CLEVER MATERIAL FOR CLEVER SENSORS
Spider Mechanoreceptors

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The importance of sensory information for the guidance of animal behavior is reflected by a fascinating wealth of **sensory organs**. These exhibit an enormous variety due to different evolutionary potentials and needs of individual species. All sensory organs and their neuronal pathways have to be tuned to the reception and perception of the biologically relevant stimulus patterns as they occur in the habitats of different species. It is the invertebrate animals in particular, where one finds the most exotic sense organs and sensory capacities, some of them alien to us humans.

The variation among sense organs serving the detection and analysis of stimuli of the same type of energy is not so much due to differences at the level of the sensory cells but to differences in the functional properties of the non-nervous structures responsible for the **uptake and transformation of the stimulus** on its way to the sensory cell. Here we have an impressive evolutionary playground and inventiveness for biologically applied physics. It is in particular here where engineers can hope for bio-inspiration and cleverly simple and unconventional solutions of technically demanding problems [1].

The lecture will illustrate this aspect using two examples of spider mechanoreceptors [2], [3] and also stress that no sense organ can be adequately understood without reference to its biological significance in normal behavior under biologically relevant conditions.

(i) The first example will address the Bauplan of **mechanosensory hairs**, the most common of all biological sensors. It will contrast a tactile hair [4] and an airflow sensor [5],[6], showing how one can be converted into the other by changing a few physical parameters only. Obviously, the properties of the materials involved and their adjustment to the particular measurement task are of prime importance. Whereas in a tactile hair sufficient mechanical sensitivity has to be combined with mechanical robustness, the outstandingly high sensitivity asks for particular attention in case of the flow sensors.
(ii) The second example are the **slit sensilla**, a type of sensor which in a way is the opposite of a hair [1,2], which can be classified as a movement detector. Slit sensilla are strain detectors embedded in the cuticular exoskeleton and responding to the slightest deformation due to loads caused by muscular activity, gravity, substrate vibrations etc. Among the several thousand slit sensilla monitoring strain in a spider exoskeleton the vibration detector will receive particular attention. Again, material properties are highly relevant in determining functional properties. A small cuticular pad in front of the organ has turned out to be the main cause of the organ´s high pass characteristic. Due to its viscoelastic properties energy loss of stimulus transmission at high frequencies is much reduced as compared to low frequency stimulation. The result is a biologically highly relevant selectivity of the organ for frequencies higher than about 30 Hz [3], [7].

References

[1] Barth FG, Humphrey JAC, Srinivasan MV (eds), Frontiers in Sensing: From Biology to Engineering. Springer Verlag, Wien,New York

[2] - F.G. Barth, *A Spider's World. Senses and Behavior*, Springer Verlag, Berlin-Heidelberg-New York, 394p, (2002)

[3] - P. Fratzl, F.G. Barth, *Biomaterial systems for mechanosensing and actuation.* Nature, **462,** 26, 442-448, (2009)

[4] - H.-E. Dechant, F.G. Rammerstorfer, F.G. Barth, *Arthropod touch reception: stimulus transformation and finite element model of spider tactile hairs.* J Comp Physiol A, **187**, 313 – 323 (s. also Erratum p. 851), (2001)

[5] – J.A.C. Humphrey, F.G. Barth, *Medium flow-sensing hairs: biomechanics and models,* in: J.Casas, S.J. Simpson (eds.) Advances in Insect Physiology. Insect Mechanics and Control, **34**, 1-80, Elsevier Ltd., (2008)

[6] - M.E. McConney, C.F. Schaber, M.D. Julian, W.C. Eberhardt, J.A.C. Humphrey, F.G. Barth, W. Tsukruk, *Surface force spectroscopic point load measurements and viscoelastic modelling of the micromechanical properties of air flow sensitive hairs of a spider (Cupiennius salei),* J. R. Soc. Interface, **6**, 681-694, (2009)

[7] - M.E. McConney, C.F. Schaber, M.D. Julian, F.G. Barth, W. Tsukruk, *Viscoelastic nanoscale properties of cuticle contribute to high-pass properties of spider vibration receptor (Cupiennius salei Keys.),* J. R. Soc. Interface **4**, 1135-1143, (2007)

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