John Hull Grundy Memorial Lecture, 1987

Warfare, Disease and the Survival of Arthropods in the Desert

J L Cloudsley-Thompson

Emeritus Professor of Zoology

University College, University of London, Gower Street, London WC1

At first sight there may appear to be little in common between an academic zoologist such as myself and all the topics embodied in the title of this lecture. Nevertheless there are, in fact, some unexpected connections due largely to historical events during the period in which I happen to have been alive. When I attended the first John Hull Grundy Lecture at the Royal Army Medical College I noticed, during tea, an old album of group photographs of the RAMC Officers' Mess, Rawalpindi. In one of these I recognised my father; he looked absurdly young as he lived till he was nearly 94 and I remembered him in his later years. After serving in the RAMC with 3rd Cavalry Division during the Great War, at first on horseback and later mounted on a motor bicycle, he had been posted to India early in 1921. My mother went too, and I was born in Murree that summer. (On the morning after my arrival, the gardener found the pug marks of a leopard in the flower beds of the bungalow; large carnivores were not endangered in those days.)

My own connection with the British Army was later, in World War II and, again, with the cavalry – now mechanised. I was commissioned into 4th Queen's Own Hussars and transferred to 4th County of London Yeomanry (Sharpshooters). We joined 7th Armoured Division in the Western Desert and Libya, first seeing action in November 1941 when we took part in the 2nd Libyan Campaign (Operation 'Crusader') and the relief of Tobruk. Apart from short breaks, the regiment remained on active service until the end of the war. Unfortunately, during the Gazala ('Knightsbridge') Battle the following summer, my own A15 Mk. VI Crusader tank was knocked out by an 88 mm. A.A./A.Tk. gun, when B Squadron 4th C L Y was rashly ordered to charge 15th Panzer Division. (The intention had been to close the range so that our puny 2-pounders could inflict damage on the more heavily-armoured German Pz. Kw. Mk. IIIs and IVs.) The entire crew was killed or wounded and I myself, did not rejoin the Sharpshooters until about three months before 7th Armoured Division embarked for the D-day landings.

During the North African desert campaigns, therefore, I enjoyed the hospitality of the RAMC on two different occasions. A month after our arrival in Egypt, I had had the misfortune to be afflicted with bacillary dysentery and spent 2½ weeks in hospital. The standard treatment at that time consisted of a large dose of castor oil, followed by salts every two hours for three days, and no solid food for another week. It left the patient feeling

rather feeble, but was otherwise most effective. That the Deutsches Afrika Korps suffered from bacillary dysentery to a greater extent than did the Commonwealth troops was not known until much later. Presumably German and Italian field hygiene was less efficient than ours. Dysentery, like typhus, has always been a disease of warfare. Throughout the ages, the two have been so common in armies and navies on active service that they used to be known as 'campaign diseases'. Although by no means restricted to desert regions, dysentery is transmitted by flies, the plague of oases and a curse throughout the Western Desert in Egypt and Libya.

It is usually assumed that the pestilence which struck the Philistines after their great battle with the Israelites about 1100 BC was bubonic plague. After the Ark of the Covenant had been captured by the Philistines and sent to Ashdod, a terrible epidemic broke out and a large proportion of the population died. (This was the plague that inspired Nicholas Poussin's famous painting in the Louvre.) In consequence, the 'priests and diviners' the Philistines recommended that the Ark should be returned, along with a 'trespass offering' of five golden images of 'mice' and five of 'emerods'. The association of the disease with rodents has often been taken to indicate that it was bubonic plague, and the suggestion made that 'emerods' may have been the swollen axillary glands of the sufferers. On the other hand, Professor J F D Shrewsbury has argued convincingly that bubonic plague cannot, by the wildest stretch of imagination, be conjured into the accounts of the Plague of the Philistines but, rather, the disease must have been acute bacillary dysentery¹. Shrewsbury pointed out that a plague of mice does not necessarily imply an epizootic plague among mice and, in any case, field mice could not possibly have been responsible for an epidemic of human plague. The word translated as 'emerods' in the Bible means haemorrhoids or piles with which, doubtless, the Philistines who survived were afflicted as a sequel to their infection.

