Heat shock-induced gynandromorphism in the pharaoh's ant, *Monomorium pharaonis* (L.)

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Summary. The ability of ants to reacting to sublethal high temperatures with production of gynandromorphs is reported for the first time. The abnormal forms produced in the pharaoh's ant range from ergatandromorphs to classical halfside-gynanders.

The influence of temperature on insects is well documented[2-4]. High sublethal temperature produces sterility or leads to diapause and developmental abnormalities. In ants, many morphological aberrations have been described[5], but the causes of these remain unknown. Gynandromorphism is known in various insects[2,4,5]. A gynandromorph is an individual containing patches of both male and female tissue[6,7]. In social insects we have to differentiate between gynandromorphs sensu stricto and ergatandromorphs. The latter are worker-male genetic mosaics (fig. b) whereas gynandromorphs sensu stricto are queen-male mosaics (fig. d). A classical halfside gynandromorph is an individual which is half male, half queen (fig. c).

Our experiments were carried out with laboratory colonies of pharaoh's ant (Hymenoptera, Formicidae) originating from the Tierpark Berlin (GDR), Kolin (Czechoslovakia), and Warsaw (Poland). The material from Berlin was held in the laboratory for 11 years, that from Kolin and Warsaw since 1976 and 1977, respectively. The laboratory colonies were reared according to Kretzschmar[8] and Berndt et al.[9]. The whole rearing device (with the top dish removed) was brought from the insectary (28±2 °C) in a thermostat. Small petri dishes filled with wet cotton were present under standard conditions. The relative humidity in the thermostat during treatment must be below 50%. Experiments were carried out with intact laboratory colonies with between 5 and 50 queens, 500-2000 workers, and equal numbers of all developmental stages. To accomplish the rearing of new sexuals colonies have to be queenless. The colonies were watched for the appearance of abnormal individuals which could be recognized as soon as the pupal cuticle darkened.

The temperature tolerance in the pharaoh's ant is very limited at high sublethal temperatures. The societies die within a few minutes at the stress temperature of 54±2 °C unless there is access to the watering place. Survival at this temperature for times ranging from 60 to over 100 min is due to cooling by evaporation. The workers carry the brood stages at 54 °C on to this water-evaporating surface and so a certain part of the colony survives. After treatment the colonies settled at rearing temperatures in the nest cell again. Brood, queens or workers which were not in the wet surface of the watering place soon died.

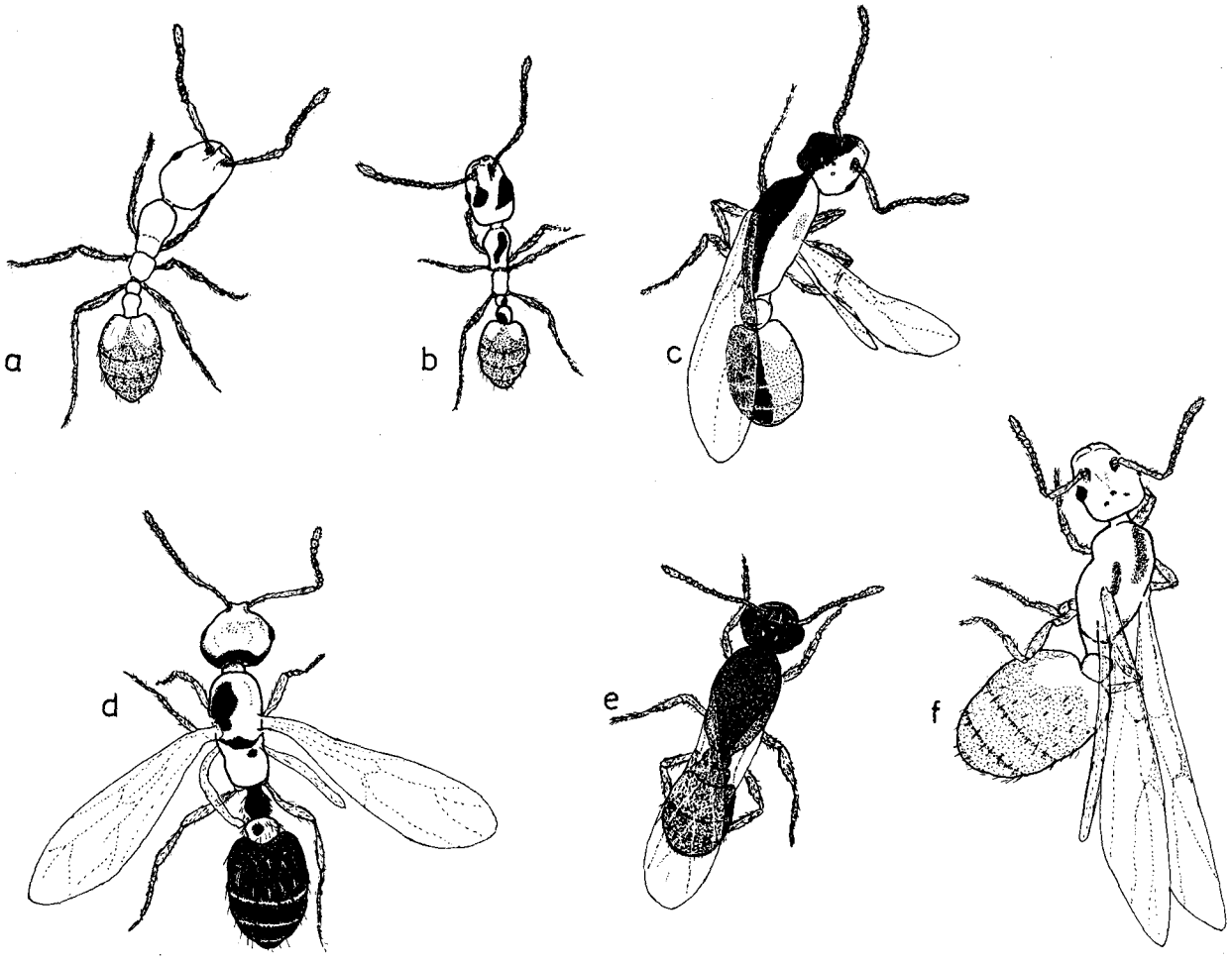
The results are shown in the table. The influence of high temperature depended on the exposure times and ranged from total extincition up to an indiscernible influence. The best exposure time for the induction of ergatandromorphs (table) and gynandromorphs sensu stricto lies between 60 and 80 min because at this time the recovery rate of treated colonies is 100%. Over 80 min, the colonies are damaged to a great extent. Developing workers and sexuals are rare and the total yield of gynandromorphs and ergatandromorphs is low, although the general percentage of aberrant forms is even higher (table No. 9). We found no significant differences between the strains from Berlin, Kolin and Warsaw. By replacing the treated queens by normal ones immediately after treatment we were able to demonstrate that the eggs laid during treatment can be influenced by temperature stress (table, No. 11). For the production of gynandromorphs sensu stricto the time of queen removal is of importance. The removal of queens later than 5 days after heat treatment yields no true gynandromorphs but ergatandromorphs. In 21 replicates (removal of queens after 1-3 days) we obtained from 1.5 to 83% gynandromorphs (mean value 40.4%) and 0 to 14% ergatandromorphs (mean value 3.7), respectively. The percentage of true gynandromorphs is expressed in relation to the number of new sexuals (brown pupae) produced in the colony, that of ergatandromorphs in relation to the number of all worker pupae present in the colony at the time when the ergatandromorphs hatched.

