Freie Universität Berlin

Weber-Fechner's law, the Goldman-Hodgkin-Katz equation and curve fitting:

a hands-on experiment for the undergraduate laboratory

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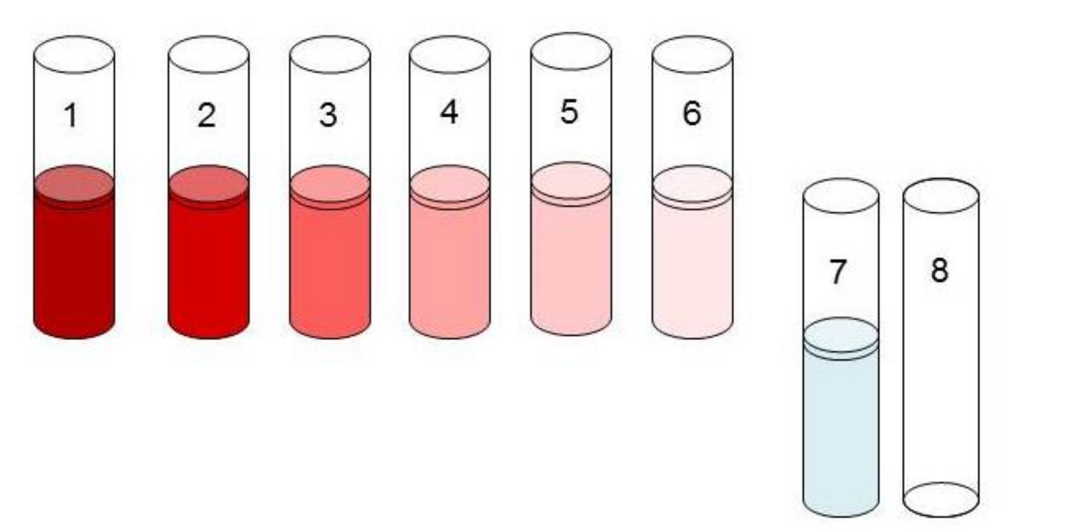
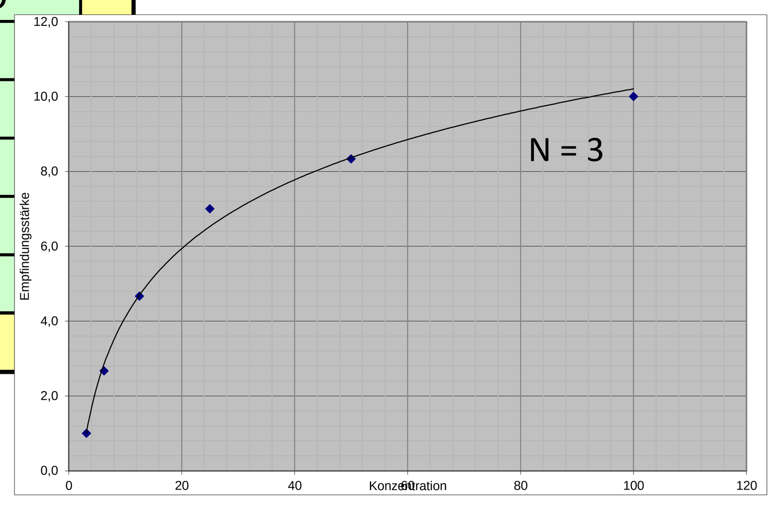
Introduction & Methods:

Weber-Fechner's law is an impressive example of early attempts to study the human response to a physical stimulus in a quantitative fashion. We attempted to develop an experiment avoiding the pitfalls of adaptational responses and suitable for training undergraduate students in data analysis using standard software.



