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## **Virtual Neanderthals : a study in agent-based modelling Late Pleistocene hominins in western Europe**

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## SUMMARY

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This study presents an agent-based simulation model exploring the patterns of presence and absence of Late Pleistocene Neanderthals in western Europe. HomininSpace implements a parameterized generic demographic and social model of hominin dispersal while avoiding parameter value biases and explicitly modelled handicaps. Models are simulated through time within a high-resolution environment where reconstructed temperatures and precipitation levels influence the carrying capacity of the landscape. Model parameter values are assigned and varied automatically while optimizing the match with Neanderthal archaeology using a Genetic Algorithm (GA) inspired by the processes of natural selection. The system is able to traverse the huge parameter space that is created by the complete set of all possible parameter value combinations to find those values that will result in a simulation that matches well with archaeological data in the form of radiometrically obtained presence data.

This study further implements and explores with the HomininSpace tool ten questions that are unresolved in the current debate on Neanderthals. Modelled Neanderthal hominins were capable of using the environment to their benefit irrespective of energy distribution or dispersal modus. Adding coastal resources to the model allows a more relaxed demographic sub-model with more realistic parameter values and less physical stress for female Neanderthals. Adding the ability to cross open water does not influence the simulation scores much, but allowed hominins to reach England earlier. With the inherent flexibility of the model the hominins appear to have difficulty staying out of England in most simulations.

Almost 40,000 simulations were executed for a total of nearly 3.3 billion simulated Neanderthal years. Very short lived and fast reproducing Neanderthals score well in certain scenarios. High birth rates and low mortality rates for (pre) fertile hominins were successful in others. Individuals of post-fertile conditions were generally selected against. Subsistence requirements could vary widely but were met with large foraging ranges, increased energy extraction, or simply by survival in very low numbers. The power of this model to recover quickly after setbacks excludes the need for implementing unwarranted hypotheses about either environment or behaviour of past hominins. With HomininSpace a new and powerful tool to explain archaeological patterns and explore new and old questions is added to the toolset of archaeologists and paleoanthropologists.