Appendix SC – An expanded and more in-depth analysis of Figure 7 in the main article

Refers to main article Andersson and Czarán, *The transition from animal to human culture – simulating the social protocell hypothesis*, Proc. Roy. Soc. B (2023)

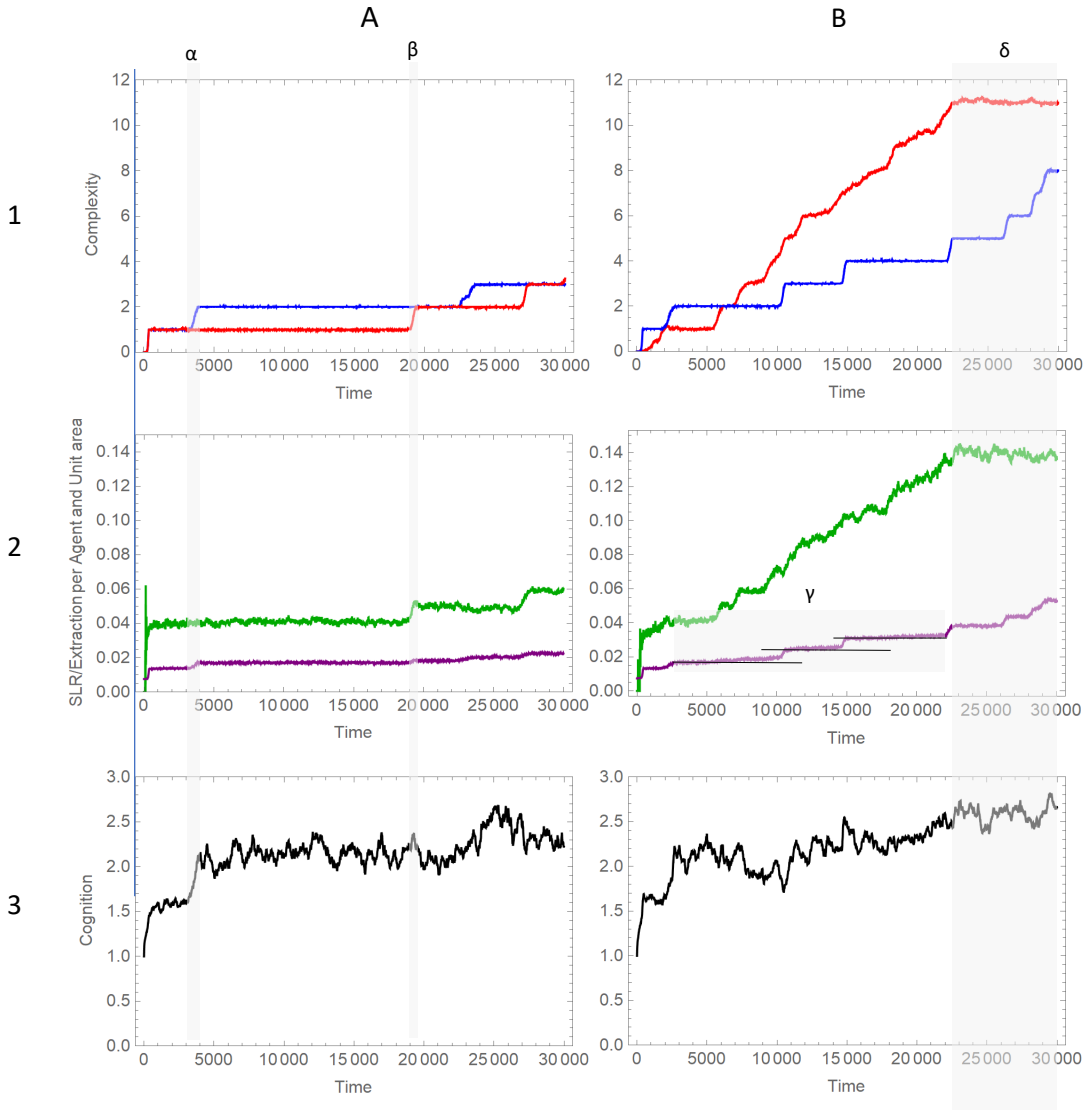

Figure C1 – (Elaborates Figure 7 in main article) The columns correspond to two runs with different random seed over 300,000 updates (30 000 "years") at a resolution of 500×500, with the SLR boost institution and the genetically inherited cognitive capacity active. The BASE case parameters are used, but with SLR=30. Row 1 shows the time evolution of complexity in the IGUT/carnivory (blue) and SLR (red) institutions. Row 2 shows the evolution of the measured social learning rate (green) and the efficiency of resource utilization (purple). Row 3 shows the evolution of the costly cognitive ability to utilize sophisticated SLR institutions. Greek letters α, β, γ and δ denote specific episodes and details discussed in the text.

Event α (Figure C1) illustrates an increase in complexity of the carnivory institution (1st row, blue). The increase coincides with an increase in resource extraction (2nd row, purple) that is more modest than the

increase that just preceded it. The reason why the second increase in resource extraction is weaker is that during the previous event, there was a simultaneous increase in the complexity of the SLR boosting institution (1st row, red). In the α event, increasing the complexity of the carnivory institution is adaptive, but since there is no other adjustment, it also reduces fidelity, which reduces the positive effect (fewer manage to learn it.)

Event β follows a long period of stasis as a rapid and distinct increase in the complexity of the SLR institution (1st row, red) causes a large hike in the measured SLR (2nd row, green), as well as a small bump in the efficiency of the carnivory institution (2nd row, purple), caused by an increase in the fraction of agents that learn and concurrently practice it. How can such a tiny edge in efficiency cause such a rapid sweep? The main reason is that increasing the SLR boost reduced losses to errors in transmission on the sociont level. While the new variant was not much more efficient than the opposition, its divisions led to faithful sociont inheritance to a greater extent (see Figure 5 in main article), demonstrating how the cultural evolution of more efficient evolutionary functions on the sociont level could be highly adaptive.

In box γ (Figure C1) we observe (against the horizontal black lines in 2nd row) how increases in the SLR boosting institution (1st row, red), together with increasing cognition (3rd row), cause an increase in the efficiency of resource utilization (2nd row, purple). The steps indicated by the vertical lines correspond to stepwise increases in the complexity of the carnivory institution (1st row, blue), but the lines let us discern that there is also a continuous increase in efficiency that must be attributed to the clearly observable continual selection for the SLR-boosting institution and cognition. We here see another mechanism by which increased SLR can be selected for. Increasing the SLR boost, and the genetic ability to benefit from such increases, causes agents to learn more loci, and on average at an earlier age. This leads to an increasing proportion of agents that can participate in extracting the resource.

During episode δ, the increase in the complexity of the SLR boost institution hits a point where increased SLR can no longer compensate for the loss in fidelity caused by increasing its complexity. The reason is that the likelihood of failing to correctly transmit the institution increases exponentially with complexity,[1] while the social learning rate does not increase as fast. At the same time, the carnivory institution can adaptively keep increasing in complexity from its lower level, since it does not yet face as steeply increasing error rates. These two institutions' fidelities are independent in the model since they (unrealistically) lack and cross-linkages in the model (no component loci belong to both).

[1] The likelihoods of successfully inheriting component traditions are multiplicatively related to the likelihood of successfully inheriting an institution that relies on them all collectively.