

1. A mathematician computed a certain probability as 85 percent, so this discipline's founder said "Not bad. But not good. The actual figure is 92.5 percent." Paul Krugman has stated that his early enthrallment with this discipline partially inspired him to go into economics. This discipline relies on the assumptions that the population being studied is very large and that they are unaware of this discipline's results and predictions. Equations colored in (*) "deviation blue" represent observations that differ from theoretical predictions of this discipline by more than 1.5 sigma. Deviations from the predictions of this discipline as large as 10 sigma were generated by the Mule, and it was only through a century of hard work by a group of mentalics living at Trantor that the Plan was put back on track. For 10 points, name this discipline invented by Hari Seldon in Asimov's *Foundation* series.

ANSWER: psychohistory

2. Flows on this object preserve the sum of the oriented area of projections of a surface onto coordinate planes; that is, they preserve the Poincaré relative integral invariant. In canonical formalism, this object is interpreted as the cotangent bundle of another manifold and thus has a natural symplectic structure. Transformations which preserve that structure on these objects are called canonical. The (*) Poisson bracket is defined for functions of time and this type of space. A harmonic oscillator follows an elliptical trajectory in this kind of space. The density of a system moving in this space is constant according to Liouville's theorem. This space is six-dimensional for a particle in three dimensions. For 10 points, name this space in mechanics that describes the position and momentum of each particle or degree of freedom.

ANSWER: phase space [prompt on "symplectic manifolds" if anyone says that for some reason]

3. A popular example of these things is based on Tarski–Grothendieck set theory and uses statements written in Fitch notation. One must be careful when using these things if phi-one is equivalent to phi-two when print phi-one equals print phi-two, because in that case, they are Pollack-inconsistent. These things use "tactics" as shortcuts in applying inference rules. The kernels of these things are typically small and separate to allow them to be checked by a simple program, in which case they satisfy the de Bruijn ("brown") criterion. The Flyspeck project was started by Thomas (*) Hale to use one of these programs, HOL Light, to formalize a result of his. HOL Light, like Isabelle and Mizar, uses the ML programming language. Georges Gonthier used an example of these programs named Coq to formalize acceptance of the four-color theorem. For 10 points, name these software programs that are used to verify mathematical theorems.

ANSWER: proof assistants [or interactive provers; or interactive theorem provers; or automated proof checkers; or obvious equivalents; prompt on obvious equivalents of "computer-aided proofs"; do not accept "automated/automatic theorem provers"]

4. One study in this field showed that object-based classification algorithms could give more accurate results than classical pixel-based algorithms. The lack of temporal resolution of SAR data is a perennial problem in this field when attempting to study fast-acting processes, such as river-ice breakup. The level to which data in this field has been processed is described by a number between 0 and 4 where 0 refers to raw data and 4 to data derived from models instead of instruments. Data gained from this process can have geometric distortions digitally removed to form DOQs. Water and carbon dioxide in the (*) atmosphere create atmospheric windows which limit the effectiveness of space-based versions of this process in the mid-infrared range. Photogrammetry has largely been superseded by the use of LiDAR or radar to create elevation maps in one application of this field. The MODIS and LANDSAT satellites are important data sources for this field. For 10 points, name this field where information is acquired about objects without being in contact with them.

ANSWER: remote sensing [accept Earth observation; prompt on "surveying"]

5. With Harold Locke Hazen, this scientist used six mechanical integrators to create the first practical differential analyzer. With Charles Smith and Laurence Marshall, this man founded a company that made helium rectifiers, which later turned into Raytheon. This man proposed the notion of a “cyclops camera” attached to the head in an essay that argues that the *Encyclopedia Britannica* could be reduced to the size of a matchbox using microfilm. That essay for *The Atlantic Monthly* proposes a (*) hypertext-like microfilm reader that could form associative trails, called Memex. This author of “As We May Think?” popularized the term “basic research” in a report for President Truman. As head of the Office of Scientific Research and Development during World War II, this scientist gained approval for the Manhattan Project. For 10 points, name this engineer whose report *Science, the Endless Frontier* laid the foundation for the National Science Foundation.

