- Information
- Early electric computers
- Silicon vs Carbon circuits
- Biological neural networks
- Artificial neural networks

- Shannon: information is the surprise in receiving a message $m \in M$

$$I(m) = \log\left(\frac{1}{p(m)}\right) = -\log p(m), p(m) = \Pr(m)$$

- Entropy is the amount of uncertainty in a message space

$$S(M) = \mathbb{E}[I(M)] = -\sum_{m \in M} p(m) \log p(m)$$

- Consider a linear function $y = at$. If at time t_1 the "message" $y_1 = at_1$ is known, is there any "surprise" in receiving at at time t_2 the message $y_2 = at_2$?

  $\rightarrow$ Expected message is $y_2 = y_1 t_2 / t_1$ with $p(y_2) = 1$

  $\rightarrow$ Information $I(y_2) = -\log 1 = 0$

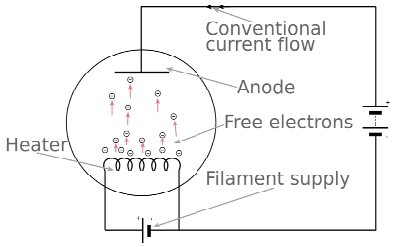
- To transfer information $y(t)$ should be close to discontinuous

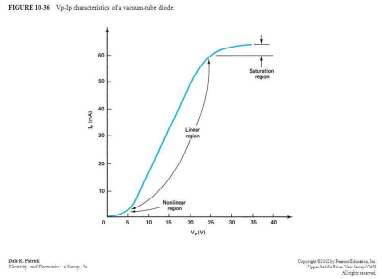
- Linear circuit elements: continuous v input gives continuous i output

Resistance	Capacitance	Inductance
$v(t) = Ri(t)$	$v'(t) = \frac{1}{C} i(t)$	$v(t) = Li'(t)$

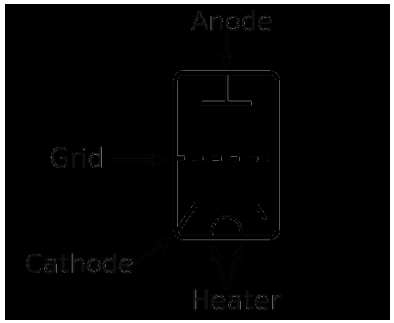
- First generation nonlinear circuit elements: vacuum tubes

