation (“fos·FOR·il·ay·shun”) of their tails allows for (\*) beta-arrestin to bind and trigger desensitization. These proteins include rhodopsins (“road·OP·sinz”) and Beta2-adrenergic (“AD·ren·ER·jick”) receptor and have 7 trans·membrane alpha helices. For 10 points, name these receptors linked to a namesake family of G·T·P-binding proteins.

ANSWER: G-protein coupled receptors [accept GPCRs, or serpentine receptors or metabotropic receptors; accept 7TM-receptors or seven-transmembrane domain receptors before mention of “7 transmembrane alpha helices”; anti-prompt on CaSR or calcium-sensing receptor]

<Biology, Abhinav Godavarthi>

2. In a method that uses two separate control loops for this quantity and stator flux, this quantity is estimated as 1.5 times the quantity [read slowly] “phi-d-s times i-q-s minus phi-q-s times i-d-s.” Unlike the similar field-oriented control, that method of motor control partly named for this quantity uses hysteresis controllers. The plot of this quantity versus omega for a damped-driven pendulum has the same shape as the current versus voltage plot of a Josephson junction. For D·C motors, a plot of this quantity versus omega is linear. The right-hand sides of (\*) Euler’s equations for rigid body motion equal zero when this quantity is absent. This quantity’s “stall” value is produced by a device with no rotational speed. Precession can be free of or induced by this quantity. Angular momentum doesn’t change when this quantity is absent because its time derivative is this quantity. For 10 points, name this rotational analogue of force.

ANSWER: torque [accept electromagnetic torque or electric torque]

<Physics, Jonathon Settle>

3. All of these objects for a compact Lie (“lee”) group can be classified by their highest weight. These objects correspond with the modules of the universal enveloping algebra of a Lie algebra. For a Lie group, these objects can be studied using Weyl’s (“vile’s”) unitary trick. If one of these objects is afforded by a simple module, then it is called irreducible. When defined over the complex numbers, every homomorphism between two of these objects is either trivial or an isomorphism, according to (\*) Schur’s lemma. These functions can be defined as the group actions on a vector space that are linear and invertible. Since it expresses every element as a 3D rotation, the most common definition of SO(3) (“S·O·three”) implicitly defines one of these functions. These functions are defined as homomorphisms from a group  $G$  to the general linear group of some vector space, so they give a way to express  $G$  as a group of matrices. For 10 points, name these functions that describe a group in terms of linear transformations.

ANSWER: representations [accept linear or matrix representations of a group or a Lie algebra]

<Math, Justin French>

4. One apparatus used in this process contains a rotating disk attached to several dippers; that is the Graesser raining-bucket system. Another apparatus used in this procedure contains a rotating disk contactor. Kuhni and Scheibel columns are commonly used for this procedure. A method of analyzing this procedure often requires the use of a conjugate curve intersecting the plait point to generate additional tie lines. This procedure, which leaves a raffinate (“RA·fee·nate”) behind, is often modeled using equilateral triangle graph paper in the (\*) Hunter-Nash method. This technique is efficient when the partition coefficient is high, and can be conducted using mixer-settlers or a pear-shaped apparatus with a stopcock. For 10 points, name this technique often conducted in a separatory funnel, in which a solute is preferentially pulled into an aqueous or organic phase.

ANSWER: liquid-liquid extraction [prompt on separation]

<Chemistry, Eric Mukherjee>

5. Lasker et al 2019 showed that photometry errors due to variation in C·C·Ds, filters, S·E·Ds, and this phenomenon do not have any effect on measurements of cosmological parameters. One method of correcting for this phenomenon is “pawprint.” It’s not related to football, but the Bortle scale measures the strength of this phenomenon. MODTRAN is used to model this specific phenomenon. Observations of this phenomenon are uniform enough that they can be used in place of flat-field screens. Telluric lines are produced by this phenomenon. Nodding and (\*) chopping are used to reduce the effect of this phenomenon. Due to this phenomenon, one must choose slit sizes very close to the seeing, which is also caused by this phenomenon. This phenomenon has the most effect in the infrared range and is what causes stars to twinkle. For 10 points, name this phenomenon which has the greatest effect on observations during twilight.

