# Cultural Darwinism:

# Natural Selection of The Spoked Wood Wheel

*F.T. Cloak, Jr.*
*Albuquerque, New Mexico*

[This article is a verbatim rendering of an automated slide presentation entitled "The Wheel", given by the author at the Annual Meeting of the American Anthropological Association, Seattle, November 1968. It was later presented, as "You Can't Reinvent the Wheel Because It Wasn't Invented in the First Place", to New Mexicans for Science and Reason, on May 8, 2002.]

**It** is an important corollary of the Darwinian theory that the evolution of one species or feature from another occurs by small increments rather than by great leaps. This corollary has occasionally been challenged over cases of functionally complex mechanisms, such as the human and avian locomotory apparatus, and these challenges have, I believe, been successfully answered by the Darwinists. The method of answering these challenges consists of showing or suggesting what the increments were, and how each increment was adaptive for the particular species in the particular ecological niche it occupied at the time.

While observing the making of a wheel in Trinidad a few months ago, I was impressed by the complexity of the process and the gestalt nature of the completed whole. The ontogeny of a wheel, like that of a living organism, seemed entirely teleological, programmed for the production of a finished product; this was especially impressed upon me by the wheelwright's explanations of the ultimate purpose of each step and by the final tiring of the wheel, which literally pulls the whole thing together.

When I began thinking about the phylogeny of the spoked wheel, therefore, I had difficulty imagining how this could have occurred incrementally. It did seem reasonable to assume that the species "wheel, spoked" had evolved from the species "wheel, solid". But there are a large number of absolutely essential differences between these two species. As a cultural Darwinist, I needed to find transitional forms between the two and to show that these forms would be adaptive. In other words, I had to show that the phylogeny of the spoked wheel was not teleological but rather could be explained in straight natural-selection terms. To give you an idea of my problem, let me show you briefly the ontogeny of a wheel, emphasizing the critical steps in its manufacture, the steps yielding those parts and relations without which the finished product cannot be an adaptively successful wheel.

The first major stage is the carving of the *nave*, or hub, from a single block of wood. First, the center is marked on the end-grains of the 9" cube. Next, the 8" diameter circle is scribed on both ends, and the cylindrical shape is roughed out with the hatchet





and finished with the jack-plane.


The locations for the spokes are scribed and then cut in with a saw


and then the compass is set to mark off the twelve centers for boring. Holes are bored with the ships-

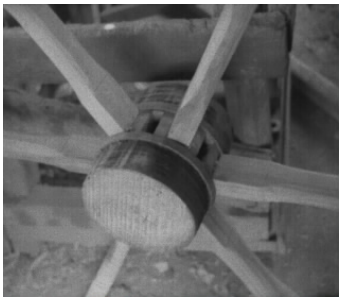

auger, and the mortises are cut with a mallet and chisel, to await


the tenons of the spokes.

The next job is to lay out the spokes, cut in the tenon, and rough


out the inner end of the spokes.


When all twelve spokes are half-finished, every other one is driven home, and then the remaining spokes




are all started and tapped, in rotation, going around and around the wheel.

Now the outside diameter of the wheel is scribed on the spokes, and


the somewhat battered excess ends are sawn off.

The shoulders on which the *felloes* will rest are now located and scribed, again using the sweep,

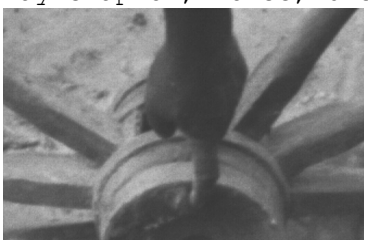
and the square. A special double-pointed scribing tool marks the

location of the pins, which will fit into the felloes, and the pins are chiseled out of the spoke-stock, first on

one side, and then on the other.

Note in this picture that the pins are off-center on the ends of the spokes. The back side of the wheel is up in this picture, that is the side of the wheel that will run next to the cart.