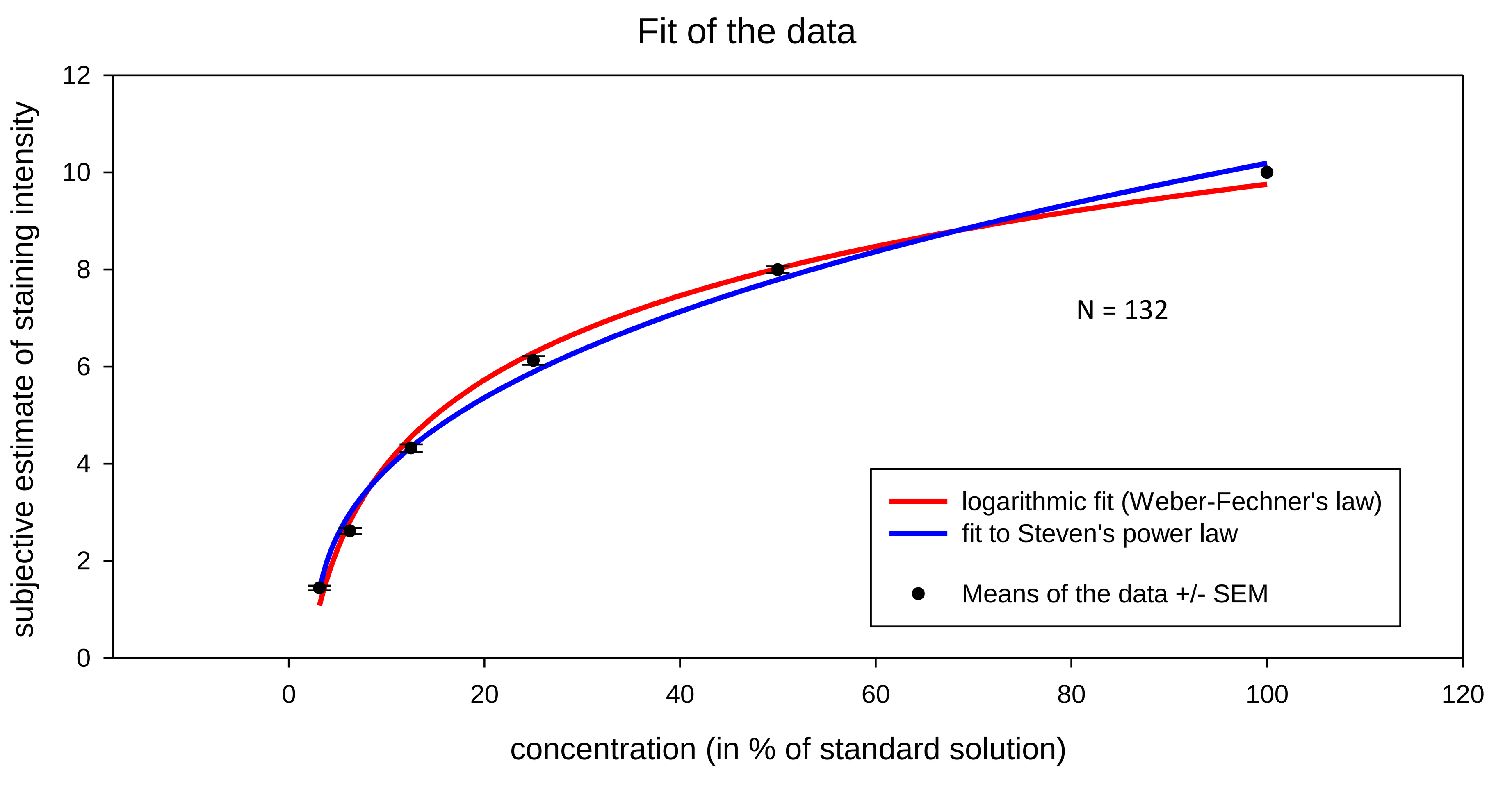
Röhrchen	Konzentration (%)	Farbempfindungswert Proband 1	Proband 2	Proband 3	Mittelwert
1	100	10	10	10	10.0
2	50				
3	25				
4	12.5				
5	6.25				
6	3.125				



132 undergraduate students working in groups of 2 were given a non-toxic red stock solution (e.g. cherry juice, 100%) and water (0%) and asked to prepare samples of 50%, 25%, 12.5%, 6.25 and 3.125% concentration ("x") via serial dilution.

The two students in the group and one uninvolved test person then ranked the staining intensity of the solutions on a subjective linear scale ("Ψ(x)") ranging from 10 (pure stock solution, bright red) to 0 (pure water). The concentrations "x" of the solutions and the subjective estimates of staining intensity "Ψ(x)" were entered into a pre-prepared excel worksheet. Instructions were given on how to calculate the mean, plot the results (n=3), and fit the data with a logarithmic function.

