## Materials

Description of the cover story, features, feature values, causal relationships, and blank properties for each of the six categories are presented below.

### Kehoe Ants

On the volcanic island of Kehoe, in the western Pacific Ocean near Guam, there is a species of ant called Kehoe Ants. For food, Kehoe Ants consume vegetation rich in iron and sulfur.

#### Features

($F_1$) Some Kehoe Ants have blood that is very high in iron sulfate. Others have blood that has normal levels of iron sulfate.

($F_2$) Some Kehoe Ants have an immune system that is hyperactive. Others have a normal immune system.

($F_3$) Some Kehoe Ants have blood that is very thick. Others have blood of normal thickness.

($F_4$) Kehoe Ants build their nests by secreting a sticky fluid that then hardens. Some Kehoe Ants are able to build their nests quickly. Others build their nests at a normal rate.

#### Causal Relationships

($F_1 \rightarrow F_2$). Blood high in iron sulfate causes a hyperactive immune system. The iron sulfate molecules are detected as foreign by the immune system, and the immune system is highly active as a result.

($F_1 \rightarrow F_3$). Blood high in iron sulfate causes thick blood. Iron sulfate provides the extra iron that the ant uses to produce extra red blood cells. The extra red blood cells thicken the blood.

($F_1 \rightarrow F_4$). Blood high in iron sulfate causes faster nest building. The iron sulfate stimulates the enzymes responsible for manufacturing the nest-building secretions, and an ant can build its nest faster with more secretions.

($F_2 \rightarrow F_4$). A hyperactive immune system causes faster nest building. The ants eliminate toxins through the secretion of the nest-building fluid. A hyperactive immune system accelerates the production of nest-building secretions in order to eliminate toxins.

($F_3 \rightarrow F_4$). Thick blood causes faster nest building. The secreted fluid is manufactured from the ant's blood, and thicker blood means thicker secretions. Thicker secretions mean that each new section of the nest can be built with fewer application of the fluid, increasing the overall rate of nest building.

## Lake Victoria Shrimp

Lake Victoria Shrimp are found in Lake Victoria, Africa. The concentration of algae that are rich in choline is unusually high in some parts of Lake Victoria.

### Features

($F_1$) Lake Victoria Shrimp use acetylcholine (ACh) as a brain neurotransmitter. Some Lake Victoria Shrimp have an unusually high amount of ACh. Others have a normal amount of ACh.

($F_2$) Lake Victoria Shrimp have an a “flight” response in which they flee from potential predators. The flight response consists of an electrical signal sent to the muscles which propel the shrimp away from a predator. Some Lake Victoria Shrimp have a flight response which is long-lasting. Others have a normal flight response.

($F_3$) Some Lake Victoria Shrimp have an accelerated sleep cycle (4 hours sleep, 4 hours awake). Others have a normal sleep cycle (12 hours sleep, 12 hours awake).

($F_4$) Some Lake Victoria Shrimp have high body weight. Others have a normal body weight.

### Causal Relationships

($F_1 \rightarrow F_2$). A high quantity of ACh neurotransmitter causes a long-lasting flight response. The duration of the electrical signal to the muscles is longer because of the excess amount of neurotransmitter.

($F_1 \rightarrow F_3$). A high quantity of ACh neurotransmitter causes an accelerated sleep cycle. The neurotransmitter speeds up all neural activity, including the internal "clock" which puts the shrimp to sleep on a regular cycle.

($F_1 \rightarrow F_4$). A high quantity of ACh neurotransmitter causes a high body weight. The neurotransmitter stimulates greater feeding behavior, which results in more food ingestion and more body weight.

($F_2 \rightarrow F_4$). A long-lasting flight response causes a high body weight. The shrimp are propelled over a greater area of the lake, and find more new food sources as a result.

($F_3 \rightarrow F_4$). An accelerated sleep cycle causes a high body weight. Shrimp habitually feed after waking, and shrimp on an accelerated sleep cycle wake three times a day instead of once.

## Myastars

In certain parts of the known universe there exists a large number of stars called Myastars. Myastars are formed from clouds of helium.

## Features

($F_1$) Some Myastars are constructed from ionized helium. Others are constructed from normal helium.

($F_2$) Some Myastars are very hot. Others have a normal temperature.

($F_3$) Some Myastars are extremely dense. Others have a normal density.

($F_4$) Some Myastars have a large number of planets. Others have a normal number of planets.

## Causal Relationships

($F_1 \rightarrow F_2$). Ionized helium causes the star to be very hot. Ionized helium participates in nuclear reactions that release more energy than the nuclear reactions of normal hydrogen-based stars, and the star is hotter as a result.

($F_1 \rightarrow F_3$). Ionized helium causes the star to have high density. Ionized helium is stripped of electrons, and helium nuclei without surrounding electrons can be packed together more tightly.

($F_1 \rightarrow F_4$). Ionized helium causes the star to have a large number of planets. Because helium is a heavier element than hydrogen, a star based on helium produces a greater quantity of the heavier elements necessary for planet formation (e.g., carbon, iron) than one based on hydrogen.

($F_2 \rightarrow F_4$). A hot temperature causes the star to have a large number of planets. The heat provides the extra energy required for planets to coalesce from the gas in orbit around the star.

($F_3 \rightarrow F_4$). High density causes the star to have a large number of planets. Helium, which cannot be compressed into a small area, is spun off the star, and serves as the raw material for many planets.

# Meteoric Sodium Carbonate

A special form of sodium carbonate ($Na_2CO_2$) is found in meteors that land on earth. Molecules of "meteoric" sodium carbonate differ from molecules of normal sodium carbonate that are found on earth in that they have been exposed to intense x-rays in space.