ANSWER: sky [or atmosphere; accept atmospheric turbulence; accept light pollution; accept atmospheric transmission function; prompt on transmission function by asking “Transmission function of what?”; prompt on turbulence by asking “Where is the turbulence?” prompt on seeing]

<Astronomy, James Lasker>

6. This quantity is negligible in a limit defined by a Henry function equal to 1.5 in the Smoluchowski (“smol-u-KOFF-skee”) approximation. For a short-range Yukawa potential whose magnitude is proportional to [read slowly] “q, divided by four-pi times permeability times r,” this quantity appears in the [emphasize] *denominator of the exponent* of such a potential. Mean-field theories based on the Poisson-Nernst-Planck equation are valid when this quantity is much larger than a similar quantity named for Bjerrum (“BYUR-um”). In D·L·V·O theory, the inverse of this quantity is designated (\*) kappa. Macroscopic neutrality is not always satisfied in a namesake “sheath” characterized by this quantity, which is proportional to the square root of temperature divided by electron number density. This quantity is on the order of 10 to the negative three meters in the ionosphere. For 10 points, name this distance over which electrostatic effects persist, which defines the characteristic length of a plasma.

ANSWER: Debye length [prompt on screening length]

<Physics, Will Alston>

7. A 1954 paper by Braude and Linstead classifies one type of these reactions as migrations, disproportionation or TH reactions. Chiral (“KYE-rull”) secondary amines and tri·fluoro·acetic acid catalyze one of these reactions involving Hantzsch esters. Adding a phosphine and bi·pyridine to valinol generates a catalyst for these reactions called S·iPr·PHOX. Another catalyst used in these reactions is coordinated to pyridine, cyclo·octadiene, and tri·cyclo·hexyl·phosphine. Decalin (“DECK-uh-lin”) and tetralin are donors one form of these reactions, which is used to liquefy coal; that is their (\*) “transfer” type. Chiral ruthenium complexes like BINAP (“BYE-nap”) catalyze an asymmetric form of this reaction named for Noyori. Sodium in liquid ammonia catalyze one of these reactions that create trans-alkenes (“al-KEENZ”). The heat released by this process is a measure of alkene stability. For 10 points, name these reactions, the addition of the lightest element.

ANSWER: (transfer) hydrogenations [or hydrogen transfers, accept asymmetric (transfer) hydrogenations, accept dehydrogenations, accept ATH, prompt on reductions]

8. Methods of performing this task can be tested on the Stanford Treebank dataset, which was first implemented on a recursive deep model. Bollen et al performed this process with the G·P·O·M·S to predict stock market prices. Hutto’s normalization procedure is used in VADER, part of Python’s N·L·T·K module that performs this task. The Turney algorithm performs this task by calculating an average polarity of all two-word units. Pang and Lee attempted this task by running a simple S·V·M or naive Bayes classifier on tokenized versions of (\*) movie reviews, with star ratings as labels. This process is often done on customer reviews or political Tweets to extract average views and summarized in word clouds. For 10 points, name this use of natural language processing to extract emotions from text.

ANSWER: sentiment analysis [or opinion analysis, or opinion mining or emotion AI; or sentiment mining; or subjectivity analysis; prompt on language processing, natural language processing, NLP; text mining; text analysis; or document analysis; prompt on things like getting opinions/emotions/feelings from social media, getting opinions/emotions/feelings from text, etc]

<Computer Science, Jaimie Carlson>

9. The set of these values less than two to the power of two to the  $n$  are isomorphic to the Galois (“gal-WAH”) field of order two to the two to the  $n$ . The indistinguishability quotient generalizes one theorem about these values to misere situations. Addition on these values can be recursively defined via the mex, or minimum excludant. The state of green hackenbush can generate these values. Fraenkel used an operation involving these values to analyze error-correcting codes, called anncodes, on directed graphs. The Sprague-Grundy theorem allows all impartial (\*) games to be reduced to these values. An operation used to calculate these values is usually written as a circled plus sign. If and only if this value is nonzero, these values’ namesake game is winnable for the next player. For 10 points, name these values that take their name from a two-player game involving removing objects from stacks and which can be calculated by finding the XOR of a set of binary numbers.