Unlike amoebic dysentery, bacillary dysentery does not last long; but it is severe and, unless treated, is frequently fatal. It might well also have been the plague which destroyed the army of Sennacherib, king of Assyria, about 700 BC, at Pelusium on the Egyptian frontier (when Sennacherib was advancing on the army of Tirhaquah, the Ethiopian Viceroy of Egypt). 'And it came to pass that night, that the angel of the Lord went out and smote in the camp of the Assyrians an hundred

four-score and five thousand; and when they arose early in the morning, behold, they were all dead corpses' (II Kings XIX 35).

The English soldiers at the battle of Crécy, in 1346, were so riddled with dysentery that the French called them the 'breechless' or 'bare-bottomed' army! On 10 October 1439, the German Emperor, Albrecht V reached the walls of Baghdad. On 13 October he was dead and his army in retreat, defeated by bacillary dysentery.

The Russo-Japanese conflict of 1904-5 was actually the first war in which wounds claimed a greater toll than sickness. In this, as in all earlier wars and especially those that took place in warm or tropical regions, bacillary dysentery played a major rôle in the destruction of human life. It is quite difficult to appreciate the enormous advances in medicine that have taken place during the last half century. I can well remember one of my uncles (who retired to Britain in 1945 after a life time in the Indian Civil Service) extolling the new wonder-drug sulphaguanidine; and I probably owe my own uncomplicated recovery in 1942 to sulphonamide.

The second of the campaign diseases, typhus fever, is specifically a disease of war and famine. Transmitted mainly by body lice, it rates with bubonic plague and malaria among the three most devastating insect-borne afflictions of mankind. Typhus and dysentery struck the Spanish Armada in 1588. The cramped and filthy conditions on board ships during the Middle Ages must have rendered disease inevitable. Dysentery and food poisoning also wrought havoc on the English ships and, when the Armada anchored at Calais on 7 August, it was decided to use fire-ships to force the enemy out to sea before disease and hunger had lessened the English power to attack².

Although many plagues in the distant past may have been epidemics of typhus, the first really authenticated epidemic of that disease occurred in 1489, when the Spanish army of Ferdinand and Isabella was fighting the Moors for Granada. Within a year 17,000 soldiers had died from it, whereas only 3,000 had been killed by the Moors. The disease spread throughout Spain and was carried from there to the New World. It played a decisive rôle in the wars between Charles V of Spain and Francis I, king of France, in consequence of which Charles was crowned Holy Roman Emperor³. The greatest influence of typhus on military history, however, lies in the part it played in the defeat of the army with which Napoleon Bonaparte invaded Russia in 1812. In combination with cold and starvation, dysentery and pneumonia, typhus enabled Prince Michael Kutusov, the Russian Commander-in-Chief, with fewer than 250,000 soldiers, to reduce Napoleon's Grand Army of 600,000 men to less than 40,000, of whom only 1,000 were ever again fit for duty⁴.

Shortly after my first birthday, I contracted malaria and was cured by means of quinine. It was not until after World War II that the exoerythrocytic cycle of the

malarial parasite was discovered and Paludrine synthesised. Another of my numerous uncles who fought in the Great War was invalided home from Salonika with *Plasmodium* so firmly entrenched in his liver, that he had an attack of malaria nearly every winter, almost until the outbreak of World War II. Malaria is yet another insect-borne disease that has had a decisive influence upon the outcome of warfare in the past⁵.

In 1909, W H S Jones published a challenging book⁶ in which he suggested that the Greeks who surrendered to the Roman legions were not the same as those who previously had fought off the Persian invaders, because their enterprise had been sapped by malaria. Sir Ronald Ross and others have also contended that the downfall of the great empire of ancient Greece was probably due to the invasion of the country, not by devastating human armies but by the malarial parasite, an infinitely more terrible, though unseen foe, which destroyed the newborn infants, undermined the health of the children or killed them outright, rendered the richest agricultural land uninhabitable, and destroyed the vitality of the people until the power and glory of ancient Greece became but a mocking memory.

Before the First Punic War, in 396 BC, the Carthaginian army besieging Syracuse was stricken by pestilence. There was an enormous death rate, and the siege had to be raised and the army dispersed. From a historical point of view, the epidemic was of the greatest importance because it meant that, more than 100 years before the Punic Wars, during which much of the early fighting took place in Sicily, Carthage was prevented from occupying the island with a powerful army and establishing naval bases there. Even so, the Romans had the greatest difficulty in conquering the Carthaginians. A similar epidemic attacked both sides in 212 BC when they met in battle at Syracuse during the Second Punic War; but whether this and the earlier disease were malaria, smallpox or bubonic plague is uncertain⁵.