## Features

($F_1$) Some meteoric sodium carbonate molecules are radioactive, i.e., theta particles get emitted from the nuclei of the sodium (Na) atoms. Other meteoric sodium carbonate molecules are nonradioactive.

($F_2$) Some molecules of meteoric sodium carbonate have their five atoms arranged in an eight-bond pyramid (four atoms at the base of the pyramid, and one at the “peak”). Other molecules of meteoric sodium carbonate have their five atoms arranged in a normal five-bond ring, as in normal sodium carbonate found on earth.

($F_3$) Some molecules of meteoric sodium carbonate are positively charged. Others have no charge.

($F_4$) Some molecules of meteoric sodium carbonate are very reactive (tend to enter into chemical reactions). Others react at normal levels.

## Causal Relationships

($F_1 \rightarrow F_2$). Radioactivity causes the molecule to take on a pyramid structure. Theta particles provide the extra energy required to form the additional atom-to-atom bonds required for the pyramid.

($F_1 \rightarrow F_3$). Radioactivity causes the molecule to have a positive charge. Theta particles are negatively charged, and so leave the molecule with a positive charge after they are emitted.

($F_1 \rightarrow F_4$). Radioactivity causes the molecule to be reactive. Theta particles break up surrounding molecules and hence accelerate the natural rate of chemical reactions.

($F_2 \rightarrow F_4$). The pyramid structure causes the molecule to be reactive. Once one atom of the pyramid is involved in a chemical reaction, the remaining atoms break apart, providing the raw material for further reactions.

($F_3 \rightarrow F_4$). Having a positive charge causes the molecule to be reactive. The molecule attracts negatively-charged subparts of other molecules, which breaks up the other molecules, and causes chemical reactions.

## Romanian Rogos

The Romanian Motor Company, located in Bucharest, Romania, manufactures an automobile called a Rogo which is designed to run on fuel refined locally in Romania. Depending on where it is refined, the fuel may or may not have butane ($C_4H_{10}$), a naturally-occurring hydrocarbon, blended in with the gasoline.

### Features

($F_1$) Some Rogos are filled with gasoline laden with butane. Other Rogos are filled with gasoline with no butane.

($F_2$) The fuel filters of Rogos have gaskets. Some Rogos have fuel filter gaskets that are extra loose. Other have normal fuel filter gaskets.

($F_3$) Some Rogos have a hot engine temperature. Others have a normal engine temperature.

($F_4$) Some Rogos have a high amount of carbon monoxide in their exhaust. Others have a normal amount of carbon monoxide in their exhaust.

### Causal Relationships

($F_1 \rightarrow F_2$). Butane-laden fuel causes loose fuel filter gaskets. The butane tends to corrode the rubber out of which gaskets are made, and so the gaskets do not fit tightly.

($F_1 \rightarrow F_3$). Butane-laden fuel causes hot engine temperature. The butane in the fuel burns at a hotter temperature than normal gasoline.

($F_1 \rightarrow F_4$). Butane-laden fuel causes high amounts of carbon monoxide in the exhaust. Butane contains more carbon than normal gasoline, and so more carbon is available to bind with oxygen to form carbon monoxide.

($F_2 \rightarrow F_4$). A loose fuel filter gasket causes high amounts of carbon monoxide in the exhaust. Loose fuel filters allow more air into the gas-air mixture, providing the oxygen which binds with carbon to form carbon monoxide.

($F_3 \rightarrow F_4$). Hot engine temperature causes high amounts of carbon monoxide in the exhaust. The heat provides the energy required for the carbon to bind with the oxygen.

Neptune Military Personal Computers

The power supplies for the Neptune Military Personal Computers are made from tungsten mined in southern Utah, some samples of which are magnetic.

Features

($F_1$) Some Neptune Personal Computers have a power supply that is magnetic and extends a magnetic field. Others have a normal non-magnetic power supply that extends no magnetic field.

($F_2$) Neptune Personal Computers have an internal clock based on a crystal oscillator that determines how fast the computer runs. Some Neptune Personal Computers have a clock speed that is too fast. Others have a normal clock speed.

($F_3$) Some Neptune Personal Computers run at an unusually high temperature. Others run at a normal temperature.

($F_4$) Some Neptune Personal Computers have a screen image that is unusually bright. Other have a screen image of normal brightness.

Causal Relationships

($F_1 \rightarrow F_2$). Magnetic power supplies cause the computer to have a fast clock speed. The magnetic field interferes with the natural phase transitions of the crystal oscillator, the result being that the crystal oscillator emits square waves at a faster rate.

($F_1 \rightarrow F_3$). Magnetic power supplies cause the computer to run at a hot temperature. The magnetic field influences the copper atoms in electrical wire to orient themselves perpendicularly to the flow of electricity, increasing the resistance, and resulting in more heat being generated.

($F_1 \rightarrow F_4$). Magnetic power supplies cause the computer to display a bright image. The magnetic field concentrates the electron beam which strikes the phosphor on the computer screen, leading to an image that is slightly smaller but brighter.

($F_2 \rightarrow F_4$). A fast clock speed causes the computer to display a bright image. The clock controls how fast the image is "repainted" on the screen. A faster clock means that the phosphors on the screen's surface are being irradiated with electrons more often, leading to a brighter image.

($F_3 \rightarrow F_4$). Hot temperature causes the computer to display a bright image. Heat increases the efficiency of the cathode ray tube, leading to a more energized electron beam and a brighter screen.