The dry weight of the above-ground parts of artificially defoliated plants (the average from all 9 strains) was by 14.7% greater than the dry weight of plants damaged by *Sitona* beetles. The corresponding difference in roots was 26.2%. The roots of plants defoliated by beetles reached only 55.3% of the weight of the roots of control plants.

The response of the above-ground parts and roots of plants to both types of defoliation was similar to that found in our previous work[6]. Large strain-specific differences in the response to defoliation were observed. This was perhaps due to the different abilities of tested strains to compensate in subsequent phases of development for the loss of leaf area in the seedling stage[7]. The results confirmed the conclusion of Capinera and Roltsch[5] that defoliation of plants by insects is difficult to simulate by artificial defoliation. Probably, the interaction between host plant and chewing insects is a more complex problem (similarly to the case with sucking insects[8]) than simple mechanical defoliation.

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2 G. Von Schaller, Zool. Jb. Physiol. *71*, 385 (1965).
3 P.W. Miles and J. Lloyd, Nature *213*, 801 (1967).
4 A.H. Showalter, R.L. Pienkowski and D.D. Wolf, J. econ. Ent. *68*, 619 (1975).
5 J.L. Capinera and W.J. Roltsch, J. econ. Ent. *73*, 258 (1980).
6 H. Havlíčková, Sb. ÚVTIZ - Ochr. Rostl. *15*, 183 (1979).
7 H. Havlíčková, Sb. ÚVTIZ - Ochr. Rostl. *17*, 217 (1981).
8 J.L. Harper, Population biology of plants. Academic Press, London 1977.

The course of *Plasmodium berghei* infection in mice latently infected with *Toxoplasma gondii*[1]

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Summary. The course of infection with 2 different virulent strains of *Plasmodium berghei* was investigated in mice latently infected with *Toxoplasma gondii*. When given the highly virulent ANKA strain of *P. berghei* all Toxoplasma-infected mice died but the survival time was prolonged. After infection with the less virulent strain K 173 mice could survive the subsequent infection. In these cases levels of parasitemia depended upon the duration of the *T. gondii* infection. Mice infected for about 6 weeks with *T. gondii* showed maximum protection.

T. gondii can exist in a very great variety of hosts, among which are nearly all mammalian species and many birds. The high incidence of contamination in humans has raised the question of the influence of a latent *T. gondii* infection on additional subsequent parasitical infections.

It is well known that laboratory animals latently infected with *T. gondii* are immune to superinfection[2-13]. This protection is not only observed against parasites of the same species but against bacteria such as *Listeria monocytogenes* and *Salmonella typhimurium*[14], against fungi, e.g. *Cryptococcus neoformans*[15], and virus infections[16]. In contrast to these observations other authors[17] found an immundepression during the acute stage of Toxoplasmosis, so that a subsequent infection with *P. berghei yoelii* leads to a stronger parasitemia than in the control animals.

In order to clarify these contradictory statements we investigated the influence of latent *T. gondii* infection on the course of *P. berghei* parasitemia in mice.

Material and methods. The animals we used in this investigation were female NMRI mice from the Versuchstierzucht Hannover. They were fed on a commercial diet and tap water ad libitum. For *T. gondii* infection mice received i.p. 10-15 cysts of the avirulent DX strain which were isolated from the brains of mice that had been infected 14 weeks earlier. At various time intervals animals additionally received 10^3 parasites of the highly virulent ANKA strain or the less virulent K 173 strain of *P. berghei*. Parasitemia was examined daily by counting the infected red blood cells in Giemsa-stained blood smears. All data are mean values from 5-10 animals per group.