ANSWER: Vannevar “Van” **Bush**

6. Sherman and Guillery proposed the “driver/modulator” distinction for inputs to this structure. Projections from this area are called “core” if they are parvalbumin-stained and “matrix” if calbindin-stained. Rat barreloids are visible within this structure. The No Strong Loops hypothesis and “rod-to-column” principle apply to this structure’s neocortical outputs, which mostly go to the granular Layer IV. A pathway named for this region and the spine is also called the (*) anterolateral pathway. The koniocellular, parvocellular, and magnocellular pathways pass through the pulvinar and lateral geniculate nuclei in this region. This area includes “nonspecific” and “association” nuclei, as well as “relay” nuclei. For 10 points, name this sense-integrating brain region above the hypothalamus.

ANSWER: **thalamus** [grudgingly prompt on “midbrain” or “diencephalon”; do not accept “hypothalamus”]

7. The Griffiths–Hurst–Sherman inequality was first proved for this system, which was shown by Guerra, Rosen, and Simon to correspond to a limit of ϕ to the fourth Euclidean field theory. Computing both the high and low temperature expansions of this model leads to the amazing result that it is self-dual. The transfer-matrix method of solving this system leads to a partition function of λ -plus to the N plus λ -minus to the N . Peierls (“piles”) used his “droplets” argument to suggest that a version of this model *does* have an ordered phase. One version of this model has correlation length equal to one over the log of the hyperbolic tangent of βJ , and thus has no (*) phase transition at nonzero temperature. Using the mean-field approximation, one can derive the Curie–Weiss equation. Onsager analytically solved the two-dimensional version of this model. For 10 points, name this lattice model of ferromagnetism.

ANSWER: **Ising** model [accept one- or two-dimensional **Ising** models, since different clues apply to different ones]

8. Eskinograms show this process to the right of an input. This process can occur after two pulses called “skeletons,” but can’t happen in “dead zones.” After transients, the vertical sections of multi-plotted actographs show this process with or without masking. Type 0 and Type 1 PRCs show this phenomenon as a step discontinuity or an N-shape, respectively. Both Aschoff’s continuous, parametric and Pittendrigh’s discrete, nonparametric models are of this process. This process can be determined by using (*) T-cycles and measuring FRPs. Zeitgebers like light-dark cycles can cause this phenomenon exemplified by jetlag. For 10 points, name this “synchronization” of a circadian rhythm with a stimulus such as light.

ANSWER: **entrainment**

9. The Serre version of a certain object relates *this thing* for a total space of a fibration to *this thing* of the base space and fiber space. That type of object that can be used to compute *this thing* for a filtered complex is a spectral sequence. For a compact boundaryless orientable manifold, the Poincaré duality gives an isomorphism between one of these groups and its dual. If you know this group when its coefficients are in the integers, you can compute it for coefficients in other abelian groups using the universal coefficient theorem. The first one of these is isomorphic to the abelianization of the fundamental group as a special case of the Hurewicz theorem. The rank of the n th of these groups is the n th (*) Betti number. The n th of these groups is defined as the kernel of the n th boundary map mod the image of the n minus one-th boundary map for a chain or simplicial or some other type of complex. For 10 points, name this set of groups associated with a particular space that loosely describes the set holes of different dimensions.

ANSWER: homology groups [accept cohomology, since several clues apply to both]

10. A 2008 analysis by Genes et al. found that one form of this effect is dominated by quantum back-action contributions to it in the good cavity limit. The root of an ion's recoil frequency over the trap frequency is an indicator for the regime in which one type of this process is possible. That Lamb–Dicke parameter quantifies a form of this process that involves forcing transitions to a state with a higher internal state and lower motional state; that is the resolved sideband type. Using several intersecting (*) lasers to trap neutral atoms is a way to do this by creating optical molasses, and adding magnetic fields to make a magneto-optical trap will better prevent atoms from diffusing out. One method for performing this action uses the Zeeman effect to change the energies at which light is absorbed to account for varying relative frequency; that method shines a laser at incoming particles and is the Doppler type. Claude Cohen-Tannoudji and Steven Chu studied, for 10 points, what process that was performed on rubidium atoms to form the first Bose–Einstein condensate?