Throughout history the Roman army was periodically ravaged by epidemic diseases, including malaria, no doubt acquired during its conquests in various parts of the world, for human barriers are not recognised by insects, nor by the pathogens they transmit. The disintegration of the Roman Empire was a gradual process, brought about by numerous complex causes of which insect-borne diseases, especially bubonic plague and malaria, clearly played an important part.

Although mosquitoes require water in which to breed, malaria was one of the main medical problems of the military forces engaged in the Mediterranean theatre during World War II. From earliest times, malaria had rampaged in the oases of the Sahara until it was eradicated from Algeria by the introduction of fish (*Gambusia* spp.) which proved to be very successful predators of mosquito larvae. Beni Ounif was a most unhealthy place until malaria was eradicated in 1924, and the disease did not reappear there until an epidemic

during the years 1944–1949 struck down one third of the population⁷.

Until the beginning of the present century the Tuareg controlled the Sahara from Libya to Timbuktu, while the Cha'amba and other Arab tribes of the north-western central Sahara enjoyed a tremendous reputation as bandits. Experts in desert warfare, they eagerly joined the French Saharan Camel Corps to fight their traditional enemies, the Tuareg and Moors. It was one of their patrols that broke forever the military power of the Ahaggar Tuareg at the Battle of Tit in southern Algeria in May 1902. With the imposition of peace, trade increased and so did the standard of living. At the same time, however, because of the reduction in disease the population also increased, oases were enlarged, the water-table fell, and intensified agriculture led to further desertification of northern Africa⁷.

At this point, I might just mention the fact that in recent years, the adverse environmental effects in arid regions, caused by off-road vehicles (ORV's), both military and civilian, have become increasingly apparent. After 40 years, only about 35 per cent of the vegetation had recovered on vehicle tracks, and some 18 per cent on a heavily used road, in the region of General G S Patton's wartime tank manoeuvre areas of California. Tank tracks, gouged deeply into desert soil, initiate erosion, while natural wind erosion is greatly enhanced when the surface crust of the desert is broken up by tanks, guns and other heavy military equipment. The microflora which stabilises the soil is destroyed, and the fauna is harmed in diverse ways. Desert varnish is a dark brown or black coat of ferromanganese 10–200 μm thick on exposed rock surfaces in arid regions throughout the world. It is easily destroyed by ORV's, but from 3,000 to 5,000 years may be required for a visible coat to be reformed, and 10,000 or more years for heavy coats to develop⁸.

Each year, at the time of the rains (July–September), there is an outbreak of malaria among the people who inhabit the semi-arid belt of Sahel desert savanna south of the Sahara. It is transmitted by the mosquito *Anopheles gambiae*, of which a few females are able to survive through the long dry season. They take frequent, but incomplete, blood meals which result in the failure of ovarian development. This partial diapause is engendered in response to the onset of cool weather, accompanied by low humidity. The ovaries undergo only one gonotrophic cycle during the dry season and develop extremely slowly so that, when the rains come, the gravid females are ready to lay their eggs⁹. (Along the Nile valley, and in places where there is permanent water, *A. gambiae* and malaria persist together throughout the year.) This work was supported by the now abandoned W H O Malaria Eradication Campaign. With the benefit of hindsight it is easy to see that the campaign was doomed to failure, but D D T was so effective when first introduced that basic ecological principles were disregarded and possible environmental

side effects not even considered.

The desert is a most extreme environment, and mosquitoes are by no means the only arthropods to evade the worst rigours of the climate by seasonal adjustments of their life cycles. At the time of rain, a vivid outburst of plant growth is accompanied by the appearance of numerous insects and arachnids. These have passed through the long period of drought either in their developmental stages or else aestivating in the adult instars, with or without diapause. In any case, the appearance of the desert is completely transformed by rain whether it falls seasonally, as on the southern fringes of the Sahara, or unpredictably, as in more central regions and in the Australian desert.

By virtue of their relatively small size and corresponding large surface to volume ratios, nearly all arthropods are faced with problems of water conservation. Adaptations to terrestrial life include a relatively impervious integument with an epicuticular wax layer, the excretion of insoluble uric acid or guanine by insects and arachnids respectively, respiration through spiracles or lung-books whose apertures are closed most of the time so that minimal loss of water takes place, and so on. These are developed to an extreme degree in desert adapted species.

