## Passage III

Star formation begins with the gravitational collapse of matter in an interstellar gas cloud. A *protostar* (forming star) affects gas in the surrounding portions of the cloud in 2 ways:

- The protostar's gravitational field attracts gas, causing the gas to *accrete* (accumulate onto the protostar).
- *Radiation pressure* (RP) associated with the protostar's emissions causes gas to be pushed away from the protostar, inhibiting accretion.

Star formation ends when the effect of RP overcomes that of gravity. At that point, the protostar can no longer gain mass by accretion and is considered a fully formed star.

Three scientists debate whether the maximum mass that a protostar can reach by accretion is great enough to account for the most massive stars observed.

*Scientist 1*

The effect of RP is uniform in all directions around a protostar. As a result, the maximum mass that a protostar can reach by accretion is 20 $M_S$ (1 $M_S$ = mass of the Sun). Any further increase in mass requires at least 1 *stellar merger* (the combination of 2 or more fully formed stars into 1). Because stars tend to form in clusters, stellar mergers are likely.

*Scientist 2*

Scientist 1 is correct that stellar mergers are likely. However, because a protostar rotates about its axis, a disk of gas forms in the plane of the protostar's equator. This reduces the effect of RP in that plane, allowing gas from the disk to readily accrete. As a result, the maximum mass that a protostar can reach by accretion is 40 $M_S$. Any further increase in mass requires at least 1 stellar merger.

*Scientist 3*

Stellar mergers are very unlikely given the vast distances between stars, even within clusters. Scientist 2 is correct about the formation and the effect of the disk. In addition, a protostar produces bubble-like regions of radiation that increase the effect of RP near the protostar's poles, promoting the flow of gas into the disk. As a result, accretion continues until the surrounding portions of the cloud are nearly depleted of gas. Therefore, the maximum mass that a protostar can reach by accretion is limited only by the amount of available gas.

**14.** Relative to the center of the protostar, does gravity more likely accelerate gas particles inward or outward, and does RP more likely accelerate gas particles inward or outward?

| | gravity | RP |
|---|---|---|
| **F.** | inward | inward |
| **G.** | inward | outward |
| **H.** | outward | inward |
| **J.** | outward | outward |

**15.** Based on Scientist 2's argument, do gas particles more likely accrete near the equator or near the poles of a protostar with a disk?

**A.** Near the equator, because the effect of RP is increased there.
**B.** Near the equator, because the effect of RP is reduced there.
**C.** Near the poles, because the effect of RP is increased there.
**D.** Near the poles, because the effect of RP is reduced there.

**16.** Detailed surveys of star clusters in and near the Milky Way have yielded no evidence of stellar mergers having occurred at any time during the galaxy's history. These results are *inconsistent* with the argument(s) of which scientist(s)?

**F.** Scientist 1 only
**G.** Scientist 3 only
**H.** Scientists 1 and 2 only
**J.** Scientists 1 and 3 only

**17.** One of the most massive stars known is Eta Carinae, which has an approximate mass of 120 $M_S$. Based on the arguments of Scientists 1, 2, and 3, respectively, what is the *minimum* number of stars, each formed entirely by accretion, that would have been required to form Eta Carinae?

| | Scientist 1 | Scientist 2 | Scientist 3 |
|---|---|---|---|
| **A.** | 5 | 3 | 1 |
| **B.** | 5 | 4 | 2 |
| **C.** | 6 | 3 | 1 |
| **D.** | 6 | 4 | 2 |

**18.** When the effect of RP overcomes that of gravity, a star is said to have "emerged from its envelope," because that is the first time the star is directly observable from outside the cloud. An observation of which of the following stars emerging from its envelope would support Scientist 2's argument but weaken Scientist 1's argument?

**F.** A 15 $M_S$ star
**G.** A 20 $M_S$ star
**H.** A 30 $M_S$ star
**J.** A 50 $M_S$ star

**19.** Scientists 2 and 3 agree that a disk forms around a protostar as a result of the protostar's:

**A.** motion.
**B.** emission of radiation.
**C.** location within a star cluster.
**D.** merger with another star.

**20.** Which of the scientists, if any, would be likely to agree that the Sun could have formed entirely by accretion?

**F.** Scientist 1 only
**G.** Scientist 3 only
**H.** Scientists 1, 2, and 3
**J.** None of the scientists