ANSWER: laser cooling [accept Doppler cooling]

11. The Grunwald–Winstein equation and Schleyer method were first used to find the formation rates of two types of these intermediates, like the Doering–Zeiss one. Saunders first used [isotopic perturbation of equilibrium] to study them, and pK_R^+ values indicate their stability. The Stork–Eschenmoser hypothesis is a “stitching cascade” with these intermediates. The classical Whitmore mechanism has this kind of intermediate. They are stabilized by the beta-silicon effect. Arnett studied these species' persistence using stable ion media. Their (*) hydride ion affinity is inversely proportional to their stability in gas phase. During nucleophilic assistance, solvents coordinate with these species. There are sigma and pi routes to the bridged or nonclassical type of these species, like the norbornyl one. Their “incipient” types are intermediates in Friedel–Crafts reactions. Carboniums and carbeniums are, for 10 points, types of what intermediates of E1 and S-N-1 reactions?

ANSWER: carbocations [prompt on “cation”; accept carbonium or carbenium until read; do not accept “carbene”]

12. The hydrogen abstraction or Babcock model proposes a five-step scheme for this complex's main function, with a dimer of dimers being formed. The formula ΔF over F_m measures the quantum yield of this structure, which is repaired by the D1 protein. O, J, I, and P, which are transients during the Kautsky effect, are formed by the activity of this complex that has a multi-flash S-state model described by the (*) Kok cycle. Atrazine works by inhibiting this structure. The core of one complex in this structure contains a quartet of manganese atoms. In lateral heterogeneity, this complex and LHC II are in the appressed regions of grana. This structure's PsbS molecule causes the initial response of non-photochemical quenching. Oxygen evolution occurs due to the oxidation of water by this protein-cofactor complex, which passes electrons through cytochrome *bf* to a larger counterpart. For 10 points, name this photochemical structure in the thylakoid membrane discovered after its counterpart.

ANSWER: photosystem II [or PSII]

13. A recent model of this process can be conceptualized using a geometric moduli space with a boundary given as a Poincaré disk with radius square root of three alpha. Renata Kallosh has led the development of those alpha-attractor models. Viable models of this process have to fall within certain hill-shaped regions on plots of primordial tilt versus tensor-to-scalar ratio. A parameter proportional to the square of the derivative of the potential divided by the potential and a parameter proportional to the second derivative of the potential divided by the potential must both be much less than one in this theory. The simplest chaotic models of this theory involve a quadratic potential. The (*) “graceful exit problem” plagued its initial formulation, which relied on tunneling from a false vacuum state, until the slow roll approximation was introduced. This theory explains the flatness, horizon, and magnetic monopole problems. For 10 points, name this theory pioneered by Guth and Linde that posits a period of rapid spatial expansion following the Big Bang.

ANSWER: cosmic inflation

14. In a reaction named for this scientist, water performs nucleophilic attack on a cyclic acetoxonium ion. That reaction uses wet acetic acid and iodine to stereospecifically convert alkenes to diols. The base-stable nature and diamagnetism of ferrocene led Wilkinson and this scientist to propose the correct structure. This scientist and Eschenmoser performed the first total synthesis of (*) Vitamin B12. He developed a reaction with the opposite stereochemical outcome to the Prevost reaction. If the sum of the number of (4q+2) suprafacial and (4r) antarafacial components is odd, then a pericyclic reaction is thermally allowed according to precepts partly named for this scientist. Fukui FMO theory predicts the same results as rules named for – for 10 points – which scientist and Hoffman?

ANSWER: Robert Burns Woodward

15. Note to all (both moderator and players): the answerline is fairly broad.

When making these objects, *erraillure* may occur from the bulb of percussion. In India, more-advanced and less-advanced versions of these objects were separated by the Movius line. Retouch can be used to distinguish these things from debitage. Grahame Clark divided these objects into five “Modes” based on time periods. François Bordes’ typology of these objects led him into a debate with Lewis Binford about the roles of style and function in their design. The (*) Levallois technique prepared these objects in stages. Use-wear analysis is often used to describe patterns of microwear on these things. Prepared-core techniques superseded pressure flaking ones for making these objects and their associated cortices. That process is called knapping. *Homo erectus* developed the Acheulean culture, which made bifacial types of these objects. An age named for the use of these objects preceded the Bronze Age. For 10 points, name these kinds of objects used by prehistoric humans made of materials often mined in quarries.

