1. The schematic *word equations* below describe a simple ecosystem model for the open ocean euphotic zone comprising 4 state variables – phytoplankton, nutrients, zooplankton and detritus.

In the blank spaces provided enter the missing processes *with the correct sign* for each term

\[
\frac{dP}{dt} = \text{______________} \\
\quad - P \text{ mortality} \\
\quad - \text{grazing by } Z \\
\]

\[
\frac{dN}{dt} = -\text{photosynthesis} \\
\quad + P \text{ excretion} \\
\quad + Z \text{ excretion} \\
\quad \text{______________} \\
\quad + \text{input from upwelling or mixing} \\
\]

\[
\frac{dZ}{dt} = \text{______________} \\
\quad \text{______________} \\
\quad \text{______________} \\
\quad - \text{fecal pellet egestion} \\
\]

\[
\frac{dD}{dt} = (1-\gamma)\text{grazing by } Z \quad \text{[inefficient sloppy feeding fraction of grazing]} \\
\quad \text{______________} \\
\quad + Z \text{ mortality} \\
\quad \text{______________} \\
\quad - \text{microbial recycling of nutrients} \\
\quad - \text{loss by sinking out of euphotic zone} \\
\]
2. Sketch a **3-dimensional** cartoon of a northern hemisphere coastal upwelling region where the ocean is to the west of the coast, i.e. an eastern boundary current regime.

(a) Indicate the upwelling favorable wind direction, the Ekman currents, temperature and/or density patterns, and the location and direction of the coastal jet. Label features clearly and/or write a caption that explains the features you depict. Pay attention to displaying the correct location of currents with respect to temperature/density patterns.

(b) Describe how this system is important for silica cycling and sedimentation in the ocean.

3. The biological pump moves carbon and nutrients into the deep sea. The biological pump is driven by surface productivity. The community evolution of the spring blooms is different in the Atlantic and Pacific. This has an impact on the transport (flux) between the surface and deep reservoirs.

(a) In both the Atlantic and Pacific, the spring bloom progresses from a eutrophic system to an oligotrophic system. The Pacific is more stratified in winter than the Atlantic. Describe the community evolution for **both** Atlantic and Pacific.

(b) Describe the flux of carbon from the surface ocean to the deep sea, at the beginning, middle, and end of the spring bloom (that is, across the progression from eutrophic to oligotrophic you described above) for **just** the Atlantic Ocean.

(c) Compare and contrast the flux of silica in each ocean for the spring bloom. Make sure to consider difference in the silica levels in the subsurface waters between the 2 oceans.