\subsubsection{Logic gate}

In biocomputing, enzymes as logic gate constituents in combination with chemical inputs to create an always-the-same end product is used to mimick Boolean logic gates such as AND and OR. To digitalize chemical processes, two levels of concentrations of chemical reaction materials are considered as input signals. 0 is usually considered as the absence of a enzyme, but it can be altered. 1 equals a significantly difference to the absence or the as 0 defined concentration.

The result is a certain substance that acts as an output signal. If it is measurable, it signals the value 1, if not, it signals value 0.

(Katz) \\

Beispiel AND

In Fig 1 the enzymes glucose oxidase (short Gox. It catalyses the oxidation of glucose to hydrogen peroxide and D-glucono-δ-lactone and is often used for analysing free sugar in blood) and catalase (catalyzes the decomposition of hydrogen peroxide to water and oxygen) operate as the logic gate machinery. The two input signals are H2O2 (Hydrogen peroxide) and glucose (blood sugar). When both substrates are present the inputs react and produce gluconic acid, which results in an optical absorbance change, that was defined as the ouput signal of the enzyme logic gate. The optical absorbance change just appeared in the presence of both inputs, mimicking the Boolean operation AND.

\begin{figure}[H] \centering \includegraphics[scale= 0.3]{pics/AND.png} \caption{Network diagramm} \label{img:and} \end{figure}

\subsubsection{networks with electrochemical transduction}

By assembling these single logic gates, mimicking Boolean operations,it is possible to create small logic networks (e.g. half-adder/ half subtractor)/enzyme logic systems!!!!!!!!!!!!!!!!!. By adding a transducer, it is possible to convert the physical change into an electric signal.

Figure 1: A combination of different enzym-based logic gates, functioning as AND or OR. The cascade of reactions, when all four input chemicals are present, results in ph changes. Ph measures the degree to which a solution is acidic or alkaline. The scale is defined from 0 (acid solution) to 14 (lye solution).

The logic network is composed of four concatenated logic gates. Those gates contain the enzymes alcohol dehydrogenase (ADH, disassembling toxic alcohols), glucose dehydrogenase( catalyst for the oxidation of glucose) and glucose oxidase act as logic gates the four specific different input signals NADH (resulting through reduction from Nicotinamid-Adenin-Dinukleotid NAD, which is a coenzyme found in all living cells), actealdehyde (also named ethanal, which is an organic chemical compound, for example naturally occuring in coffee, bread, and ripe fruit), glucose and oxygen (O).

When all inputs are present the reaction yields to an acid medium, lowering the original pH value of the solution from initial 6-7 to approximately 4.

%erst kombination von reaktionen

\begin{figure}[H] \centering \includegraphics[scale= 0.3]{pics/biocomputing\_sensor.png} \caption{Network diagramm} \label{img:grafik-test} \end{figure}

%verbindung mit transducer

The lower pH value resulted in switching to ON of an electrochemical interface that functioned as a transducer which makes the electrical signal readable (with low voltage as the 0-value and a defined higher voltage as 1). While 16 different combinations of input signals were possible (being present or absent) only four of those resulted in an ON state.

\begin{figure}[H] \centering \includegraphics[scale= 0.4]{pics/ph.png} \caption{Network diagramm} \label{img:ph} \end{figure}

This combination is an example for a multisignal processing enzyme logic system coupled with an electrochemical transduction readout of the output signal (with pH change).