Results



In all but one of the 66 groups, a logarithmic fit of Ψ(x) versus x yielded a coefficient of determination $R^2 > 0.90$, in 58 groups, R^2 was > 0.97. A fit of the means of all 132 measurements to Weber-Fechner's law gave

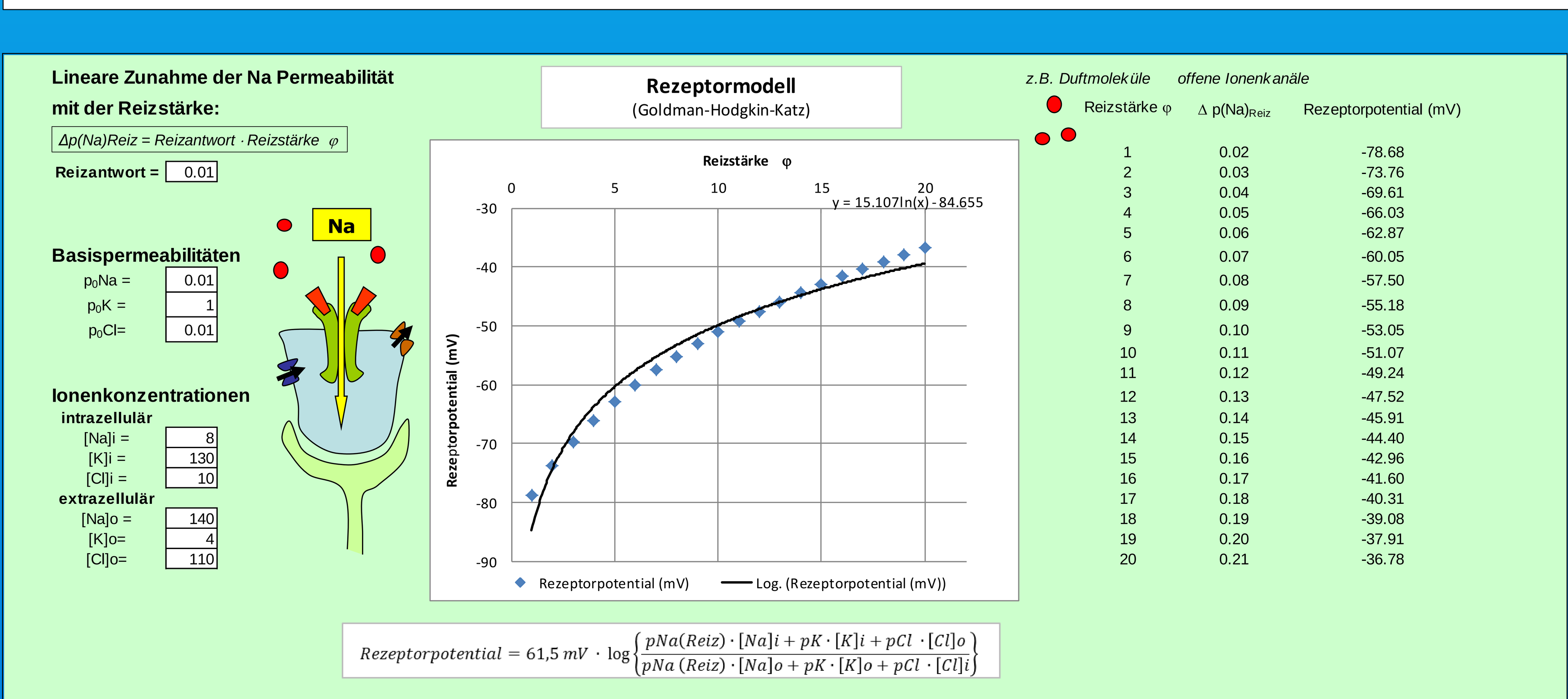
$$\Psi(x) = 2.5\cdot \mathrm{Ln}(x) - 1.77 \quad (R^2 = 0.99).$$