ANSWER: stone tools [or lithics; accept any specific kind of stone, like flint, chert, or obsidian; accept any specific tool, like scrapers, choppers, arrowheads, or handaxes; prompt on “tools” by asking “What are the tools made of?”]

16. To create a minimal example of this type of form, one would compute iterated dominance frontiers. To create that example of this type of form, one creates new variables for every assignment to a variable beyond the first, and inserts placeholder phi functions where the variable definitions merge. That example of this type of form requires that every variable be assigned exactly once and is the static single assignment form. An example of this type of form that consists of assembly-like instructions with at most three-operands per instruction is the three-address code. Compiling a Java program to bytecode can actually be considered (*) transforming it to this type of representation, which is then interpreted by the JVM. The syntax trees created during the analysis phase of compilation are an example of this form, [as is the code that the synthesis phase of compilation combines with the symbol table to create assembly code]. For 10 points, name this transitional form of a program during compilation, on which a compiler performs optimizations and transformations.

ANSWER: intermediate code [accept obvious equivalents in place of “code,” including representation, language, program, or form]

Commented [1]: hard to parse

Commented [2]: Go ahead and fix if you get time at lunch

17. One may compute a function that maps to these objects by using growth diagrams that fit in an n -by- n box or by using Viennot’s geometric construction. Specht modules are generated from equivalence classes of these objects. Knuth extended a function that maps permutations to these objects to map permutation *matrices* instead. That function that bijects permutations to them is named for Robinson and Schensted. These objects correspond to different bases for irreducible representations of the symmetric group. The number of these things is the (*) factorial of the number of cells divided by the product of each cell’s hook length, which is defined as one plus the number of cells below or to the right of the cell. These represent ways of associating a set of numbers to a Ferrers (“FARE-ers”) diagram. For 10 points, name this diagram which involves writing n numbers in n cells such that numbers increase top to bottom and left to right, a tableau named for a British mathematician.

ANSWER: Young tableaux

18. One example of this type of reaction is usually reversed using a solution of molecular iodine in acetonitrile. Another example of this type of reaction that produces octane as a byproduct is followed by heating the product to 870 kelvins to generate a spinel that superconducts below 13 kelvins. Thin film electrochromic devices often use tungsten bronzes prepared by this type of reaction. “Getter” reactions can topotactically perform the *reverse* of these reactions. A family of superconductors can be prepared by performing a (*) reductive variety of this reaction between alkali metals and fullerenes. Lithium ions often undergo these reactions to produce electrode materials. Graphite can undergo these reactions with a wide variety of substances including alkali metals and fluorine. For 10 points, name this type of reaction in which ions or molecules are inserted into a solid lattice.

ANSWER: intercalation [accept reductive or oxidative intercalation, accept lithiation until “tungsten bronzes” is read; anti-prompt on “deintercalation”; prompt on “redox” or “reduction” or “oxidation” or “insertion”]

19. A model in which these objects form “inside out” has been proposed to explain the abundance of systems in which they are observed to be “tightly packed.” Theories of how a class of these objects *stop* moving in the early stages of their development include interaction with a central cavity, magnetospheric truncation, or, most likely, tidal interactions. $2 G m$ over r^3 squared quantifies how much gravity increases the cross-section of these objects. That is the (*) Safronov number. One class of these objects is unlikely to form closer than the ice line, also called the frost line or snow line. A type of these that are called “hot” are thought to generally undergo type II migration. Proplyds are very well-lit regions which evolve into these objects. Part of the definition of these objects is that they “clear their neighborhood.” One method of finding these looks for small periodic Doppler shifts in the spectrum of a star, and another method detects small periodic drops in brightness of stars; that is the transit method. For 10 points, name these bodies which include Neptune and Mars.

ANSWER: planets [accept exoplanets; accept specific types of planets, like gas giants, etc.]