Results (fig. 1-3). In the control groups, mice infected with the highly virulent ANKA strain or the less virulent K 173 strain of *P. berghei*, parasites were found in the peripheral

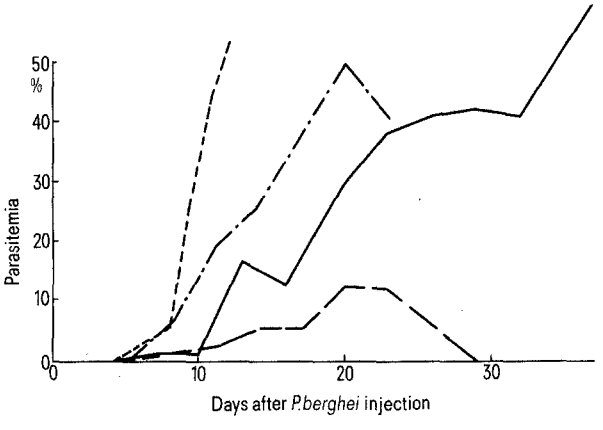

Figure 1. *P. berghei* parasitemia in mice with a *T. gondii* infection of 6 weeks duration.
P. berghei (K 173), ——; *P. berghei* (K 173) and *T. gondii*,— —; *P. berghei* (ANKA), -----; *P. berghei* (ANKA) and *T. gondii*, ·····.

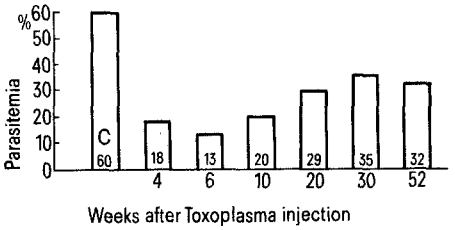

Figure 2. Maximum values of *P. berghei* (K 173) parasitemia related to the duration of the *T. gondii* infection (C = control group).

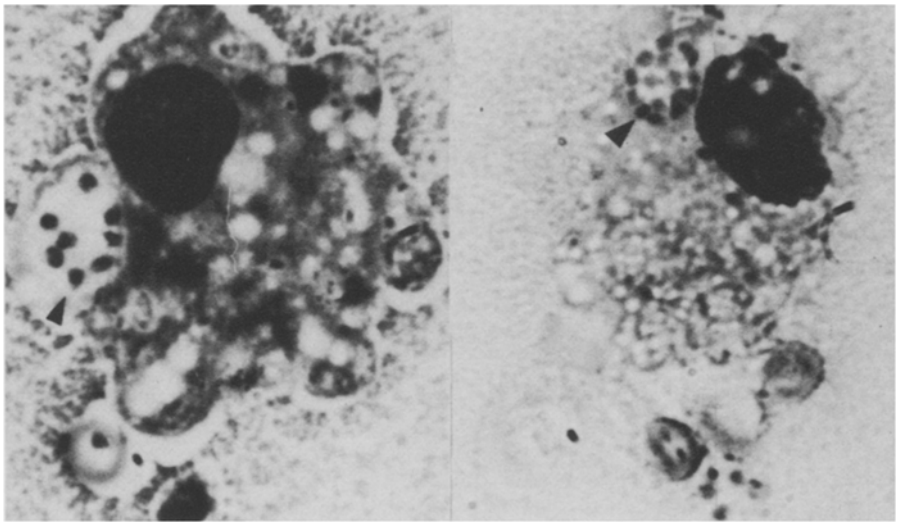

Figure 3. Macrophages with phagocytized *P. berghei* schizonts from the peritoneal exudate of mice latently infected with *T. gondii*.

blood at day 4–6 after injection. In the case of the ANKA strain parasitemia increased very quickly up to more than 50% and all animals died on about day 12. On injecting the K 173 strain parasitemia rose very slowly and reached its maximum values between days 21 and 37 with 50–60%. Death occurred in all cases.

In the experiments with double infection, mice with a 4–10 weeks existing latent *T. gondii* infection were additionally infected with the highly virulent ANKA strain of *P. berghei*. All doubly infected mice died with a high parasitemia of about 50%, but survival time was significantly lengthened, up to about 28 days when compared with the controls.

The less virulent K 173 strain was given to mice between 4 and 52 weeks after the injection of *T. gondii*. A *T. gondii* infection of 4–10 weeks duration gave complete protection against *P. berghei*. There was mild parasitemia with maximum values of 13–20% at days 19–25, whereas at days 27–36 no parasites could be found in the peripheral blood microscopically. All animals survived. Even mice latently infected with *T. gondii* for up to 52 weeks showed good protection against *P. berghei* when compared with the control group. In these animals parasitemia reached maximum values of 29–35% and most of them survived.