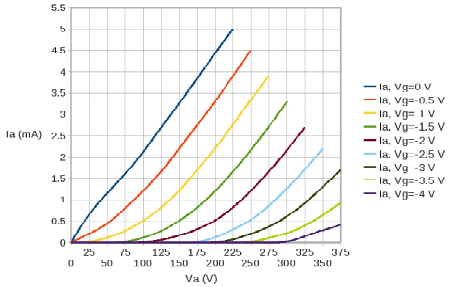
Diode



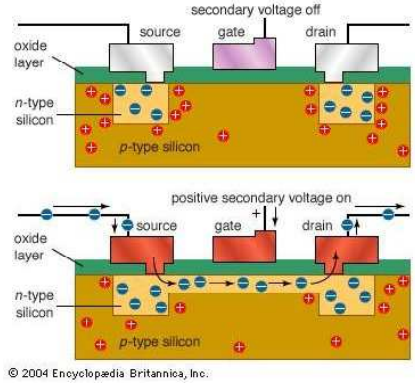


Triode





- Vacuum tubes replaced by transistors



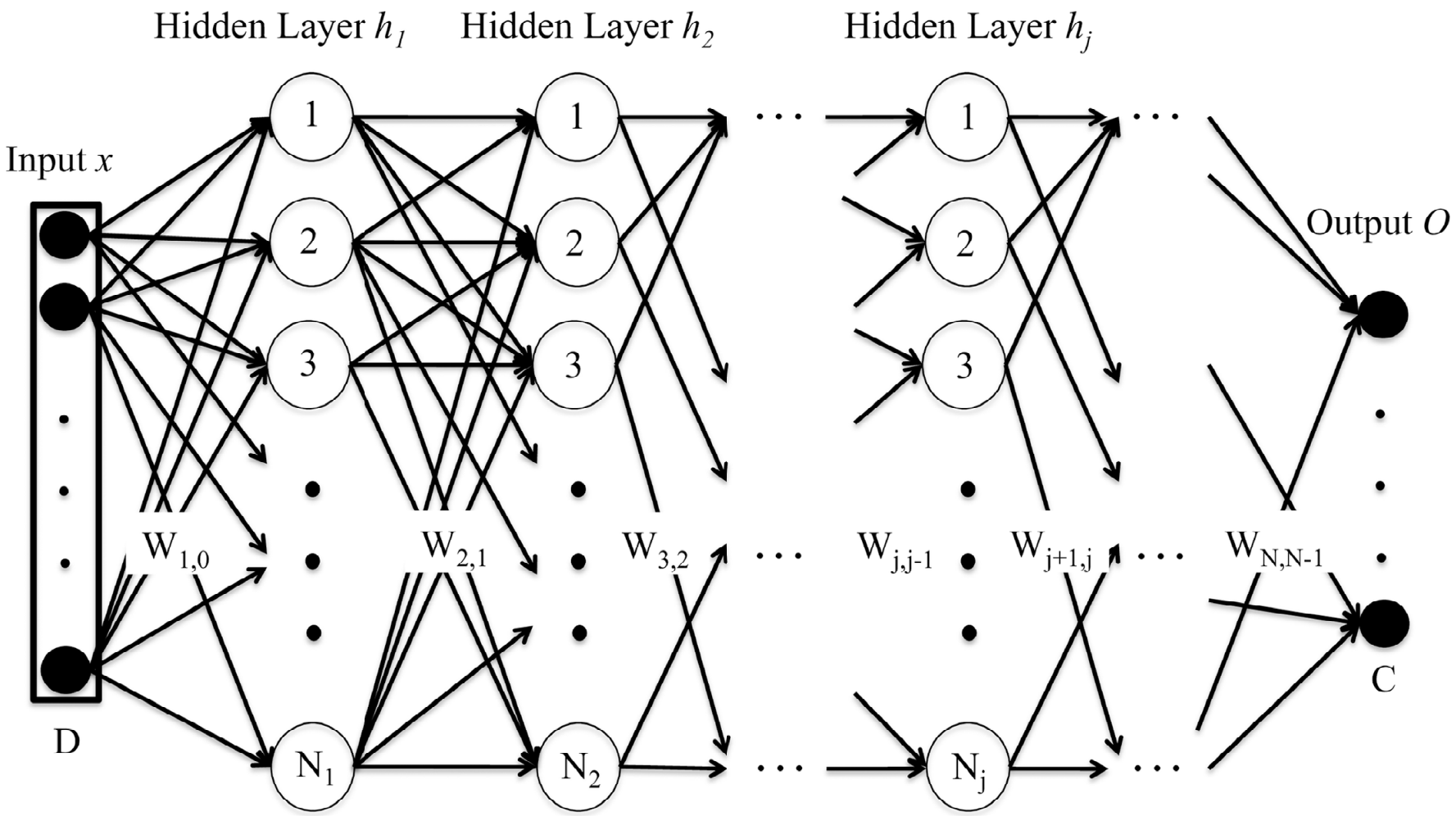
- Different technology, Silicon replacing vacuum tubes, but the key aspect is close to discontinuous response

- Transistors replaced by integrated circuits, i.e., multiple transistors produced by etching a silicon substrate
- Metal-Oxide-Semiconductor-Field-Effect Transistor
- Fourth generation: Very Large Scale Integrated circuits
- "Fifth generation": Massive Parallel Computing

- Localized increase of charge carriers ("doping") carried out at $\sim\mathcal{O}(10)$ nm

- Hodgkin Huxley model:

  $\longrightarrow$ highly nonlinear response



$h_1 = g(W_{1,0}\, x+b_1)$ $h_2 = g(W_{2,1}h_1+b_2)$ $h_j = g(W_{j,j-1}h_j+b_j)$