trol the access of hydrophilic molecules (such as GABA or muscimol) to the binding site by increasing lipid content in the environment. This contention is supported by the observation that Triton X-100 treatment increases the affinity for hydrophilic (that is, lipophobic) ligands such as GABA or muscimol but does not alter the affinity of lipophylic molecules (such as SL 76 002, a GABA-mimetic benzophenone) for the binding site (*3*, *12*).

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19 January 1979; revised 10 April 1979

## Vibrations: Their Signal Function for a Spider Kleptoparasite

Abstract. *The stealing behavior of* Argyrodes elevatus *suggests that this kleptoparasitic spider monitors the movements and the hunting success of its web-building host. Wrapping of prey by the host regularly elicits raids from the kleptoparasite. The prey-catching activities of the host generate vibrations that were recorded with a position-sensing photodiode. The recordings indicated that wrapping movements produce a characteristic pattern of vibrations.*

Tropical spiders of the theridiid genus *Argyrodes* Simon inhabit the webs of other spiders (*1*). The kleptoparasitic *Argyrodes elevatus* Taczanowski constructs no web of its own but primarily uses the snares of the orb-weaving spiders *Nephila clavipes* and *Argiope argentata* to secure its food. Fine threads connect its resting place, 20 to 30 cm outside the host's capture area (*2*), with the hub and several radii of the host's web. The kleptoparasites move along these lines either in search of small insects entangled in the sticky spiral, but neglected by the host, or to steal large prey items caught and stored by the host (*3*, *3a*, *4*). Raids for stored prey packets are triggered by the host's prey-catching movements, and a distinct stealing behavior is displayed by the kleptoparasites, indicating a high degree of specialization toward either host species (*4*).

While studying the stealing behavior of *Argyrodes* (*4*), I subjected hosts and kleptoparasites to experiments in which dead prey was presented on the tip of a vibrator but often retrieved from the web before the host reached and "caught" it, thus simulating prey escape. Only in a few instances (9 percent; $N = 100$) did the kleptoparasites venture into a raid if the host ran toward the prey and searched but did not succeed in catching it. In contrast, a raid was regularly elicited (86 percent; $N = 518$) if the prey was captured by the host. Close observations, as well as film analysis of the movements of hosts and kleptoparasites during the experiments, showed that in most cases the kleptoparasites started a raid the instant the prey was wrapped by the host. Since the vision of most web-building spiders is poor (*5*) and the use of acute olfaction has not been demonstrated, it is generally assumed (*6*) that vibrations are of major importance for these spiders. My experiments suggest that vibrations generated by the host during the wrapping sequence of prey capture were of crucial significance to the kleptoparasites. The prominence of these wrapping vibrations in the vibratory pattern of prey capture will be demonstrated.

I employed three methods for recording the vibrations of silken threads to investigate the pattern of vibrations generated by the host spiders during prey catching (*7*, *8*). The best results—recording of large as well as small translocations of a single web strand—were obtained with a position-sensing photodetector (*9*).

A beam of parallel light is sent onto a reflector plate (3M Scotch-Lite High Gain Foil) placed at the hub of the spider web. The returned beam passes through a 100-mm macrolens onto the position-sensing silicon photodiode (Scotty Barrier PIN-SC 10, United Tech.) housed in a camera case. Movements of the reflector are displayed as magnified alterations of a cathode-ray beam. Since the reflecting angle is 0° to 1°, small twists of the reflector influence only the signal amplitude, but do not otherwise alter the signals. To minimize inertial effects, the reflector plate (0.5 mg, 1 to 2 mm$^2$) is not fixed directly to the *Argyrodes* signal line but is attached to the intersection of a radius and spiral thread at points where signal threads originate. It is assumed (*10*) that the taut signal thread transmits vibrations from its point of attachment at the radius to the receiver with little alteration. Although vibrations in the spider web travel along the radii as longitudinal, transversal, and torsion translations (*11*), I measured only the longitudinal vector (*12*).