ANSWER: nimbers [prompt on answers involving “nim”; prompt on “nim sums” by asking, “what value does a nim sum give you?”]

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

10. Laskay and Jackson used leucine enkephalin to develop a pulsed q dynamic version of this technique. High-amplitude short-time excitation, or HASTE, cuts the time needed for this technique. One version of this technique occurs in a multipole cell outside of a curved-linear apparatus; that version of this technique is used in Orbitrap instruments. A high-energy version of this technique is used to remove isobaric tags. The second quadrupole in a triple quadrupole arrangement is used to carry out this technique. A version of this technique that uses sustained off-resonance irradiation is commonly paired with (\*) F·T·I·C·R. In this technique, a sample is accelerated into helium or argon. This technique occurs in the gas phase and separates a sample into b-type and y-type ions. This technique occurs between the two stages of tandem mass spectrometry. For 10 points, name this technique in which ions are fragmented by ramming them into a neutral gas.

ANSWER: collision-induced dissociation [or CID or collisionally-activated dissociation or CAD or higher-energy collisional dissociation or HCD; prompt on fragmentation, ion fragmentation, peptide fragmentation; prompt on mass spectrometry or tandem mass spectrometry; prompt on collision, using a collision cell]

<Chemistry, Eric Mukherjee>

11. This process requires R·n·f·12 to ubiquitinate (“yew-BICK-wit-in-ate”) REX·1. A site required for this process, D·x·z·4, separates its product into two megadomains with several long-range contacts. A locus critical to this process contains a bidirectional promoter called D·X·P·a·s·34. A regulator of this process requires Y·Y·1 and h·n·R·N·P·U to localize to clouds. To assess tumor lineages, the HUMARA (“hew-MARR-uh”) locus is often used as it is easily distinguished based on the results of this process. One regulator of this process is itself upregulated by J·p·x, which displaces C·T·C·F; that regulator contains a repeat called Rep·A that binds to S·U·Z·12. P·R·C·1 and P·R·C·2 (\*) tri-methylate H·3·K·27 during this process. This process is regulated by a long non-coding R·N·A called Xist (“exist”), which recruits Polycomb-group proteins to form hetero·chromatin. This process is responsible for the mottled appearance of calico cats. For 10 points, name this mode of dosage compensation in female mammals in which a Barr body is created.

ANSWER: X-chromosome inactivation [accept X-inactivation or Lyonization; prompt on epigenetic modification or histone modification or silencing]

<Biology, Abhinav Godavarthi>

12. The International Commission which governs the study of these physical things placed a so-called “golden spike” in Australia, which exemplifies a reference for these things called a G·S·S·P. Instrumental well logs are one method of establishing “indirect correlation” between these things when it is not possible to physically demonstrate “direct correlation.” Depending on the reasons that one of these things is absent, the interval not represented by one of them can be called a hiatus or a vacuity (“vuh-CUE-ity”). An angular unconformity results when angular examples of these things are (\*) covered by new ones which are formed under the usual condition of original horizontality. The Catholic priest Nicholas Steno formulated the principle that the oldest of these things in a sequence will be the one at the bottom, which is called the principle of superposition. For 10 points, give this geologic term for layers of rock and soil.

ANSWER: (geologic) **strata** [or **stratum**; accept **chronostrata** or **lithostrata**; accept **facies** before “Steno”; prompt on layers or soil layers or sediment layers by saying “we’re looking for a broader geologic term”]

<Earth Science, Will Alston>

13. While exclusive calculations of this quantity can be I·R divergent, this quantity is always finite for inclusive processes. It’s not lifetime or binding energy, but plotting the log of this quantity against number of neutrons shows “dips” at magic numbers. This quantity is related to the charge distribution structure function and magnetic moment structure function by the Rosenbluth formula. In one context, this quantity times beam flux times density equals the nuclear reaction rate. This quantity is equal to four pi over k times the imaginary part of f of zero by the (\*) optical theorem. The derivative of the cosine of the lab angle with respect to the cosine of the center-of-mass angle transforms this quantity from the C·M-frame to the lab frame. The impact parameter over sine theta times the derivative of the impact parameter with respect to theta is equal to its differential form. For 10 points, name this quantity measured in barns, the effective area of particle interactions.

