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Postglacial formation and fluctuations of the biodiversity of Central Europe in the light of climate change

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We are living in an interglacial period, in one of the several cycles of glacial formation and melting that have occurred since the continuous decrease of the average temperature during the Pliocene beginning about 2.5 million years ago. Glacial periods usually last about 90,000-100,000 years, interglacial periods are much shorter, usually 15,000-20,000 years or less. (There is, however, some variation, and the length of these cycles was distinctly shorter at the beginning of the ice age.)

The present biodiversity of Central Europe, including animals, plants, fungi, but also (with some restriction) eukaryotic and prokaryotic unicellular organisms and, thus, also at least many parasitic organisms s.l. and even, to some respect, viruses, particularly those transmitted by arthropods, is largely the result of a deep climate change and, moreover, of various climatic fluctuations during the past – roughly spoken – 15,000 years. At that time the latest (certainly not the last!) glacial period (i.e. the Würm period = Weichsel period) came rather rapidly to an end. The annual average temperature increased gradually and finally reached values up to 12°C (average annual temperature) higher than a few thousand years before. 20,000 years ago the northern and, moreover, larger parts of Central Europe were covered by huge ice sheets, partly of a thickness of several hundred metres up to more than three kilometres. At the maximum of glaciation in the most recent glacial period (about 18,000 years ago) the southern border of the huge area covered by ice ran through the northern parts of Germany. (The Saale-Riß glacial period, which lasted from 230,000 to 130,000 B.P., was accompanied even by a larger glaciation, which included larger parts of Germany.) Also the Alps were straddled by huge glaciers, of course. (The area of Innsbruck e.g. lay under a glacier with a thickness of more than 1.5 kilometres.) The parts of Central Europe between the northern glaciers and those covering the Alps were of a tundra-like character without forests and with an extremely reduced number of species of animals, plants and other organisms, however, inhabited by several spectacular mammals (homoiothermic animals!) like mammoths, woolly rhinoceros, musk oxen, sable-tooth cats, and others like roe deer. The South European peninsulas, largely covered by forests of various kinds, represented, however, huge refugial areas with distinctly different inventories of biodiversity. These refugial centres, particularly the Atlantomediterranean, the Adriatomediterranean, the Balkanopontomediterranean subcentre and several others as parts of a big Holomediterranean centre were of utmost importance for the biological recolonisation of Central Europe. However, another important corridor became increasingly significant for the growing biodiversity of Central Europe after the end of the latest (in principle, however, of each) glacial period, namely the broad area in the east. From the Palaearctic parts of Asia numerous species could invade the central parts of Europe; these

are called Siberian faunal elements, usually adapted to ecosystems in cooler climates. (The animals associated with spruce forests are typical examples, but also many mosquito species occurring in Central Europe are Siberian faunal elements.)

Mediterranean faunal elements in Central Europe are characterised by distributional patterns including at least refugial centres in one of the South European peninsulas and covering smaller or larger parts of Central Europe, in many cases also of Northern Europe. These species migrated northwards, when the increasing temperature led to markedly improved ecological conditions. Several *Anopheles* species (*A. algeriensis*, *A. hyrcanus*, *A. plumbeus* …) are examples for Mediterranean faunal elements.

The Siberian faunal elements (with refugial centres as far as Mongolia in the east) are usually characterised by distributional patterns covering large Palaearctic parts of Asia as well as northern and central parts of Europe, but not the Mediterranean parts of Europe (except in higher mountains). Moreover, extramediterranean European faunal elements have contributed to some extent; these are organisms which have survived the latest glacial period in refugial centres in various southern parts of Central Europe (particularly south of the Alps). In addition, there are few other centres (e.g. the Pontocaspian centre) which have also contributed – although to a very small extent – to the biodiversity of Central Europe. Moreover, due to polycentricity and various degrees of expansivity, the situation may become rather complex in many cases.