The spokes are now tapered, on this back side only, to the width of the felloe. This is very important. When the wheel lurches into a rut, the cart body and axle slide down and slam against the nave with tremendous force. If the down spoke is not properly tapered, it may snap or, worse, break the nave.



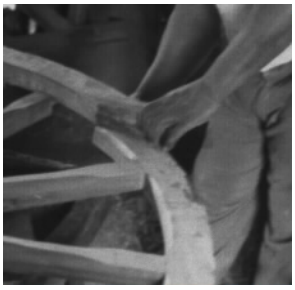
See the piece pushed out of place here? That nave is ruined. The spokes must taper away from the cart, so the thrust is transmitted partly down the spoke as well as across it. This is sometimes called "dishing" the wheel, because the wheel then appears to be saucer-shaped. In fancier wheels, the spokes are actually set in so as to angle away from the cart.

The next step, after the spokes are smoothed with plane and spokeshave, is to make and attach the felloes. The blank is laid out

to the proper curvature, a saw-cut is made to the inside curve, and

the felloe is chopped out with adze and hatchet.

The holes are located, as is the end joining an already-attached



felloe, and the free end. The ends are sawn off and

the holes bored.

The felloe is now installed and

tapped down onto the shoulder,

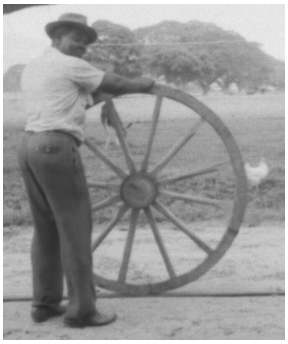
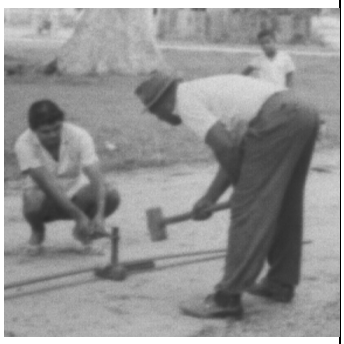
and wedges are driven into the ends of the pins to hold it fast. Now we come to another minor, but essential, step, called *seating the felloe*. A saw-cut is made around the joint, removing material from spoke-shoulder and felloe alike, to assure an exact matching of their joining surfaces so that the pressure on the spoke will be distributed evenly in running. Otherwise, the felloe may splinter.

The felloes are joined together by driving a triangular bit of scrap metal into the outer edge of each joint, and the wheel is now complete except for the tire. But here is another engineering essential: *There must be a one-quarter inch gap* somewhere in the circumference of the wheel, so that the tire, when shrunk on, can pull the whole wheel together even more tightly than it is already.

Tiring is next. The exact circum-ference is

measured, as shown here;

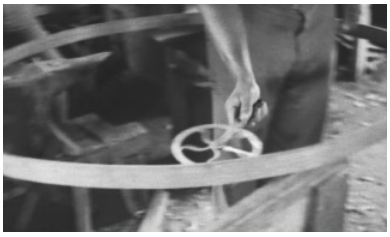
then the wheel is rolled along the strip of iron to measure it and the iron is cut off.

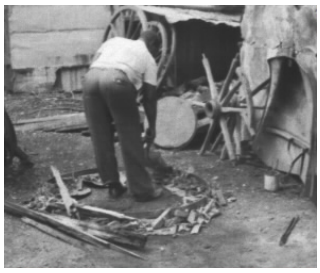
The iron is chained to the wheel and then rolled up to form the tire. The two ends are heated red-


hot, hammered flat, reheated, and then welded on


the anvil, so that when checked with the follower, the tire is 1" shorter in circum-ference than the felloes.



Now the whole tire has to be heated to expand it. When a white oxide has formed all over, the tire



is snatched from the fire and placed over the wheel

and hammered and pried into place.