ANSWER: **cross section** [accept inclusive **cross section**; accept exclusive **cross section**; accept nuclear **cross section**; accept neutron **cross section**; accept scattering **cross section**; accept differential **cross section** or total **cross section**]

<Physics, Jonathon Settle>

14. An example library for these systems which implements reducing algorithms is Hoberock and Bell’s Thrust. MATLAB (“MATT-lab”) can integrate with them using Jacket, and n·v·v·p is a testbench utility for debugging these systems. They can be programmed in core-profile or immediate mode, and ones implementing the Kepler architecture group threads into warps. They’re not neural networks, but training several of these devices using model replicas is a common Tensorflow tutorial. Libraries like N·P·P and N·V·M·L come with an A·P·I for these devices called (\*) CUDA. DirectX is a Windows system for using these things, whose major brands include the GeForce G·T·X and the A·M·D Radeon R·X. General purpose computing on these devices take advantage of their many cores for parallel problems. They implement shaders and draw pixels and vertices with Open·G·L. For 10 points, name these devices contrasted with the C·P·U, used to speed calculations for visual output.

ANSWER: **graphics processing unit** [or **GPU**; or **GPGPU** or **general purpose GPU** or **general purpose graphics processing unit** computing; prompt on video card or graphics card]

<Computer Science, Jaimie Carlson>

15. A result involving the lengths of constructs with this property was proven using Goldston, Pintz, and Yildirim's result on small prime gaps to show that a "transference principle" is applicable. Erdős ("AIR-dich") conjectured that if the sum of reciprocals of a sequence diverges, that sequence must contain arbitrarily large subsequences with this property; that conjecture would generalize Szemerédi's ("seh-meh-RAY-dee's") theorem. An observation regarding the distribution of primes in two sequences with this property is called (\*) Chebyshev's bias. Dirichlet ("dee-rih-CLAY") introduced his namesake L-functions to prove that, except in some trivial cases, every sequence with this property contains infinitely many primes. Ben Green and Terence Tao proved that the prime numbers contain arbitrarily long progressions with this property. Every congruence class modulo  $n$  forms a sequence with this property. For 10 points, name these sequences in which terms are separated by a constant difference.

ANSWER: arithmetic [accept arithmetic progressions or arithmetic sequences or arithmetic series; accept congruent mod  $n$  until "congruence class;" accept constant difference until "constant difference"]

<Math, Justin French>

16. A version of this disease in which visual symptoms occurs first is its Heidenhain ("HIDE-in-hein") variant. An E·200·K mutation is responsible for the high incidence of this disease in Libyan Jews. Cortical ribboning on D·W·I and T·2 hyper-intensities in the pulvinar ("PULL-vin-arr") nuclei are M·R·I findings of this disease. An assay for this disease subjects a nasal swab to quaking-induced conversion. Triphasic periodic spikes on E·E·G are characteristic of this disease, as is startle myoclonus ("MY-uh-CLONE-us") and rapidly-progressive (\*) dementia. C·S·F 14-3-3 protein is elevated in this disease, which is sometimes linked to a M·129·V mutation. Dura mater ("matter") allografts and pituitary hormone preparations are known sources of this disease, whose pathogenesis is similar to kuru ("KOO-roo"). Sporadic, variant, and familial forms of this disease exist, which is caused by the conversion of P·R·P to a mostly beta-sheet configuration. For 10 points, name this human prion ("PREE-on") disease.

ANSWER: Creutzfeldt-Jakob disease [or CJD]

<Biology, Eric Mukherjee>

17. In B·C·S theory, this quantity is given by a piecewise function that decreases rapidly from infinity above the gap, denoted delta, but is zero before it. The kinetic energy term for the surface energy of a nucleus arises because, if the wavefunction vanishes on a plane boundary, this quantity will decrease by a term proportional to the area of the bounding surface. The relationship between this quantity and the integral of the Green's function of the Hamiltonian can be derived using the Lorentzian approximation to smooth out the expression for this quantity as a sum of Dirac deltas. This quantity is constant for a two-dimensional (\*) electron gas, and varies with square root of energy for a three-dimensional one. Calculating this quantity involves dividing by the volume of a region in  $k$ -space. The integral of the particle distribution function times this quantity with respect to energy gives the particle number. For 10 points, name this quantity that describes the number of states in a given energy interval.