In principle, the data could also be fitted to Steven's power law

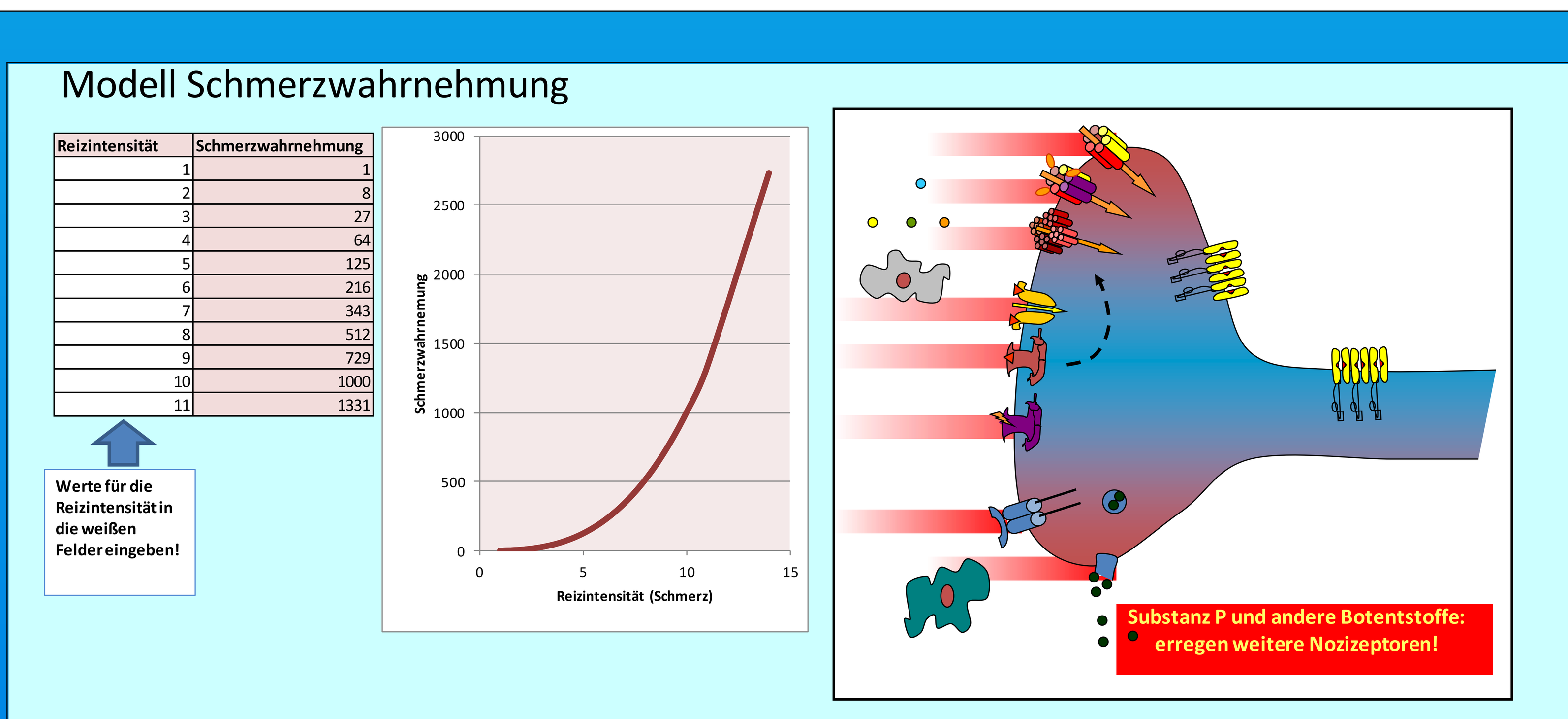
$$\Psi(x) = 1.85*(x-2.68)^{0.37} \quad (R^2 = 0.99)$$

However, this requires introduction of a third constant, which is not offered by the basic trendlines menu of excel. Since the more complex fitting routines of excel tend to be difficult to handle, it is not a good idea to attempt such a fit in an undergraduate course. More advanced students should probably be introduced to software specialized for curvefitting (e.g., Igor Pro, SigmaPlot).

