Biological Engineering

An important distinction between biological engineering and other physical engineering disciplines is understanding how living systems operate similarly and differently than inanimate physical/chemical systems. Another important aspect of living systems is their ability to modify/control their interactions with both inanimate systems and other living systems.

Engineers learn scientific principles, e.g. laws of energy/thermodynamics, physics of electricity/magnetism, radiation, gravitation, etc. The great success/value of engineering is the ability to create useful quantitative models based on these principles to design/control of systems/products to meet people’s needed/desires, e.g. engineering, e.g. Fourier’s law of heat transfer, 1st order reaction kinetics, Navier-Stokes model of fluid dynamics, Ohm’s law, etc.

Example quiz questions/answers:

Enthalpy (H) called a convenience form of energy, defined as internal energy (U) plus pressure (P) times volume (V), i.e. H=U+PV. Why is enthalpy considered a ‘convenient’ form of energy for open systems?

When mass enters/leaves a system, it carries internal energy (U) and requires work to move a mass into/out of the system (modeled as PV work). Therefore, the total energy interaction must include the work to move the mass. It is inconvenient to calculate this for every mass flow entering/leaving an open system. Hence, for convenience, enthalpy is defined as the internal energy (U) plus the transfer work (PV) so you don’t have to calculate the transfer work each time separately. Note: Enthalpy is not a real form of energy but rather a convenience form (sort of like including the cost of transportation in the total cost of purchasing an item). Gibb’s and Helmholtz energies are similarly combinations for convenient calculations of energy changes under different situations.

If you want an assignment to be re-evaluated/graded, you will need to make a critical argument as to why this should be done. How long do you have after the assignment has been returned to request a re-evalution?

1 week

As a biological engineer, what are the fundamental rules which guide the engineering of biological systems? Do living systems operate under the same physical laws/constraints as inanimate systems? If so, how are they different? What models exist/are needed to design/control biologically engineered systems/products?

Questions for group discussion:

1. The 2nd law of thermodynamics states that in all spontaneously processes the change in entropy must increase, i.e. dS/dt >0 or Sfinal > Sinitial. One way to comprehend entropy is that increases in entropy correspond to more randomness, i.e. a decrease of order/complexity. In general, biological systems (microbes, plants, primates, etc.) appear to spontaneously increase in complexity/organization as they grow/replicate. Please explain whether living systems violate the 2nd law, and if not, how this is possible.
2. Environmental sustainability is a compelling contemporary societal theme for engineering design. However, convenience/comfort often are in direct conflict with sustainability. One way to analyze sustainability is to understand that the greater the convenience/comfort, the greater the gradient/rate of utilization. For example, on a cold day, it takes more energy to maintain a comfortable indoor temperature, i.e. greater temperature gradient; to get faster cell phone processor speeds or internet speeds requires a greater electrical/voltage gradient; to maintain a clean home environment/healthy body requires higher chemical gradients (separations), e.g. flushing the toilet/disposing of your trash. Assuming you exist in a system that always has gradients between the system and the environment, is it possible for this system to ever be at equilibrium with the environment, i.e. sustainable? Asked another way in engineering terms, what is the cost of maintaining a comfortable/convenient sustainable environment (gradients)?

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