It is important to emphasize that the results described can be reached only under the experimental conditions described. A rearing temperature below 20 °C after treatment yielded no gynandromorphs or ergatandromorphs. A temperature above 30 °C gave no better results than at 28 °C. High temperatures for a short time without any influence from the cold of evaporation gave no positive results. In

Production of ergatandromorphs of the pharaoh's ant after treatment with temperature shock at 54±2 °C. The percentage of ergatandromorphs is expressed in relation to the number of all worker pupae present in the colony at the time when the ergatandromorphs hatched

No.	Origin	Numbers of replicates	Exposure time (min)	Ergatandromorphs (extreme values)	Recovery rate of the colonies
1	Berlin	15	15	0	100
2	Berlin	20	30	0.0- 0.01	100
3	Berlin	10	50	0.0- 0.20	100
4	Berlin	40	60	0.1- 1.00	100
5	Kolin	10	60	0.1- 0.70	100
6	Warsaw	10	60	0.2- 1.00	100
7	Berlin	25	80	0.5-13.30	100
8	Berlin	20	90	0.6-15.50	80
9	Berlin	20	110	0.7-18.80	10
10	Berlin	10	150	-	0
11[a]	Berlin	18	80	0.2- 3.50	100

[a] After treatment the queens were replaced immediately by untreated ones of the same origin.



Examples of normal forms and temperature-induced gynandromorphs of the pharaoh's ant. *a* Normal female (worker); *b* ergatandromorph (worker with spots of black male cuticle); *c* halfside gynandromorph (left male, right queen); *d* gynandromorph sensu stricto (genetic mosaic between worker and queen); *e* normal male; *f* normal female (queen).

our experiments we never found any influence of temperatures between −20 and 20 °C on the production of gynandromorphs[10], in contrast to findings in the honey bee[4].

A detailed description of the gynandromorphs obtained (morphology, physiology, behavior) will be published elsewhere. We collected in 2 years nearly 3000 ergatandromorphs and about 700 gynandromorphs, including 4 classical halfside-gynandromorphs. The distribution of spots over the body of the ergatandromorphs showed remarkable differences. In 36%, the spots are located only on one part of the body. There are many papers about gynandromorphism in ants but normally related to one or a few individuals among many species. Hall et al.[7] found somatic mosaics in small numbers in the pharaoh's ant in normal laboratory colonies. The causes of this aberrant development remain unknown. Furthermore the aberrant ants were normally discovered in collections of many thousands of dead individuals. Therefore no statement on behavior and physiology was possible. Our findings provide the opportunity to produce many different gynandromorphs and ergatandromorphs in the pharaoh's ant. An analysis of the causes of the phenomenon of gynandromorphism in ants is thus made easier.

Considering the similiarities between the biology of *Monomorium pharaonis* and other myrmicids (e.g. *Plagiolepis pygmaea*), it is our opinion that similar results may be obtained in other ants. Furthermore it would be interesting to know how such temperature stress operates in other hymenopterans. Workers with characteristic patterns of spots can be used for special investigations relating to some features of social organization (e.g. division of labor).

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