What is the definition of a PID controller?

- **The Proportional Response**

depends only on the difference between the set point and the process value. This difference is referred as 'error' (ε). The proportional factor or gain (*P*) determines the output response to the error signal. Increasing the proportional factor will increase the response time of the controller. However if the proportional factor is too high the system will become unstable and oscillate around the set point. If the proportional factor is too small the system is not able to reach the set point in a given time.

- **The Integral Response**

sums the error term over time. The result is that even a small error term will cause the integral component to increase slowly. This means there is a continually increase over time until the error term reaches zero.

- **The Derivative Response**

causes the output to decrease if the process variable is increasing rapidly. The response itself is proportional to the rate of change of the process variable. Increasing the derivative time (*Td*) will cause the controller system to react more strongly to changes in the error term and will increase the speed of the overall control system response. The derivative response is very sensitive to noise in the process variable signal. If the sensor feedback signal is noisy or the control loop is too slow, the derivative response can make the control system unstable. These reasons and the absence of fast increasing process variables make it unnecessary for a biological control system to have a derivative component (see formula 3 on the following slide).

What is the definition of a PID controller?

$$PID.OUT(t) = P \cdot (\varepsilon + \frac{1}{t_i} \int \varepsilon dt + T_D \frac{d\varepsilon}{dt}) \qquad (1)$$

$$PID.OUT(t) = P \cdot (\varepsilon + \frac{1}{t_i} \sum \varepsilon \Delta t + T_D \frac{\Delta\varepsilon}{\Delta t}) \qquad (2)$$

$$PI.OUT(t) = P \cdot (\varepsilon + \frac{1}{t_i} \sum \varepsilon \Delta t) \qquad (3)$$

$$PI.OUT(t) = P \cdot (SP - PV) + \frac{P}{t_i} \sum (SP - PV) \Delta t \qquad (4)$$