

Fig. 3. Dreidimensionale Strukturbildung. Zusammensetzung: NaBrO_3 $5 \cdot 10^{-2}$, Malonsäure $2 \cdot 10^{-1}$, H_2SO_4 $1,25 \cdot 10^{-1}$, Ferrioin $6 \cdot 10^{-4}$ M in 1proz. Agar-Gel

gung bilden sich zuerst normale Triggerwellen. Die Front der zweiten Triggerwelle ist aber in der Mitte gestört, und es kommt zur Etablierung eines neuen Führungszentrums, von dem sich spiralförmige Wellen sowohl nach innen als auch nach außen ausbreiten. Dreidimensionale Strukturbildung (Fig. 3). Wenn Störungen durch Konvektion in festen Gelen ausgeschlossen

Chiral Pheromone and Reproductive Isolation between the Gypsy- and Nun Moth

K. Hansen, D. Schneider and M. Boppré

Max-Planck-Institut für Verhaltensphysiologie, D-8131 Seewiesen

Disparlure, cis-7,8-epoxy-2-methylotadecane, has been identified as the sex attractant of both the gypsy moth, *Lymantria dispar*, and the nun moth, *L. monacha* [1, 2], which live sympatrically in parts of Europe.

In field trapping experiments with synthetic disparlure, males of both species were attracted to either racemic disparlure [3] or to the (7*R*,8*S*)-(+)-enantiomer alone [4, 5]. However, when additional amounts of the (7*S*,8*R*)-(–)-enantiomer were offered with the racemate, the response of the male gypsy moths was suppressed and eventually failed [5], while the attraction of the male nun moths was not influenced [4]. In experiments with the naturally produced pheromone, males of the nun moth were lured to crude gland extracts of female gypsy moths, but males of the gypsy moth were either non-re-

werden, breiten sich Triggerwellen als normale sphärische Wellen aus.

Komplizierte Strukturen (scroll-waves), wie sie Winfree [7] beschrieb, sind vermutlich auf ein inhomogenes Medium zurückzuführen.

Ich danke für die experimentelle Mitarbeit C. Zirkel, für zusätzliche fotografische Hilfe R. Kuhnert und für Diskussionen über den Echo-Effekt und die Gel-Technik A.M. Žabotinskij und V.I. Krinskij.

Eingegangen am 11. Januar und 23. März 1983

1. Luther, R.: Z. Elektrochem. 12, 596 (1906)
2. Turing, A.M.: Trans. R. Soc. 237, 37 (1952)
3. Belousov, B.P.: Sb. Ref. Radiats. Med. Moskau 1958, 145 (1959); Zabotinskij, A.M.: Konzentrationije Avtokolebanija. Moskau: Nauka 1974
4. Jirgensons, B., Straumanis, M.: Kurzes Lehrbuch der Kolloidchemie. München 1949
5. Blandamer, M.J.: Faraday Disc. Chem. Soc. 57, 275 (1974)
6. Rosenblueth, A.: Am. J. Physiol. 194, 491 (1958)
7. Winfree, A.T.: Science 181, 937 (1973)

sponsive or less responsive to the females of the nun moth or to their glandular extracts [6].

An electrophysiological study with racemic disparlure and analogous compounds indicated similarities in the olfactory receptor systems of the two moth species [7]. Stimulation with disparlure enantiomers by using electroantennogram recordings suggested that the males of the gypsy moth possess specific odour receptors for each of the two enantiomers [8]. The determination of the chirality of the natural disparlure of these moths is not possible with presently available polarimetric or chromatographic methods. – This paper is a preliminary report on recordings from single olfactory cells in antennal hairs of males of the gypsy and the nun moth during stimulation with gland extracts and synthetic enan-

tiomers of disparlure [9]. The complete report will follow [10].

Two odour receptor cells were found within antennal hairs of both moth species. In *L. dispar*, one of these neighbouring cells responds to (+)-disparlure, and the other to (–)-disparlure; in *L. monacha* both cells respond to (+)-disparlure. This specific deficiency of (–)-disparlure sensitivity in the nun moth is corroborated by electroantennogram recordings, which showed no response to this enantiomer.

Single cell responses of the male gypsy moth to different concentrations of the synthetic enantiomers of disparlure were then compared to responses elicited by female glandular extracts of both species. The hexane extracts of the gypsy-moth glands stimulated almost exclusively the receptor cells specialized for (+)-disparlure, while both cells were stimulated simultaneously by the gland extracts of the female nun moth (Fig. 1). From the stimulus-response characteristics of the cells we estimated the pheromone production of the nun moth to be approx. 90% (–), and 10% (+)-disparlure and that of the gypsy moth to be almost 100% (+)-disparlure. Since the two synthetic disparlures are only 98% optically pure (statement in [9]), we are unable to precisely determine the receptor cell specificity to the chiral stimuli. This is the reason why the gland contents can not be judged precisely.

Because the gland extracts did only elicit responses in the disparlure-specific odour receptor cells of the sensilla trichodea, we may state that no additional hexane-soluble – yet unknown – pheromone component exists in these species.

The inhibition of the pheromone reaction of the male gypsy moth by (–)-disparlure is a central nervous function since both enantiomer-specific receptors send their messages independently to the brain. The positive pheromone response (anemotaxis) in the gypsy moth is not only in the field but also in the laboratory only elicited by the (+)-enantiomer which in tethered flight experiments alone 'controls' the thrust and height stabilisation [11].