The morphological adaptations of arthropods to the desert environment fall into two broad classes: adaptations that reduce water loss by transpiration, and adaptations for moving across or burrowing into sand. The closing mechanisms of spiracles and lung-books are especially well developed. Adaptations of the family Scorpionidae include the massive pedipalps, reduced metasoma, and small pectines with comparatively few teeth. Some of the buthid scorpions (which have slender claws) are surprisingly good burrowers too, but they use their legs more. Camel-spiders or 'jerrymanders' (Solifugae) bite the substrate with their chelicerae, and rake loosened particles back under the body with the second or, less often, the third pair of legs. Many desert spiders and insects likewise inhabit burrows in the sand. In xerophilous buprestid beetles, the spiracular openings are covered by a basketwork of outgrowths which are believed to impede the diffusion of water molecules to a greater extent than those of oxygen or carbon dioxide. The abdominal spiracles of desert Tenebrionidae open into the sub-elytral cavity rather than directly to the atmosphere. This significantly reduces water loss.

Physiological adaptations include tolerance of high temperature, facultative hyperthermia, relatively low cuticular and respiratory transpiration, efficient nitrogenous excretion, the uptake of atmospheric water, the conservation of metabolic water, and resistance to desiccation. Although no single species exhibits every one of these features, they are all to be found among one or other of the different orders of desert-dwelling Arthropoda.

Most desert arthropods evade the high temperature

and low humidity of the desert surface by burrowing or seeking shelter during the day, and restricting their activities to the hours of darkness. This behaviour is regulated by their circadian biological rhythms. Desert arthropods are not only more strictly nocturnal than are temperate and tropical forest species, but they are generally more active. Two alternative predatory strategies are available to large tropical Arthropoda. They may remain relatively inactive within their sheltered burrows and retreats, or else they can venture forth in search of prey. Forest and woodland forms adopt the first of these. They are far less active than desert species and also less rhythmic. A correlation is evident between the type of habitat, the amount and timing of locomotory activity, and the rate of transpiration¹⁰.

Day-active desert beetles, such as Tenebrionidae and Scarabaeidae are, in general, distasteful, and their black colours have an aposematic and warning function. Desert wasps and bees are likewise conspicuously black. Although nocturnal, most desert arachnids have evolved remarkably cryptic coloration in response to the scarcity of vegetation cover; only a few scorpions and some of the Rhagodidae (Solifugae) are black. Even at night, the light of the moon is so bright that concealment is an important selective factor in the desert. Despite their poisonous stings, scorpions are vulnerable to several species of reptiles, birds and mammals, so even they cannot afford to be conspicuous. Nevertheless, scorpions are mimicked by Solifugae, especially the short-legged Rhagodidae, and ant-mimicry is common among day-active jumping-spiders (Salticidae)¹⁰.

Most contemporary wars have been fought in desert regions of the world and, even with modern equipment, camouflage and disguise are still of vital importance. Military vehicles are usually coloured to match the sandy background; in World War II lorries were disguised as tanks to mislead the enemy, and so on – for surprise can be, and frequently has been, achieved in desert warfare. During the Yom Kippur War of 1973, for instance, the attention of the world was focussed on the question why Israel had not been forewarned of the impending Egyptian attack. The element of surprise may, however, have been deliberately exaggerated by the Israelis in order to create an impression that the Egyptian crossing of the Suez Canal would have been a failure had they themselves been better prepared. 'Blitzkrieg', too, may well exploit uncertainty in featureless desert country, but it is by no means always efficacious in a slow war of attrition, such as the Israeli invasion of Lebanon.

Now I have almost come full circle. British military involvement in the desert originated with the Indian Empire and its communications, in defence of which British soldiers were garrisoned in the Sind, fought on the North-West Frontier, in the Crimea, Afghanistan, Egypt and the Sudan¹¹. Until about 1960, there used to be a leather-bound volume in the Governor's Palace at

Suakin. In this were entered the names and units of British soldiers and marines who died during the long siege of the town during the Mahdia. After heatstroke, the most common recorded cause of death was from disease. In 1896, the Anglo-Egyptian Nile Expeditionary Force, under command of Major-General Sir Herbert Kitchener, was struck by an epidemic of cholera during the reconquest of the Sudan. Lieut W S Churchill (4th Hussars) described this in *The River War* (1899). (Churchill was attached to 21st Lancers and took part in the famous cavalry charge by that regiment during the Battle of Omdurman).