ANSWER: density of states [or DOS; do not accept or prompt on "density"]

<Physics, Justin French>

18. It's not molecular oxygen, but a tetra-kis-tri-methyl-silyl derivative of this molecule was used to measure its 13.9 k·cal per mole singlet-triplet energy gap. A common source of this compound is its iron tri-carbonyl ("CAR-bun-eel") derivative first synthesized by Rowland Pettit, which is reacted with ceric ammonium nitrate to liberate this compound. A method of synthesizing this compound involves photo-lysis of alpha-pyrone in solid argon at 8K, a method called matrix isolation. Donald Cram's group synthesized this compound within a hemicarplex ("hemi-CAR-sih-plex"). This molecule's bonds interconvert between lengths of 1.57 and 1.35 in a pseudo-Jahn-Teller ("yaan-tell-er") effect. Above 35K, this molecule tends to (\*) dimerize via the Diels-Alder reaction, where it reacts as both a diene ("DIE-eeen") and dienophile ("die-EEN-o-file"). Huckel molecular orbital theory predicts that this smallest annulene has a square shape, which is incorrect. For 10 points, name this anti-aromatic compound with four carbon atoms and two double bonds in a ring.

ANSWER: 1,3-cyclobutadiene [or [4]annulene or cyclobuta-1,3-diene]

<Chemistry, Eric Mukherjee>

19. **Description acceptable.** The pathway triggering this phenomenon is downregulated by T·H·L·1 and T·H·L·2, and a kinase in that pathway activates ARC·1. Mutation in the M·L·P·K gene abolishes this phenomenon in one organism, which in another organism requires a series of 50 k·D·a glyco·proteins with twelve conserved cysteine (“SIS·teen”) residues. In one organism, this phenomenon requires the p·26 pyrophosphatase (“pie·roh·FOSS·fuh·tace”), which is triggered by a calcium wave. R·N·ases with extensive N-linked glycosylation mediate this phenomenon in another organism, which is inhibited by S·L·F/S·L·B-mediated ubiquitination (“yew·BICK·wit·in·ay·shun”). In another system, S·C·R/S·P·11 binds to S·R·K/S·L·G to mediate it This phenomenon, which in (\*) *Solanaceae* (“soh·luh·NAY·see·eye”) is gametophyte-driven and in *Brassicaceae* (“brah·see·KAY·see·eye”) is sporophyte-driven, is used to ensure S-haplotypes differ between pollen and pistil. For 10 points, name this phenomenon that promotes outcrossing in plants.

ANSWER: self-incompatibility [or self-sterility, accept any answer involving “inhibiting self-fertilization” or “plants can’t fertilize themselves” before it is mentioned]

<Biology, Eric Mukherjee>

20. **Either residuals named for these constructs or Schoenfeld residuals are used to test goodness-of-fit of the Cox proportional hazards model. On an Erdos-Renyi (“AIR·dich·ren·YEE”) graph, the edge-exposure and vertex-exposure examples of these constructs are used to bound the chromatic number. If two of these constructs have bounded differences, the Azuma-Hoeffding inequality applies. Wald’s theorem can be proven using these constructs’ optional stopping theorem, which states that altering their (\*) stopping time doesn’t change their expected value. For any set of random variables and a function over them, the expected value of the function conditioned on the variables gives one of these constructs named for Doob. They take their name from a strategy in which one doubles their bet after losing. For 10 points, name these sequences of random variables in which the expected value of each observation, conditioned on all previous observations, is equal to the value of the previous observation.**

ANSWER: martingale [accept Doob martingale, semimartingale, submartingale, supermartingale]