The earlier interspecific field reactions to gland extracts [6] and the recent ones to the disparlure enantiomers [4, 5] are well in conformance with our estimates of the natural ratios of dispar-

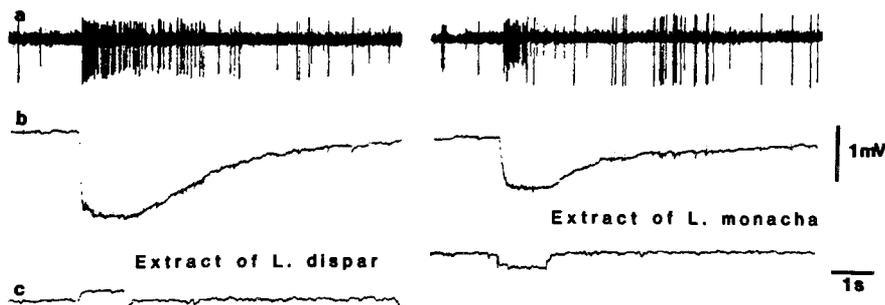


Fig. 1. Extracellular recordings from a single antennal hair of a male *L. dispar*. Hexane extracts corresponding to the yield from 15.0 female glands of gypsy moth and the yield from 16.5 female glands of the nun moth are used for stimulation of the olfactory receptor cells. Large impulses: (+)-disparlure receptor cell; small impulses: (-)-disparlure receptor cell. (a) Trace of the AC-amplified signal, (b) trace of the corresponding DC-amplified signal, (c) trace of the response of the anemometer, recorded near by the antenna

lure enantiomers in the two species. Though our results clarify the observed differences of behaviour between the two species, it must still be presumed that the reproductive isolation of the gypsy- and the nun moth is only partly due to pheromone production and recognition. While the total activity rhythms of the two species do partially overlap [12], female gypsy moths show the maximal pheromone release in daylight [13] and are thus not molested by the nocturnal nun-moth males?

K. Hansen was supported by the Danish Natural Science Research Council, the Danish Agricultural and Veterinary Research Council and the Max-Planck-Gesellschaft. His present address is: Vildtbiologisk Station, Kalø, DK-8410 Rønde. M. Boppré was supported by the Max-Planck-Gesellschaft. His present address is: Institut für Zoologie der Universität, D-8400 Regensburg.

An Acoustic Duet is Necessary for Successful Mating in *Corixa dentipes*

J. Theiß

Institut für Zoologie der Universität, D-8400 Regensburg

The corixid waterbugs spend their life under water leaving only occasionally for dispersal flights. The males of *C. dentipes* stridulate under water, a single movement of the file over the scraper inducing transient volume pulsations

Received May 30, 1983

1. Bierl, B.A., et al.: *Science* 170, 87 (1970)
2. Bierl, B.A., et al.: *Z. Naturforsch.* 30 c, 672 (1975)
3. Schneider, D., et al.: *Oecologia* 14, 19 (1974)
4. Klimetzek, D., et al.: *Naturwissenschaften* 63, 581 (1976)
5. Vité, J.P., et al.: *ibid.* 63, 582 (1976)
6. Görnitz, K.: *Anz. Schädlingskde.* 22, 145 (1949)
7. Schneider, D., et al.: *J. Comp. Physiol.* 113, 1 (1977)
8. Miller, J.R., et al.: *J. Insect Physiol.* 23, 1447 (1977)
9. Mori, K., et al.: *Tetrahedron Lett.* 21, 3953 (1976)
10. Hansen, K.: in preparation
11. Preiss, R., Kramer, E.: *Physiol. Entomol.* 8, 55 (1983)
12. Schröter, H.: *Mitt. dtsh. Ges. allg. angew. Ent.* 3, 268 (1981)
13. Richerson, J.V., Cameron, E.A.: *Environ. Ent.* 3, 475 (1974)

of the respiratory air bubble of the animal. These cause a train of sound pulses to be radiated into the water [1, 2]. The sounds can be heard by conspecifics via tympanal organs [3, 4]. *C. dentipes* males have a repertoire of 4

different songs which are all sung spontaneously even by isolated individuals [1]. The present investigation demonstrates that pre-mating exchange of acoustic signals is an important prerequisite for successful mating in this species.

Adult males and females were collected from the field during their main mating period in spring 1981 [5]. They were transferred to 60-l aquaria (5♂:5♀), where their behaviour was observed in daylight and their sounds were recorded [2]. The males produced all 4 songs (Song A–D). Only Song A elicited ‘chorus stridulation’ in nearby male conspecifics [1] and frequently led to agonistic behaviour (pushing and chasing a rival away) between males engaged in the chorus. Males mounted females several times a day. If the male was not dislodged immediately, short copulations occurred between the swimming pair lasting up to 2 min. During the whole time the male produced another acoustic signal, the ‘mounting signal’ [6, 5]. Females showed no response to any of the male songs.

In the spring of 1982, the investigations were repeated with virginal females kept separate from males in the field since autumn. I observed only single pairs to be sure of the identity of the stridulating animal. Under these conditions the females stridulated eliciting a response in conspecific males. This is the first time that female stridulation in *Corixa* has been reported. The females use the same stridulation mechanism as males [1]. The female song is 10–20 dB fainter than Song A, successive pulse trains are equally loud and the mean pulse-train rate is slightly higher (1.25 times ± 0.16 , $n=21$, $p < 0.01$).

Figure 1 demonstrates a typical pre-mating duet of the sexual partners combined with the following behavioural sequence: female joins in verse C_{end} ; male stops singing, turns on the spot to the female, swims near the singing female and sings Song A; female keeps on singing or answers Song A after a short pause; antiphonal song is repeated; male mounts female bringing his abdomen in the position typical for copulation [7]; pair comes loose from the ground during mounting and swims ‘in copula’ while male produces the mounting signal; pair swims down-