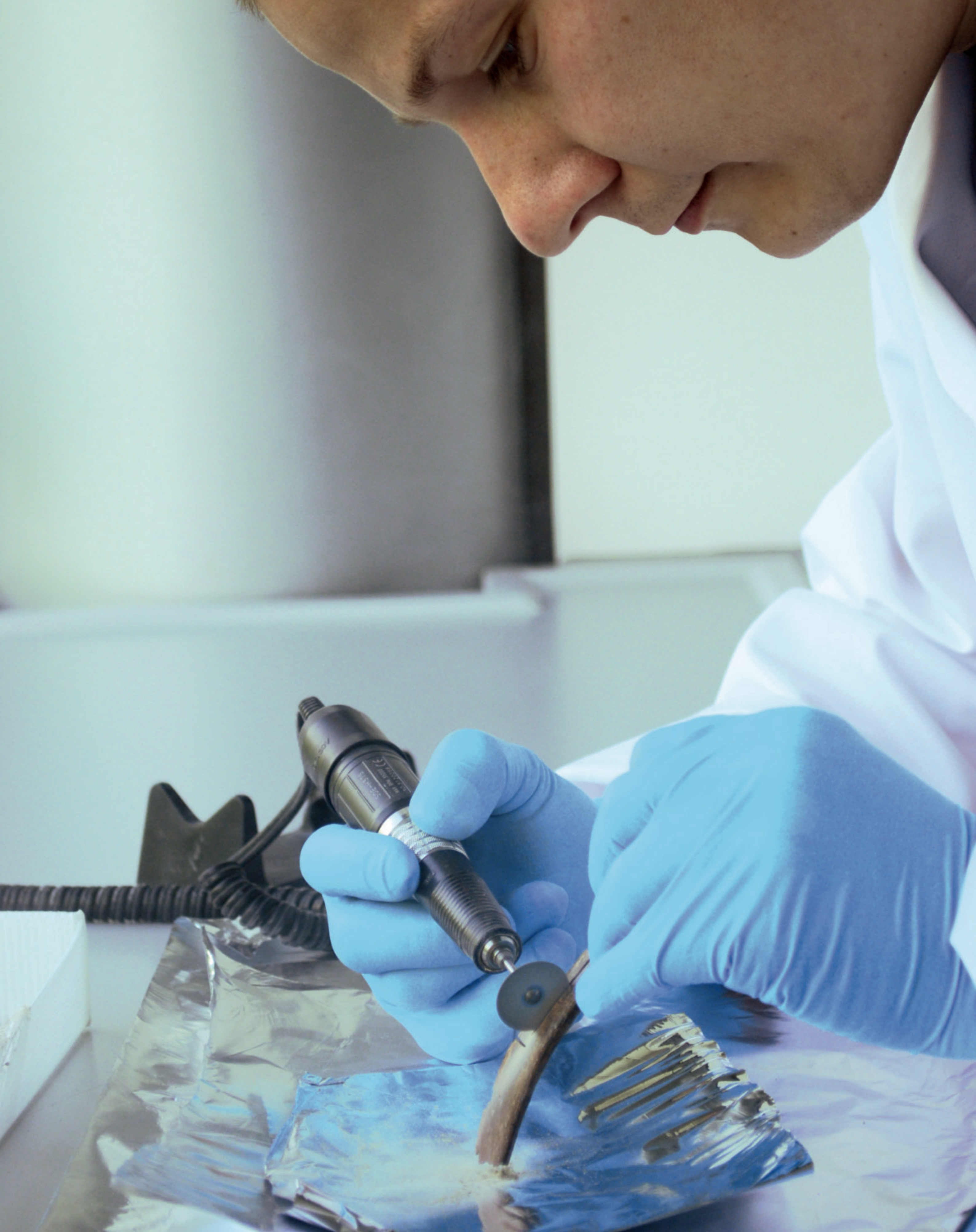

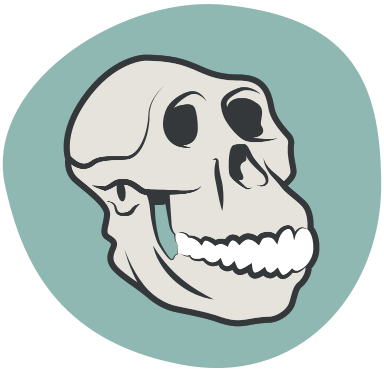

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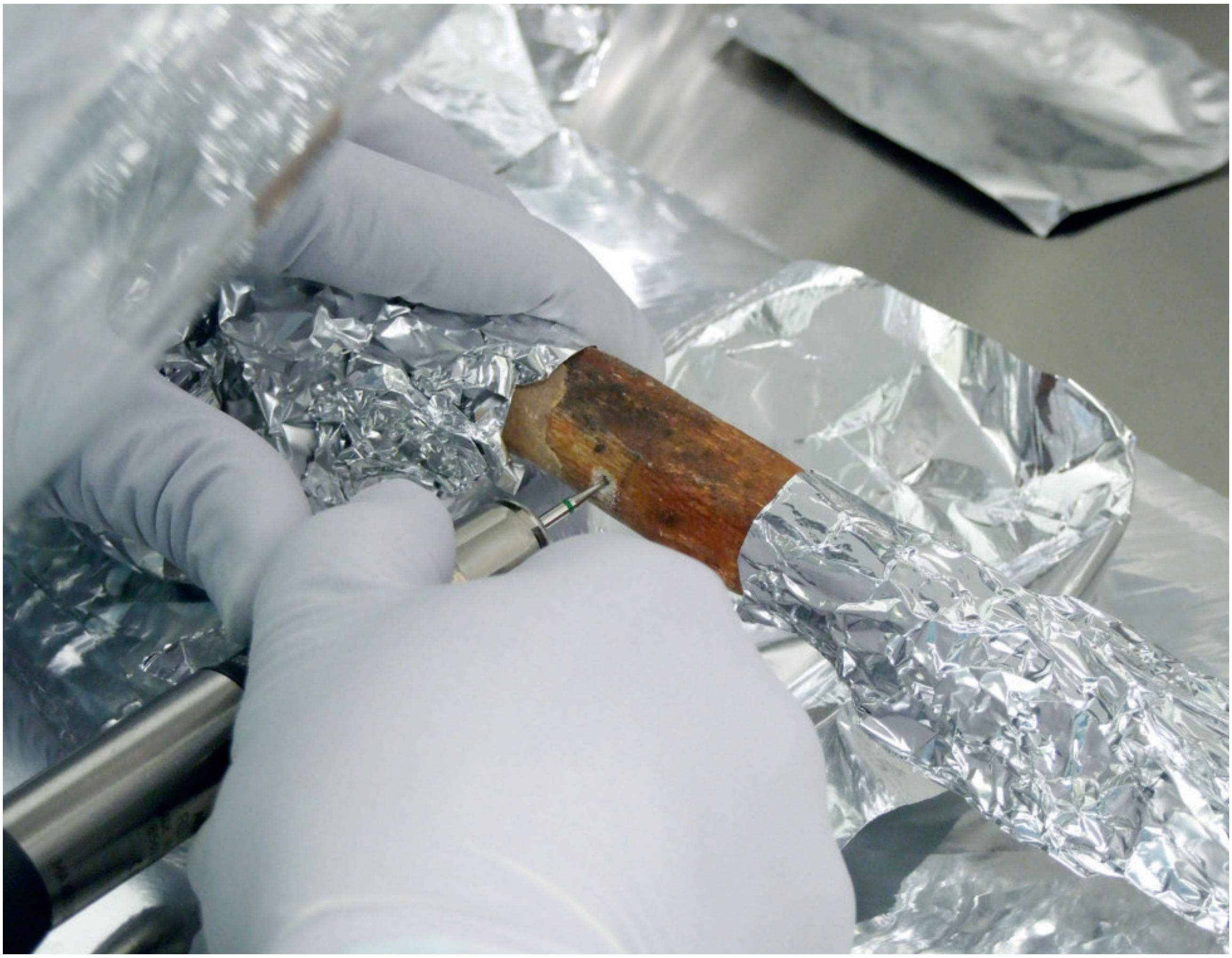
Tracing the steps to becoming human: research and scientific methods

The process of becoming human after the divergence of the human evolutionary line from that of the chimpanzees goes back many millions of years. It begins long before the first known cultural products such as tools. Over the past decades, a variety of methods were applied or specially developed to decipher this process. A complex system of analytical methods has emerged with broad involvement of the natural sciences, including geology, biology, chemistry, physics, and engineering. We present some of these fascinating ways to gain insight into our past below.

The **time dimension** is the most important context of historical research. The interpretation of data and observations is impossible without a temporal classification, as this is the only way to identify sequences and separate causes from effects. A distinction must be made between relative and absolute dating techniques using stratigraphy (geological methods that describe the sequence of layers) and geochronology (physical methods). Relative dating determines the sequence of two events (or the time two objects were created) and the relative timespan between them. Absolute dating indicates a date for an object. In the time depths of interest here, such a date is determined using various methods, such as the radioactive decay of certain elements, and expressed with age ranges. Sometimes it is more important to know whether a fire occurred right before a new settlement was built rather than to know that both events occurred 6,832 +/- 65 years ago, without a clear order of events.