On 30 December 1899, the Earl of Dunraven was granted permission to raise a squadron of 'Sharpshooters' for service in the Boer War. On 6 April 1900, however, a whole battalion of 'Sharpshooters' (18th Bn, Imperial Yeomanry) embarked at Southampton, landing at Beira four months later. Here they formed part of the Rhodesian Field Force. Shortly afterwards, two additional battalions were recruited.

Lord Dunraven's summary of his own military career (as a supernumerary Captain in his regiment) was 'brief but not glorious'. Along with many others, he contracted dysentery shortly after landing in Africa, and was invalided home. With the return of peace, the 'Sharpshooters' were reconstituted as 3rd County of London Yeomanry (Sharpshooters). During the Great War, this territorial regiment served in Egypt, Gallipoli, Macedonia and Palestine. 4th C L Y (Sharpshooters) was formed in 1939, and both regiments sailed in the same convoy to the Middle East in August, 1941. Until the present time, detachments of British troops have been serving in the Gulf States of Arabia.

In his speech before the Battle of the Pyramids, in 1798, Napoleon Bonaparte said: 'Soldiers, consider that from the summit of these pyramids, forty centuries look down upon you'. He might perhaps have remembered Cambyses II, Emperor of Persia, whose army, after conquering Egypt in 525 BC, disappeared in a sand storm while marching westwards from the Nile to Kharga Oasis. Napoleon's own Army of the Orient was destined to be plagued by disease, and was eventually defeated at the Battle of Alexandria by the British under command of General Sir Ralph Abercrombie who was himself mortally wounded.

The Sharpshooters was just one of the numerous territorial and regular units of the British Army to have served in the desert during the past century or so, and to have suffered losses through insect-borne disease. What ghastly epidemics would ravage the poor starving survivors of any large-scale nuclear war today? Transformation of the entire world into a desert¹², coupled with the breakdown of sanitation and other essential services, would surely herald the most terrifying *Dies Irae*, while the nuclear winter that followed would add a chilling *Lacrimosa* to this awe-inspiring *Requiem* for mankind.

REFERENCES

1. SHREWSBURY J F D (1964). The Plague of the Philistines and other Medical-Historical Essays, London: Gollancz. 189 pp.
2. KEEVIL J J. (1957). Medicine and the Navy 1200–1900, Vol 1 (1200–1649). Edinburgh: Livingstone. 255 pp.
3. ZINSSER H. (1934). Rats, Lice and History, Boston: Little, Brown 301 pp.
4. CARTWRIGHT F F. (1972). Disease and History, London: Hart-Davis. 248 pp.
5. CLOUDSLEY-THOMPSON J L. (1976). Insects and History, London: Weidenfeld and Nicolson. 242 pp.
6. JONES W H S. (1909). Malaria and Greek History. Manchester: Manchester University Press. 175 pp.
7. CLOUDSLEY-THOMPSON J L. (1977). Man and the Biology of Arid Zones. London: Edward Arnold. 182 pp.
8. WEBB R H and WILSHIRE H G (Eds) (1983). Environmental Effects of Off-Road Vehicles. Impacts and management in arid regions. New York: Springer-Verlag. 534 pp.
9. OMER S M and CLOUDSLEY-THOMPSON J L (1970). Survival of female *Anopheles gambiae* Giles through a 9-month dry season in Sudan. *Bull Wld Hlth Org* 42: 319–330.
10. CLOUDSLEY-THOMPSON J L. (1986). Desert adaptations in arachnids. *Proc IX Internat Congr Arachnology* (Panama 1983): 29–32.
11. BARTHORP M. (1984). War on the Nile: Britain, Egypt and the Sudan 1882–1898. Poole: Blandford Press. 190 pp.
12. WESTING A H. (1980). Warfare in a Fragile World. Military impact on the human environment. Stockholm: International Peace Research Institute. London: Taylor & Francis. 249 pp.

NOTICE TO ADVERTISERS

Space orders should be sent to Combined Service Publications Ltd., P.O. Box 4, Farnborough, Hampshire GU14 7LR. Artwork and/or Copy should be forwarded to the same address to arrive by the first day of the month preceding issue, publication dates being February, June and October of each year.

Advertising Rates and Technical Details are as listed in British Rate and Data.