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

21. **Molecular clouds have a value for this quantity equal to 1.1 times size to the 0.38 power or 0.42 times mass to the 0.2 power according to Larson’s laws. When two out of effective radius, surface brightness, and this quantity are known, they can be used to estimate the third using the fundamental plane. There is a power law relationship between this quantity for a galaxy and the mass of its central supermassive black hole. This quantity to the fourth power is proportional to the luminosity of an elliptical galaxy according to the (\*) Faber-Jackson relation. Galaxy clusters have a value for this quantity of 1000 km/s and individual elliptical galaxies have a value of 200 km/s. For 10 points, name this quantity which is the statistical scatter among the speeds of constituents of an astrophysically bound system.**

ANSWER: velocity dispersion [prompt on partial answer; prompt on sigma before read]

<Astronomy, James Lasker>

22. **Tan and Lanzavecchia (“lan·zuh·VECK·ee·uh”) discovered that some antibodies to the causative agent of this disease have insertions from the LAIR·1 gene. A medication used to treat this illness causes a delayed hemolytic reaction called P·A·D·H. Halofantrine (“hal·uh·FAN·tryne”) kills its causative agent by complexing with ferri·proto·porphyrin IX. Maurer’s clefts and Schuffner’s dots are histological findings of this disease, whose causative agent expresses RIFIN (“riffin”) and STEVOR (“STEE·vor”). A drug used to treat this disease has a 1,2,4-tri·oxane motif as part of its ses·qui·terpene lactone backbone. Several drugs used to treat it stop the polymerization of heme. Southeast Asia is home to the (\*) *knowlesi* (“know·LESS·ee”) species of its causative agent. The Duffy antigen is a receptor for one causative agent of this disease, which is treated with drug combinations containing artemisinin (“ar·tuh·MISS·in·in”). It is caused by the *vivax*, *ovale* (“oh·VAL·ey”), and *falciparum* (“fal·suh·PAR·um”) species of an organism carried by Anopheles (“uh·NAW·fill·eez”). For 10 points, name this disease caused by *Plasmodium* (“plaz·MOH·dee·um”).**

ANSWER: malaria

<Biology, Eric Mukherjee>

23. Structures that *lack* this effect are the subject of Sachse-Mohr theory. The [1,2]-sigmatropic step of the Demjanov (“DEM-yan-off”) rearrangement is driven by this effect, which also is used to thermally drive Cope rearrangements and the R·O·M·P reaction. The potential increase in this effect prevents fluxionality in trans-decalin. The Bertozzi group’s synthesis of several C·P·Ps used aromatization to overcome the energy of this effect. This phenomenon is responsible for the lower limits established by Bredt’s rule, which concerns double bonds at bridgeheads. It is the sum of angle, (\*) torsional, and transannular components. It is decreased by puckering to form envelope conformers in cyclopentane or by adopting a chair conformation in cyclohexane. For 10 points, name this effect that occurs when sp<sup>3</sup>-hybridized carbon atoms in a ring don’t have bond angles of 109 degrees.

ANSWER: ring strain [accept Bayer strain, torsional strain, eclipsing strain, angle strain, transannular strain, Pitzer strain, Prelog strain, small-angle strain, large-angle strain, van Der Waals strain, steric strain; prompt on steric effects or steric hindrance]

<Chemistry, Eric Mukherjee>

24. MODERATOR NOTE: Be sure you say “operation” and NOT “operator”

Molecules are considered “beads on strings” in a form of molecular dynamics named for this operation. For anti-commuting c-numbers, an extension of this operation named for Berezin (“buh-REY-zhin”) is often applied. The “no-boundary proposal” uses these operations to find the preferred initial state for quantum gravity, termed the Hartle-Hawking state. A mathematical aid to compute these operations replaces t with negative i times t to move from (\*) Lorentzian to Euclidean space. The time evolution amplitude can be calculated by performing these operations on kernels weighted by a phase factor of [read slowly] “e to the power of i times the action over h-bar”. This operation is used to find the propagator between two states by summing over all trajectories between them. For 10 points, name these operations which name a formulation of quantum mechanics by Richard Feynman (“FINE-mun”).

ANSWER: path integrals [or path integration; accept path integral formulation; accept line, contour or curve or curvilinear in place of “path”; prompt on integrals or integration]

<Physics, Will Alston>