Discussion. Our investigations demonstrate that mice latently infected with *T. gondii* can survive a subsequent, normally lethal, running infection with *P. berghei* under special conditions. The degree of protection depends on the virulence of the *P. berghei* strain additionally injected and on the duration of the *T. gondii* infection. Maximum protection was observed when the less virulent K 173 strain of *P. berghei* was given to mice infected with *T. gondii* about 6 weeks previously. Our results agree with those of Ruskin and Remington[14], Remington and Merigan[16] and Sethi et al.[15], who found good protection of *T. gondii* infected mice against bacteria, fungi and viruses. Our observations would at first sight appear to differ significantly from those of Strickland et al.[17], who noted an immundepression on injecting *P. berghei yoelii* during the acute stage of *T. gondii* infection. However, when interpreting this phenomenon, the reaction of the lymphoid organs must be taken into consideration. Pelster[18] and Pelster et al.[19] have shown that in early *T. gondii* infection in mice there is a remarkable loss of lymphocytes in the thymus with consequent decreased general resistance and therefore the parasitemia of *P. berghei yoelii* was stronger than in the control mice. After the acute stage of Toxoplasmosis there is a regeneration of the thymus and lymphocytes seem to be activated[19].

Another important role in this view is attributed to unspecific stimulated macrophages. Ruskin and Remington[14] and Ruskin et al.[20] reported that macrophages of mice infected latently with *T. gondii* showed a higher increase in phagocytotic activity in vivo and in vitro against *Listeria monocytogenes* than macrophages from normal mice. We also suppose that in our experiments a latent *T. gondii* infection stimulates the macrophages, so that parasitemia of *P. berghei* is reduced if their phagocytotic activity is greater than the mitotic index of the malarian parasites. It seems that in latent *T. gondii* infection in mice phagocytosis has its maximum about 6 weeks after injection, because all doubly infected mice survived. Thereafter it evidently decreases; but macrophages seem to be activated even when the *T. gondii* infection has existed for 52 weeks. Therefore protection against *P. berghei* still remains.

1 These studies were conducted in the Institut für Medizinische Parasitologie der Universität Bonn (D-5300 Bonn, Federal Republic of Germany).
2 F.G. Araujo and S.J. Remington, Proc. Soc. exp. Biol. Med. *139*, 254 (1972).
3 E.C. Cutchins and J. Warren, Am. J. trop. Med. Hyg. *5*, 197 (1956).
4 H. de Roever-Bonnet, Trop. Geogr. Med. *15*, 45 (1963).
5 B.C. Foster and W.F. Culloch, Can. J. Microbiol. *14*, 103 (1968).
6 G. Huldt, Acta path. microbiol. scand. *58*, 457 (1963).
7 M.N. Lunde and L. Jacobs, J. Parasit. *49*, 932 (1963).
8 E.K. Markell and W.P. Lewis, J. Parasit. *43*, 38 (1957).
9 U. Mengs, Inaugural-Dissertation, Math.-Nat. Fakultät, Universität Bonn, Bonn 1974.
10 I. Nakayama, Keio J. Med. *13*, 7 (1964).
11 I. Nakayama, Keio J. Med. *14*, 63 (1965).
12 I. Nakayama, Keio J. Med. *15*, 23 (1966).
13 Y. Oka, Y. Ito, M. Furuya, M. Okugi and H. Osaki, Jap. J. Parasit. *18*, 226 (1969).
14 J. Ruskin and J.S. Remington, Science *160*, 72 (1968).
15 K.K. Sethi and B. Pelster, in: Activation of macrophages, p.269. Eds W.-H. Wagner and H. Hahn. Excerpta Medica/ American Elsevier Publ. Comp., Amsterdam, New York 1974.
16 J.S. Remington and T.C. Merigan, Proc. Soc. exp. Biol. Med. *131*, 1184 (1969).
17 G.T. Strickland, A. Voller, L.E. Pettit and D.G. Fleck, J. infect. Dis. *126*, 54 (1972).
18 B. Pelster, Proc. 3rd Int. Congr. Parasit. *1*, 278 (1974).
19 B. Pelster, G. Piekarski and N. Suzuki, Z. ParasitKde *49*, 113, (1976).
20 J. Ruskin, J. McIntosh and J.S. Remington, J. Immun. *103*, 252 (1969).