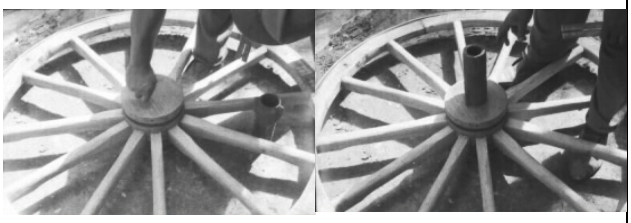



At intervals the wheelwright picks up the wheel and

quenches it to stop the wood from

burning too much and to control the process of shrinking. Then he puts it down and continues to tap the tire into place.

Next, it gets its final quenching all around. All that remains to do is scribe the



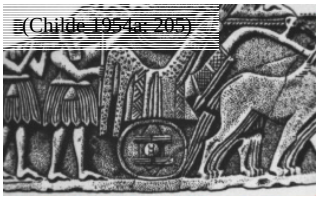
location of the iron bushing, bore some holes, chisel them out, and

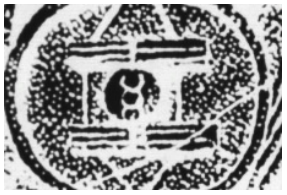
drive in the bushing. The wheel is

now complete and ready to roll.

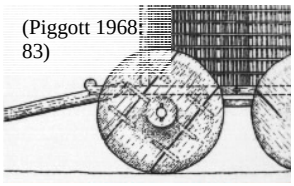
I think one point is clear already. The problem is not, how did somebody get the *idea* of the wheel-and-axle or, in this case, how did somebody get the *idea* of spoking a wheel? These ideas may have popped up many times, like mutations. But only once, apparently, were they adaptively successful. Witness the wheel in Mexico(1), and the many bright ideas of Leonardo da Vinci.

The parent species, the solid wheel, had become established in the culture of Mesopotamia somewhere between 3500 and 3000 B.C. It consisted of



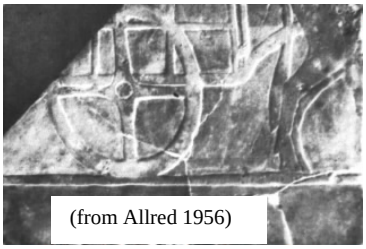



three planks cleated together, with a thick place in the middle plank serving as the nave. The complex of cultural instructions represented in this wheel diffused quite rapidly over much of the eastern hemisphere, along with a specific set of instructions for hitching a pair of animals to whatever the wheels were attached to. Among these latter were a



wide variety of war and hunting chariots, funerary vehicles for royalty, and utilitarian carts.

Since we are here concerned with the spoked wheel, let us simply assume [was: "speculate"] that this rather cumbersome solid wheel was better than no wheel at all and thus, in its time, was adaptive.


(from Allred 1956)

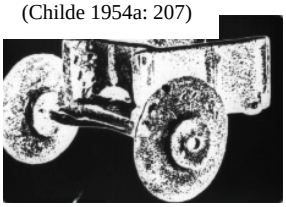
About a thousand years later, around 2,000 B.C., we find spoked wheels replacing solid ones on chariots, and 500 years later still, we find them used for the first time on utilitarian vehicles.

It is easy to see the adaptive superiority of the spoked wheel over the solid wheel on utilitarian vehicles. For one thing, it is much lighter in weight, thus increasing payload or decreasing the strain on animals. For another thing, this lightening is all concerned with "unsprung weight". With the spoked wheel, the same total weight of vehicle and load delivers, I suspect, significantly less shock at the point where the wheel touches the ground, and hence there is less rapid deterioration of the rim than with a solid wheel. For one more thing, the lateral thrust of a vehicle is always felt by that portion of the wheel in a direct line between the hub and the ground, as indicated in our discussion of dishing. In a solid wheel, this thrust will be delivered part of the time across the grain of the wood, so the wheel may collapse, splitting sideways; in a spoked wheel, it is always delivered against (and down) the grain of the down spoke.

So the adaptive superiority of a properly made spoked wheel is clear. But as we have seen, a spoked wheel is the outcome of a large number of cultural instructions; it is an immensely complex piece of engineering; it is a gestalt, a functionally integrated whole. If any part, or relation between parts, is not correctly executed, the wheel is not superior, it is definitely inferior to a good solid wheel. (As my informant put it, a properly made wheel will last five years under heavy loads in the tropics; an improperly made wheel will last about two months.)