Figure 1 shows the pattern of vibra-


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tions during a typical (*3a, 13*) fly-catching sequence of *Argiope* and *Nephila*. After the fly had been attack-wrapped and bitten (Fig. 1b, C and D), it is pulled or cut from the webbing and carried to the hub either on silk or in the chelicerae. At the hub the spider turns 90° and wraps the prey again (Fig. 1a, E), rests briefly and suspends the prey packet from a silk strand 1 to 2 cm long and attached to several radii, whereafter the spider reassumes its resting position. The fly-capturing technique of *Nephila* differs in several respects. *Nephila* attack-bites the fly (Fig. 1a, D) and wraps it only after returning to the hub (Fig. 1a, F). The wrapping sequence is of much longer duration. After return to the hub, *Nephila* frequently turns 180° to the resting position and then has to turn another 90° to the wrapping position (Fig. 1a, $E_1$).

The figure illustrates that a spider moving on its web and catching prey generates a distinct signal consisting of large as well as small translocations of the radii near the hub, at points where kleptoparasites have attached signal lines. The large vacillations (up to 1.5 mm) are generated by the host shifting its weight in the web. The small vacillations are of shorter duration and constitute complex oscillations which are generated by local movements such as biting or wrapping. These small vibrations have distinct patterns corresponding to different actions of the hosts (Fig. 1, insets). "Equal action" vibrations are similar in both webs. Most of the differences are presumably due to the unlike structure of the two webs (*14*).