The concept of formation of the postglacial biodiversity of Central Europe by invasion of Mediterranean faunal elements, on one hand, and of Siberian elements, on the other hand, is particularly valid for animals inhabiting the arboreal biomes (i.e. areas in which natural forests can develop), thus also for all vectors for infectious diseases in Central Europe. The show horses among the animals following these biogeographical mechanisms are the arthropods as ectothermic animals, and from the standpoint of medical entomology and acarology the arthropod vectors. Several other mechanisms of distribution exist, which are of high significance particularly for plants and free-living micro-organisms, but need not be discussed in this context.

At the beginning of our interglacial – about 12,000 years ago – the average temperature increased rapidly, it reached a first peak about 10,000 years ago, and after a period of about 1,000 years it increased again continuously until it attained values higher than or approximate to present ones. This period marked by two peaks about 6,500 and about 4,500 years B.P. is known as the Holocene climatic optimum (or Atlanticum), and these 2,000 years were of utmost significance for the immigration of organisms, in particular also arthropods and thus also potential vectors of infectious micro-organisms into Central Europe. The arthropod fauna of Central Europe harbours many species of Mediterranean origin, which show a more or less continuous distribution pattern in the south, but gradually becoming scattered northwards. Several species occur for example in few isolated spots in Northern Germany, and if they had not been detected many decades ago, but were to be discovered today, one might conclude that they are recent immigrants due to global warming. They are, however, not newcomers, but the remains of the intensive and extensive immigration of Mediterranean faunal elements during the Holocene climatic optimum – or in some cases of later immigrations during warmer periods, a particularly marked one occurring about 2,000 years ago.

A good example for vectors which have only recently been found to occur in Germany are the Phlebotominae/sandflies (*Phlebotomus mascittii*). It was claimed that they demonstrate global warming, but we know that the species was found several decades earlier in adjacent regions outside Germany. It is a reasonable assumption that sandflies had immigrated from the south of Europe in the Atlanticum, that they were widely distributed in Central Europe

during that time, that they died out during the following colder periods, but remained in a few xerothermic places like the southwestern parts of Germany, where there are many other insects of Mediterranean origin (e.g. *Mantis religiosa*, *Libelloides longicornis* and *L. coccajus*, *Mantispa styriaca*,…). *Uranotaenia unguiculata* is another good example among mosquitoes. Usually it is believed that the present Alpine glaciers are the remnants of the huge glaciers of the latest glacial period; however, most probably this is not true, since most probably the glaciers in the Alps had totally disappeared during the Atlanticum, and we definitely know that the timber-line in the Alps was considerably higher 6,000 years ago.

The fluctuations of the post-Pleistocenic climate demonstrate that considerable fluctuations of the biodiversity of Central Europe must have occurred and continue to occur. Every year new species are detected, while others seem to have disappeared. One should keep this in mind when concluding hastily that a new record of a Mediterranean species so far unknown in Central Europe is the result of global warming. It cannot be questioned that 6,000 years ago, and probably also (again) during the height of the Roman Empire, Central Europe harboured considerably more Mediterranean faunal elements, and among these also potential vectors of infectious diseases, than today. Nevertheless, this does not discharge us from being aware of possibly new immigrating – emerging – vectors and thus also emerging diseases. The increase of the temperature has now reached values which are comparable to those of the warmest postglacial periods, i.e. the Atlanticum, or which are about to exceed them gradually. Ten years ago it was argued that the climate change lies entirely within the postglacial fluctuation and can thus be neglected. Today we must confess that it would be irresponsible to neglect the present trend which will inevitably lead to further increase of the temperature and thus to considerable ecological and chorological consequences including the possible immigration and dispersion and spread of vectors of micro-organisms causing serious infectious diseases in humans.

The present day molecular biological methods have opened new ways of studying the provenance of migrating organisms so that we can trace the origin of newly detected populations. Phylogeography has become a very important new field not only in biogeography, but also in the epidemiology of infectious diseases.

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