Since becoming human is also a biological process, the scientific discipline of biology, including anatomy, physiology, genetics, zoology, and botany, plays a significant part in this research. The **evolutionary relationship** of our ancestors to one another and specifically *Homo sapiens* can be examined through comparative morphology (analysis of shapes and patterns) of the preserved bones and

1 Sampling of a rib for radiocarbon dating and determination of the carbon-nitrogen ratio.



2 Taking a bone sample for genetic analysis.

teeth. Pronounced brow ridges above the eyes characterize the Neanderthals, but—expressed in a slightly different form—also other early human species, whereas they no longer occur in modern humans. If bones and teeth still contain organic substances such as collagen, an analysis of the preserved genetic fragments or proteins can sometimes provide very detailed information on evolutionary and individual relationships. The Denisova humans were recognized as a distinct species based on genetic snippets extracted from a fingertip bone. *Fig. 2* And the genetic material extracted from the bone fragment of a girl who lived in Siberia around 90,000 years ago provided evidence that her mother was a Neanderthal woman and her father a Denisovan!

Comparative morphology provides numerous clues about the **life history** of individuals and populations. By examining the different age stages of a specific human type, it is possible to obtain information about growth and development, and the length of childhood. We now know that Neanderthals and all our ancestors had much shorter childhoods and became adults much earlier. We can learn a lot about their developmental biology and sociology from this. By estimating age at the time of death, we can also roughly determine the mean life expectancy.

We can examine important aspects of **reproductive biology** using comparative morphology. The anatomy of our female ancestors' pelvis is different from ours. Australopithecines did not have a narrowed birth canal, so the babies did not have to rotate during birth. The babies came into the world much more mature, that is, less helpless and dependent on their mother, since their smaller heads did not require early births. It is possible to determine how long a child was breastfed based on the ratio of the elements calcium and strontium in tooth enamel. During the formation of tooth enamel, these elements are incorporated into the tooth depending on their prevalence in the food. Mother's milk is made up of a different ratio of these elements than subsequently consumed food. It was found that Neanderthal children were given solid foods from the age of 5–6 months.

Fig. 3

References to the **social structure** and **social behavior** of our ancestors could also be encoded in their bones. Hormonal predispositions change bone growth and influence the social behavior of a species. If male and female individuals differ only slightly in anatomy and body size, and the length of the index and ring fingers of their hands are the same, this indicates monogamous relationships. Modern gibbons are an example of this. If, on the other hand, male individuals are significantly larger and stronger than females in terms of body mass, canine teeth, and muscle attachments, and the index fingers are significantly shorter than the ring fingers in both sexes, this indicates polygyny, that is, harem behavior, as we observe among gorillas and chimpanzees. Our modern human behavior lies between the two extremes, albeit much closer to the gibbons.

Who has not heard the saying: "Do I have to chew your food for you too?"! The evidence of toothless old individuals who could no longer chew their food without help from others (for example by pre-chewing) provides important information about social bonds and altruistic behavior. This truly human behavior, unknown in the animal kingdom, was first documented for *Homo erectus,* 1.8 million years ago. We can also draw conclusions about social behavior from geoarchaeological studies of dwellings and social spaces such as hearths and sleeping quarters.

Bone modifications indicate injuries, illnesses, or malnutrition, which in turn have a lot to do with **living conditions** and **diets**. The diet is an important mirror of our living conditions. Analyses of the anatomy of teeth and jaws, as well as their diseases, not only provide us with information on behavior (for example using teeth as tools, using toothpicks, smoking pipes) but especially on the type of food consumed. We can interpret whether it was tough or firm, like dried meat or vegetable roots, or soft, like porridge or fast food, from the wear on the teeth, from their position and structure. Very sugary food can lead to tooth decay, and the different nutritional properties provided by plants, fish, and meat are stored as different isotope ratios in the bones. Food remains are preserved in rare instances, for example as microscopic traces on tools or vessels. In such cases, chemical analyzes can help identify the use of blood or milk or even the production of wine or cheese.