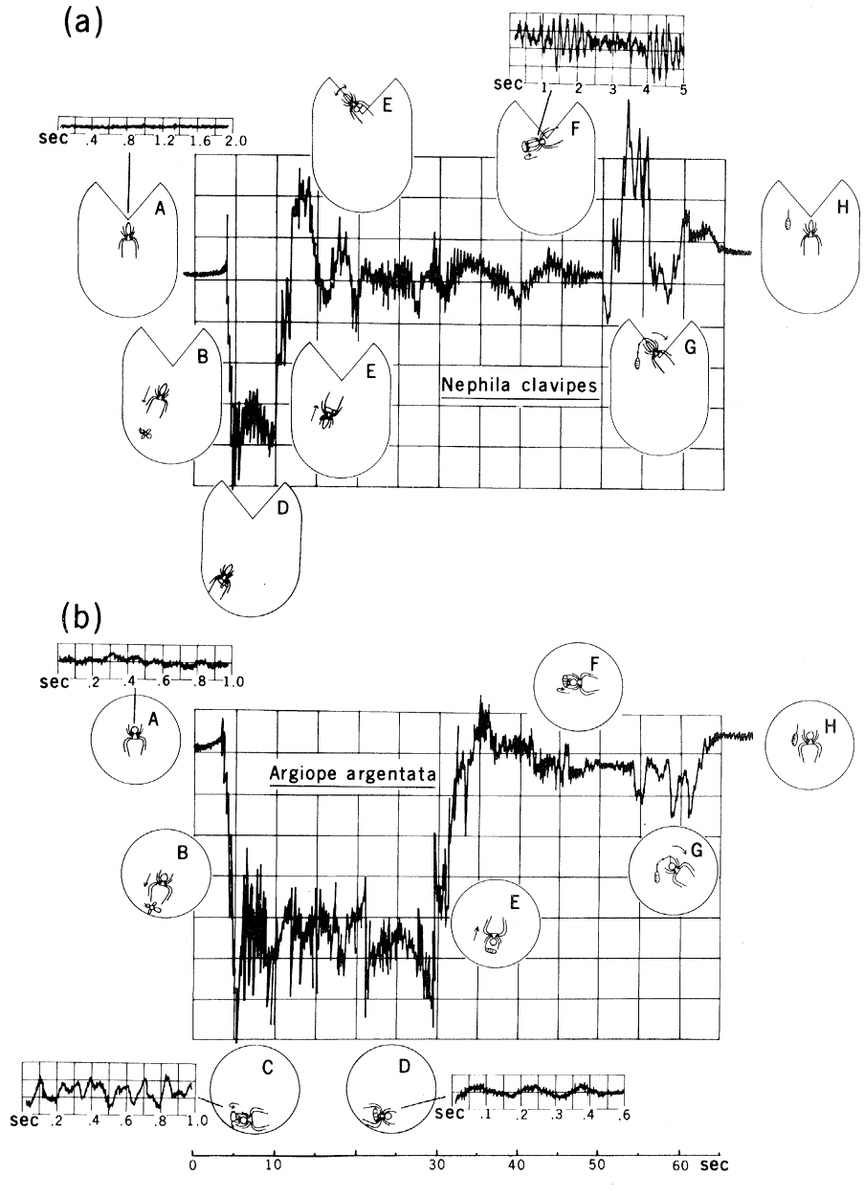


Fig. 1. Recordings of vibrations generated during the prey-catching sequence of the two host spiders, (a) *Nephila clavipes* and (b) *Argiope argentata*. (A) Spider at rest at hub; (B) spider dashes toward prey; (C) spider attack-wraps prey; (D) spider bites prey; (E) spider carries prey to hub; ($E_1$) spider orients at hub; (F) spider wraps prey at hub; (G) spider suspends prey from hub; (H) spider at rest at hub with prey hanging close by. Vertical axis: foil displacement, maximum translocations 1.5 mm; foil displacement of insets in 0.1-mm steps.

When the spiders are at rest (Fig. 1, A insets), or wrapping, or biting, prey vibrations are generated that enable us, and probably the kleptoparasite as well, to distinguish these actions. Wrapping vibrations are distinct from all others by virtue of their peculiar shapes, displaying double or plateau peaks (Fig. 1b, C inset). It is assumed that these patterns originate from complex interactions between the vibrations generated by the spiders and the resonance frequencies of their webs. This summation of vibrations of different origins becomes clear in Fig. 1a, F inset, where the continuous and similar wrapping movements of *Nephila* create an interference pattern.

I also observed that the pumping and sucking of the host's stomach pump (all spiders have extraintestinal digestion) altered the pressure in the spider's cephalothorax enough to minutely stretch and flex the legs, creating measurable oscillations of the hub. These, too, constitute signals that are received by the kleptoparasites.

The hypothesis that the wrapping vibrations trigger the raids was then tested. Since a playback of recorded signals is subject to distortions owing to the inertia of the vibrating mechanism, a simple behavioral experiment was designed. A piece of cricket was carefully fed directly to the mouthparts of *Nephila*. This resulted in feeding without prior prey capture movements. In ten experiments this "prey" was not wrapped. The kleptoparasites were alerted by the feeding (pumping vibrations); however, they did not venture onto the hub. In ten different experiments this "prey" was wrapped after 5 to 10 minutes of feeding. Within the following 5 minutes the kleptoparasites had moved onto the hub. If one recalls the prey capture and prey escape experiments mentioned above, it can be inferred that it is not the host's run toward prey nor the feeding that elicits a raid, but that the wrapping alone lures *A. elevatus* to the hub in search of prey.

By using the information received through vibrations generated by the host spider, the kleptoparasite is able to adjust its stealing behavior to the prey-catching success of its host. The vibrations generated by the wrapping behavior constitute a good potential releasing signal. The pattern is distinctive and in-

dicates (i) that the host's prey run has been successful and (ii) that a prey item is stored and hence can be stolen. Small prey are never wrapped, but instead are held in the chelicerae and therefore are not available to the kleptoparasites.

The results of the behavior experiments suggest that the kleptoparasites indeed read the vibratory pattern of their host's prey-catching sequence and that they use the information it contains to adjust their stealing behavior accordingly. The host has certain "antiparasitic" behaviors—such as searching for stolen prey or abandoning its present web site for another—which are detrimental to the kleptoparasites (*4*). By monitoring the host's movements, a kleptoparasite can reduce the likelihood of being perceived; for example, it avoids moving on the orb when the host is inactive at the hub and most sensitive to vibrations in its web. In addition, an ability to evaluate the vibratory pattern enables the kleptoparasite to adjust its pillaging to the availability of prey packets and consequently allows it to conserve energy.