20. One may compute this quantity in two dimensions by drawing parallelograms from a reference line in a procedure named for Wellman. Kinematic vorticity number is an “invariant” of this quantity and provides a way to analyze its history. The product of multiple matrices describing the “incremental” form of this quantity can give its complete “finite” form. This principal x-axis over the principal y-axis is plotted against principal y-axis over principal z-axis in a Flinn diagram. Looking at the shape of (*) reduction spots is one way to examine the extent of this process, and other important “markers” for it include boudinage dikes, belemnites, and graptolites. Long thin regions where rocks experience intense amounts of this quantity are called shear zones. Earthquakes occur when high amounts of this quantity are stored and released according to elastic rebound theory. For 10 points, name this deformation caused by stress.

ANSWER: strain [prompt on deformation?]

21. The Tertiary reassembly of angiosperms may have caused the rise of some lineages of this group, including the ponerines and dolichoderines, according to the dynastic succession hypothesis, which also explains these animals’ consumption of elaiosomes and their symbioses with homopterans. These organisms frequently fixate on landmarks during their learning walks. An experiment in which stilts were attached to the legs of these animals demonstrated how they measure distance. Gp-9, the first (*) greenbeard allele, was discovered in one of these organisms. The fungus *Ophiocordyceps unilateralis* grows from the heads of these organisms after causing them to clamp down on a leaf, though some of these animals also farm fungi on leaf fragments. Bert Hölldobler and E. O. Wilson wrote a Pulitzer Prize-winning natural history of these eusocial animals, whose family name, Formicidae, comes from the fact that some make formic acid. For 10 points each, name this group of hymenopteran insects that include “army” and “leaf-cutter” types.

ANSWER: ants [accept Formicidae]

22. One of this equation’s two mixing rules replaces a parameter with a double sum over species and includes a binary interaction parameter. Those rules make use of the Berthelot–Lorentz combining rules. The critical exponent, gamma, equals 1 for this equation, so the isothermal compressibility diverges at the critical points. The exponent alpha equals zero for this equation, but many extensions give its heat capacity a temperature dependence. The principle that fluids at the same reduced temperature and pressure exert about the (*) same reduced pressure was first applied to this equation by its formulator. This equation has a critical point at p equals a over $27 b$ squared and T equals $8 a$ over $27 b$ squared. Problematic regions, where this equation predicts that the derivative of pressure with respect to volume is positive, may be fixed by drawing straight lines in an “equal area rule” due to Maxwell. For 10 points, name this equation of state that improves upon the ideal gas law by accounting for long term attractive forces and nonzero particle size.

ANSWER: van der Waals equation

23. In Frank Schatzing’s *Limit*, Owen Jericho searches for a character named Yoyo who is known to engage in this activity. Hiro Protagonist’s business card says that he’s the last of the freelance *these* and best sword fighter in the world. A five-part xkcd comic about a girl who is a prodigy at this activity ends with the line “You’d make a wonderful dread pirate, Roberts.” Henry Case’s central nervous system is damaged with mycotoxin so that he is unable to perform this action. He is healed so that he may perform this action again to free the entity (*) Wintermute. Hugh Jackman portrayed a character who is forced to perform this action while being held at gunpoint and receiving oral sex. One character engaging in this activity says “It’s a Unix system. I know this.” For 10 points, name this activity performed by characters in *Snow Crash*, *Neuromancer*, *Swordfish*, and *Jurassic Park*, perhaps to gain access to a mainframe.

ANSWER: hacking [prompt on “programmers” or other computer-related fields]

24. Experiments performed by Serge Haroche and others measured this process by coupling a trapped Rydberg atom to a quantum harmonic oscillator “Schrödinger’s cat.” W. H. Zurek primarily developed the theory of this process, explaining it as environmental monitoring destroying all but a set of more resilient pointer states, which he called *einselection*. Unlike dissipation, this process involves no loss of energy. This process corresponds to the decay or vanishing of (*) off-diagonal matrices of the reduced density matrix obtained by tracing over environmental states. The theory of this phenomenon explains wavefunction collapse as the observer becoming entangled with her experiment. For 10 points, name this process that corresponds to the loss of quantum effects like interference as a system interacts with its environment to transition to a classical or macroscopic state.

ANSWER: decoherence [accept anything having to do with losing coherence; accept dephasing]