How, then, could the first spoked wheel have survived the selective competition of the well-adapted solid wheel? I'm not speaking in metaphors here; wheel-making is passed along by apprenticeship. Wheelwrights who make worse wheels get to train fewer apprentices. In the long run their ideas are selected against, in favor of those of wheelwrights who make better wheels. Yet I submit that it is extremely unlikely that some Mesopotamian wheelwright-genius invented all the cultural instructions for making a successful spoked wheel in a tour de force of creative imagination and reasoning. Hence, I want to try to suggest how the spoked wheel evolved by increments, such that one instruction at a time could be thought up, introduced into the wheelmaker's bag of tricks, and become established through natural selection, before the next innovation came along, and how this sequence of incremental innovations could lead to the apparent unity that you have seen made.

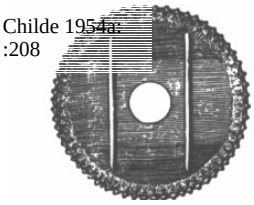
(Childe 1954a: 207)



First off, we know that early solid wheels, at least by 3,000 B.C., were studded with copper nails. These nails may have held leather tires to the rim. Some solid wheels were made thick near the hub, tapering to the rim.

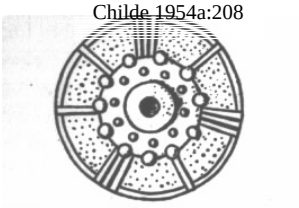
Felloes seem to have been added around 2,500. While this innovation ultimately proved to be a crucial increment, we have no right to say that it was a pre-adaptation for spokes, which came along 500 years later. Rather, we must speculate about its immediate adaptive value. One possible function of the felloe on a solid wheel is to protect the tire from being cut from inside by the corners of the planks. Another is simply in providing replaceable rim-segments so a wheel would not have to be cut down or discarded while its nave was still good.

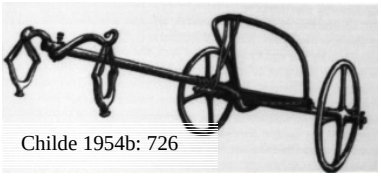
Childe 1954a: :208



Around 2,000, metal shoes were being attached all around the rim, replacing the leather tire. At about the same time, or a little after, the planking between the nave and the felloes was replaced by spokes, and the new species of wheel, as we see it now, became a reality. The critical ecological factor here, is, I believe, that these early spoked wheels were used exclusively in chariots.

Childe 1954a:208

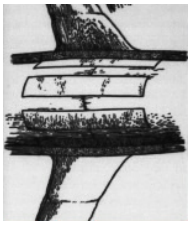




Childe 1954b: 726

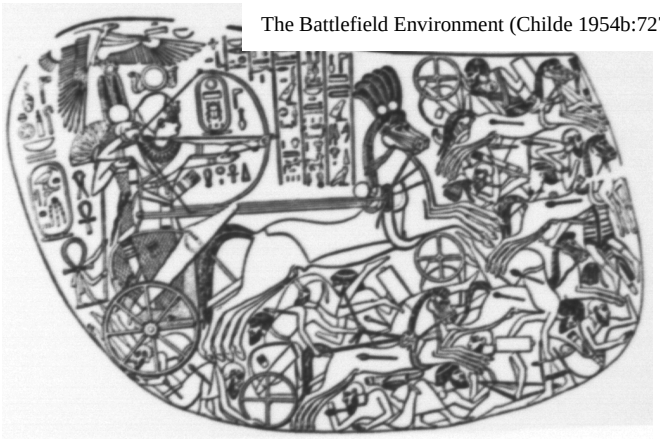
Thus they did not have to carry tons of weight and they did not have to last five years. They had merely to carry at the most two men, and last through one year's fighting-season or perhaps only one battle. Note that in this 15th-century chariot the spokes are tapered, but there is no indication of dishing.