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14. The web of an *Argiope* female is wide-meshed with high elasticity (40 cm in diameter, 30 radii, 40 spiral turns). This contrasts with the web of the *Nephila* female which is fine-meshed, tightly woven (55 cm in diameter, 150 radii, 160 spiral turns) and which gets additional tension through guy threads connecting the hub with a surrounding space web.
15. I thank O. V. Helversen, M. H. Robinson, P. Weygoldt, and P. N. Witt for help during the study, which was financed by a GRAFOG grant to the University of Freiburg and in parts supported by NSF grant 30/BNF/75/09915 to P. N. Witt and by a Smithsonian Fellowship.

17 April 1979

## Pharmacologic Effects in Man of a Potent, Long-Acting Dopamine Receptor Agonist

Abstract. *Single-dose administration of pergolide mesylate (100 to 400 micrograms) results in a dose-related inhibition of prolactin secretion which persists for more than 24 hours. During multiple-dose administration of pergolide, plasma prolactin concentrations remain markedly reduced (greater than 80 percent) and gradually return to control levels several days after drug administration is discontinued.*

Dopamine receptor agonists inhibit prolactin secretion and are clinically effective in the treatment of amenorrhea and galactorrhea (*1*). They are also useful in the treatment of Parkinson's disease when administered either alone or in combination with L-dopa (*2*). Two dopamine receptor agonists of the ergoline class that have been extensively investigated in animals and man are $\alpha$-bromocriptine and lergotrile. These drugs can reduce serum prolactin concentrations in normal volunteers and patients with hyperprolactinemia at doses of about 2 to 2.5 mg (*3*); however, the duration of their effectiveness is only about 6 to 8 hours after the administration of a single dose.

In this report we describe the clinical pharmacology of pergolide mesylate, (8$\beta$)-8-[(methylthio)methyl]-6-propylergoline, a potent ergoline with a long duration of action.

Eight normal, healthy male volunteers aged 28 to 47 years participated in this study. The volunteers were given an oral and written explanation of the study design and the associated hazards, and they gave their informed consent. They were hospitalized on a clinical research ward throughout the entire study period.

Initial single-dose studies were designed so that we could increase the dose of pergolide cautiously and evaluate its safety and pharmacologic effects. Five of the volunteers participated in this phase of the study. For several days the subjects were given placebo medication; then a dose of 50 $\mu$g of pergolide was given orally to one of the subjects instead of the placebo. On specific days thereafter, pergolide was substituted in increasing doses (50 to 400 $\mu$g) for placebo medication in the four other subjects. At the higher doses, pergolide caused pronounced uncomfortable symptoms, including nausea, emesis, and nasal stuffiness. These adverse effects occurred 30 to 60 minutes after drug administration and lasted for up to 4 hours (*4*). The drug also produced dose-dependent decreases in plasma prolactin concentrations (*5*) that persisted for more than 24 hours (see Fig. 1).

Multiple-dose studies were conducted after we had established a range of safe doses. Placebo medication was administered to five subjects for the first 7 days. Pergolide was administered orally for the next week. The initial dose of medication was administered as a single 250-$\mu$g dose. In only one of the subjects was this dose well tolerated without uncomfortable side effects, and this dose was continued in this individual for the entire week. However, for the remaining four subjects, who experienced nausea (and emesis in two subjects) and nasal stuffiness, the daily dose was reduced to 150 $\mu$g. This dose was continued for the next 4 days, after which the subjects were given a 250-$\mu$g dose for the final 2 days. Tolerance developed to the adverse effects of pergolide in all five subjects, as evidenced by the failure of the 250-$\mu$g dose to produce any significant side effects on days 6 and 7 of the study.

The concentration of prolactin in the plasma of all subjects was measured by radioimmunoassay (*6*). The prolactin concentration was unaffected by the placebo medication, whereas after a single dose of pergolide the concentration was markedly reduced. This suppression lasted at least 24 hours, at which time the next dose of the drug was administered. The long-term administration of pergolide (for 7 days) resulted in a significant decrease in plasma prolactin concentration (greater than 80 percent) ($P < .01$) (Fig. 2). In some subjects the plasma prolactin was reduced to concentrations at or below the limit of detection of the method (that is, 0.5 ng/ml). In one of the five subjects the plasma prolactin was only slightly reduced after pergolide adminis-


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