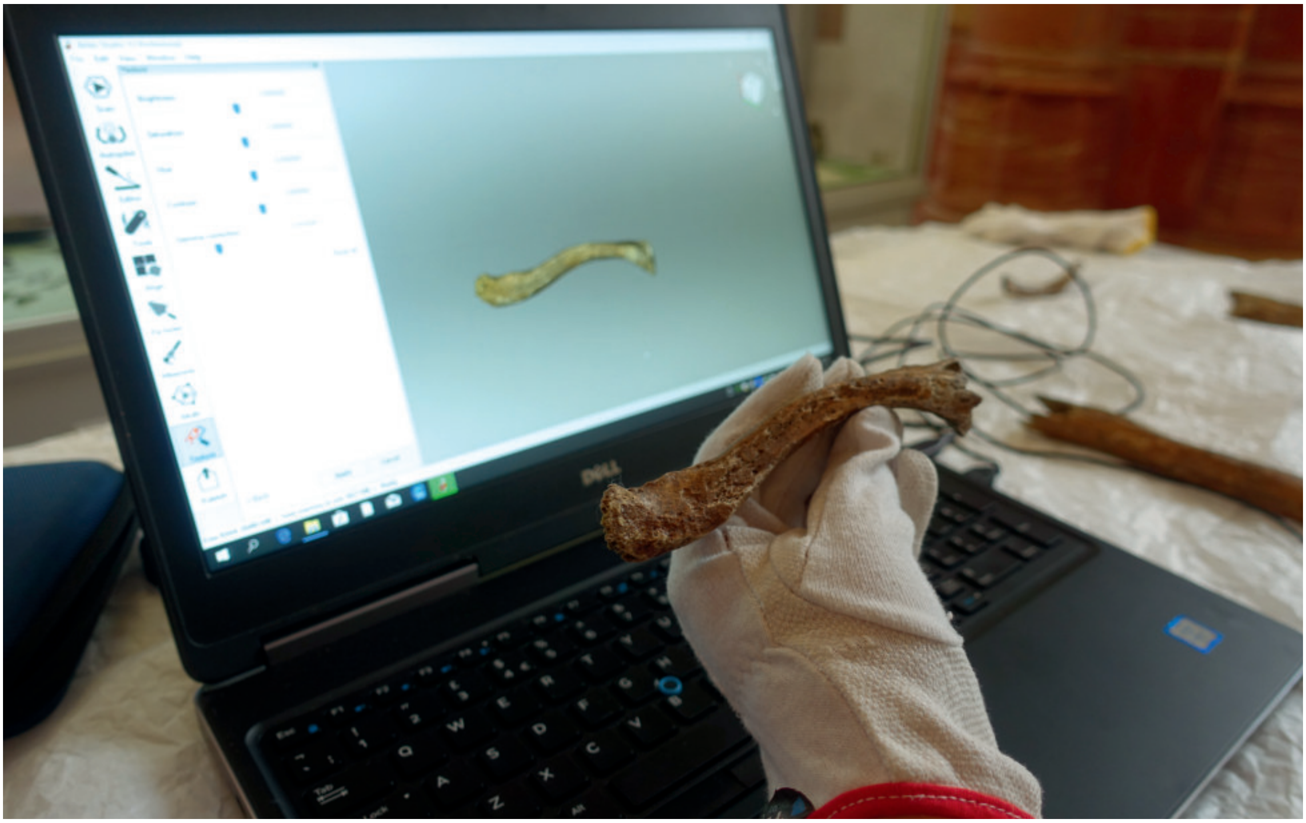
Fig. 1

That brings us to the **preparation of the meal**. The control and use of fire and thus the ability to cook, bake, or grill is of crucial importance for human evolution. In many cases, it only made it possible to digest certain foods and absorb their nutrient in the first place, for example by detoxifying and changing the consistency, or at least decisively improving the experiences, as in the case of starchy plants. Due to the thermal pretreatment of food, the (cooking) human is the only mammal with the ability to (pre-)digest, outside of the stomach. Evidence for the use of fire was discovered by analyzing charcoal and hearths and also through observing chemical or physical changes of heated stones or floor surfaces.

The procurement of food is dependent on **hunting and gathering**, and later **farming and agriculture**. Cut and impact marks on bones are evidence of the use of meat or bone marrow. Hunting tools are rarely preserved as well as the oldest-known weapons in human history, the approximately 300,000-year-old wooden spears and throwing sticks associated with *Homo heidelbergensis* from Schöningen. Plant residues rarely survive in the archeological record, which is why less can be said about the plant-based diet in the Paleolithic. Analyses of the dental tartar of Neanderthal teeth identified plant remains from a wide range of foods.

Technological development is another, extensive research field of human evolution. It is not limited to material aspects of organic raw materials such as wood and bones or inorganic materials such as stone and pigments, but also includes the spatial distribution of objects and constructions, as they arise from the processing of materials or the organization of settlements.

Raw materials, in turn, provide us with evidence for **economic and ritual action**. The origin of organic and inorganic raw materials reveals a lot about supra-regional relationships and knowledge transfer. By analyzing devices, art objects, and burials, we learn something about the values and beliefs of early communities.



3 Comparative morphology helps reconstruct the life story of a person. Modern scanning techniques facilitate this process.

Further reading

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