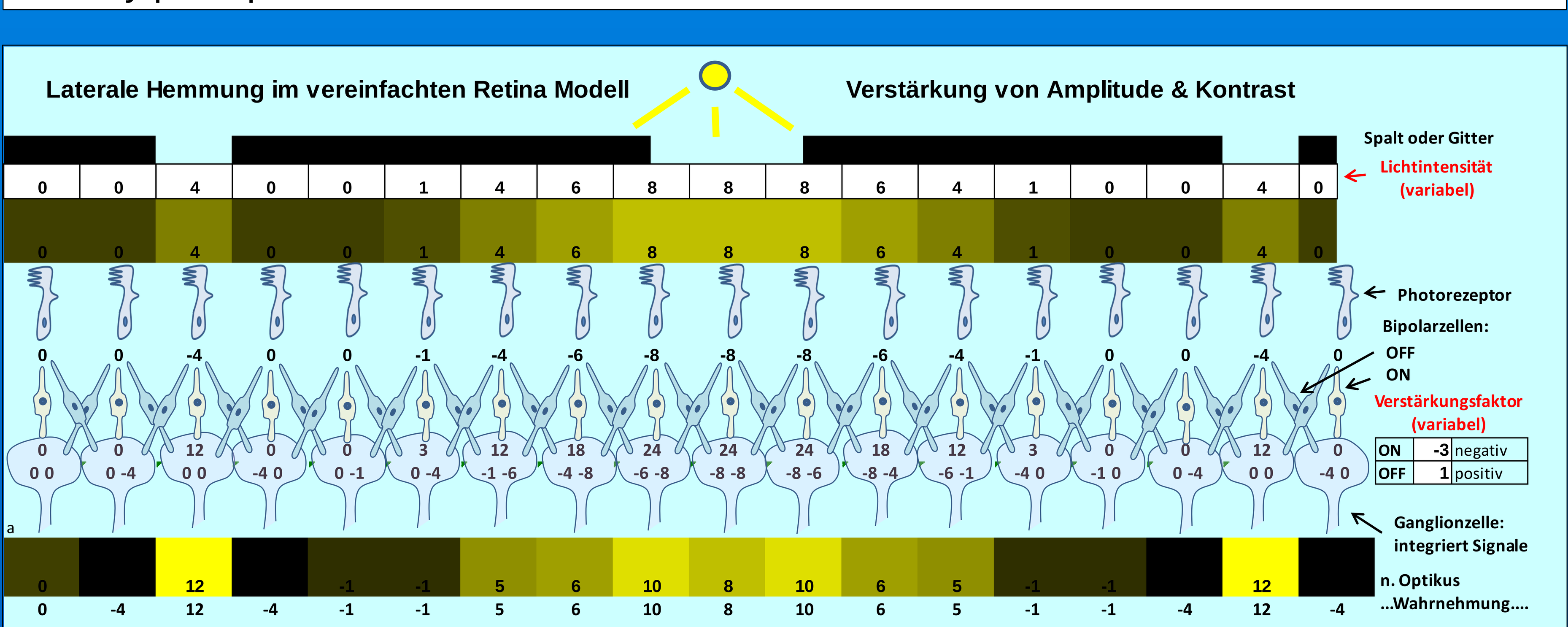
Discussion

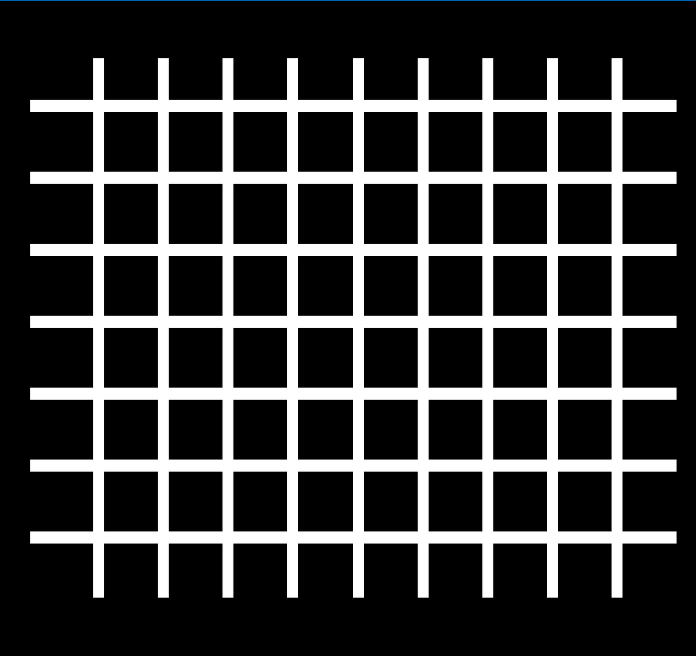


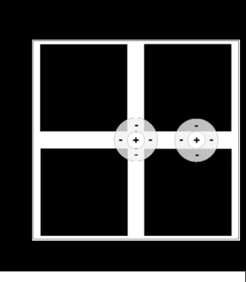
A model for the receptor potential based on the Goldman-Hodgkin-Katz equation is developed on a separate spreadsheet. The limits of this model and of other models of sensory perception are discussed.



In particular, an important exception to Weber-Fechner's law is high-lighted: pain perception. One possible reason for the fact that pain perception rises in an exponential manner with the stimulus (multiple receptors and extracellular signalling) is presented in a separate spreadsheet. Again, the limits of the model are pointed out: thus, the model does not incorporate central processing.







Finally, a classical model of lateral inhibition is presented in spreadsheet form and discussed with regard to to Hermann`s grid.

http://www.leinroden.de/files/Hermanngitter%20und%20die%20Folgen.pdf

Conclusions

Subjective estimates of staining intensity closely follow Weber-Fechner's law and corresponding experiments can be easily performed in the undergraduate laboratory. Simultaneously, students can be introduced to current methods of data evaluation via predefined spreadsheets of standard Excel software.