Childe 1954a:211



This specimen, shown in section through the nave, is 100 years younger, about 1350 B.C. Note that dishing is pronounced, even exaggerated. Apparently dishing is not necessary in a chariot wheel; it is merely an improvement in one. Since lightness of weight is so highly adaptive in a chariot, the spoked chariot wheel was quickly successful under the intense selection pressure of the battlefield environment.

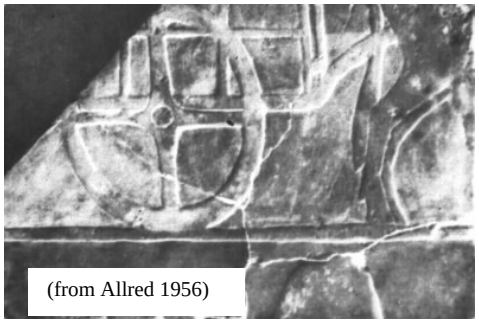
The Battlefield Environment (Childe 1954b:727)



With the spoked chariot wheel, all the basic engineering problems seem to have been solved. But the first utilitarian use of the spoked wheel seems not to have occurred for another 500 years. I would speculate that the period between 2000 and 1500 BC saw many little improvements in the craft of the military wheelwright. New instructions were invented, and adopted, to make the wheel more sturdy and durable. These might have included instructions involving the selection and preparation of woods

for the various parts, and such little tricks as seating the felloes and shoeing the wheel under pressure.

Other instructions invented during that period must have served to make wheelmaking more efficient, and thus to make wheels cheaper. Besides the engineering essentials I dwelt upon in the description of wheelmaking, there are dozens of little tricks and shortcuts involved that I didn't have time to discuss. Improved tools, and motor habits for their use, were no doubt added as well. Finally, then, a utilitarian spoked wheel became a practical reality, and its selective competition with the tripartite solid wheel could now begin.


(from Allred 1956)

The finishing of a wheel by shrinking on a one-piece iron tire really accentuates the gestalt effect, for me. Everything the modern wheelwright does seems to be pointed to that ultimate consummatory act. Yet, oddly enough, wheels were still being shod, instead of tired, in 19th century (A.D.) England. It should be stated, however, that a gap was left between the felloes even when they were to be shod. This gap was squeezed closed with a special screw-clamp while the last red-hot shoe was nailed down across the joint.

So I conclude that the species "spoked wheel" did evolve by increments from the species "solid wheel", with the addition of felloes to the solid wheel being the crucial intermediate increment. Then the spoked chariot wheel evolved, again, by increments into the spoked utilitarian wheel, and ultimately into the tired wheel.

I want to draw a general conclusion about culture from this brief discussion of the wheel. Many cultural taxa are, like the wheel, functionally integrated wholes. Kinship systems, social structures, ideologies, modal personalities, and art styles, not to mention languages, can be and are often looked at as such. Indeed, an entire culture can be considered a functionally integrated whole.

As the case of the spoked wheel seems to indicate, however, it is not necessary to conclude that the integration of these cultural systems is necessarily due to the operation of special cultural principles; it may well be that in every case they have evolved bit by bit through the operation of one basic principle, that of Darwinian natural selection, working on the system as it is at the moment, in the total ecological context -- including natural and cultural features -- with which it has to deal.



To contact the author: tcloak@unm.edu

1. Parenthetically, we may ask, What happened to the wheel in Mexico? Ekholm (1946) has suggested that the lack of suitable animals for traction prevented the development of the wheel beyond the idea stage (that's the idea stage). I agree that this is the critical factor, but it had occurred to me that human traction could have been used to pull wheeled vehicles. I now suggest that although lightweight wheels are adaptive with human traction (in competition with litters and backpacks), solid wheels are too heavy. But the solid wheel is a necessary condition for the development of felloes, which in turn are a necessary condition for the development of spokes, which in turn are necessary for a light wheel. Hence no wheels at all in Mexico.

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