Throwing Fire

Projectile Technology Through History

ALFRED W. CROSBY
University of Texas at Austin

CAMBRIDGE
UNIVERSITY PRESS

PUBLISHED BY THE PRESS SYNDICATE OF THE UNIVERSITY OF CAMBRIDGE
The Pitt Building, Trumpington Street, Cambridge, United Kingdom

CAMBRIDGE UNIVERSITY PRESS
The Edinburgh Building, Cambridge CB2 2RU, UK
40 West 20th Street, New York, NY 10011-4211, USA
477 Williamstown Road, Port Melbourne, VIC 3207, Australia
Ruiz de Alarcón 13, 28014 Madrid, Spain
Dock House, The Waterfront, Cape Town 8001, South Africa

http://www.cambridge.org

First published 2002

Printed in the United States of America

Typeface Sabon 10.5/15 pt. *System* QuarkXPress™ [HT]

A catalog record for this book is available from the British Library.

Library of Congress Cataloging in Publication Data

Crosby, Alfred W.
Throwing fire: projectile technology through history / Alfred W. Crosby
p. cm.
Includes bibliographical references and index.
ISBN 0-521-79158-8
1. Projectiles—History. I. Title.
UF750 .C76 2002
623.4′51 – dc21 2001052556

ISBN 0 521 79158 8 hardback

Contents

Preface

In early 2001 I finished writing this book about mankind's penchant for, and skill with, projectiles and combustion, and the resulting effects on life on this planet. I wrote this book because I think that historians too often focus on the finest grained and most subtle evidence, and often, after great effort, produce studies so finely grained and subtle as to be quite nearly unintelligible.

I decided to begin with the gross and undeniable fact that humans and, probably, other hominid species effected change at a distance via projectile and fire, and were alone in doing so. We have, by pursuing a love affair with this capability, altered the course of our history and of evolution on earth, and have ventured into space.

One of the manifestations of this capability that intrigued me most was the power it gave us to produce effects out of all proportion to means. A Clovis hunter spears the last mammoth in North America; a Zionist fanatic shoots Yitzhak Rabin; Wernher von Braun hits London with a rocket and later helps send rockets to the moon; and Osama bin Laden dispatches lieutenants to hijack airplanes and on September 11 of 2001 murders thousands in New York City and Washington, D.C.

We are fascinated with explosive projectiles, an obsession that benignly manifests itself in firework displays at holidays, weddings, and other such events; in Mehemed II's giant bombard; in the Vengeance Weapons; and in the atomic bomb of World War II. We

are obsessed with delivering projectiles that produce at a distance loud noises and fireballs. John Milton knew that when he created an alluring Satan and made him a Pre-Adamite inventor of gunpowder and cannon "whose roar Embowell'd with outrageous noise the Air, And all her entrails tore, disgorging foul Their devilish, chain'd Thunderbolts and Hail…."[1]

I should have left my copy of *Paradise Lost* on the shelf and waited for the terrorist attacks of September 11 to use for my illustrative example. Osama bin Laden – charismatic and murderous – makes a worthy stand-in for Milton's Satan, although he was forced to substitute fanaticism for expertise and to parasitize on the technology of enemies in order to procure and direct his projectiles. The effects fell short of Milton's Satanic artillery, but impressed all of us. The Twin Towers stood "as Rocks, but down they fell" and " Angel on Arch-Angel roll'd…."[2]

The heaving of projectiles characterizes our species as unequivocally as bipedal locomotion and tool making. On the fateful September 11, 2001, the Mars Odyssey Mission vehicle, launched by rocket in April to determine the content of Mars' surface and to detect water and therefore the possibility of life there, past or present, was approaching that planet at a speed, relative to the Sun, of 24 kilometers a second. On October 24th, as American missiles fell on Afghanistan, the vehicle started into orbit around the fourth planet from the Sun and began its inspection.[3]

Whether we end in the pit or space, we will do so while throwing fire.

[1] John Milton, *Paradise Lost, Paradise Regained, and Samson Agonistes* (Garden City, N.Y.: International Collectors Library, 1969), 148.

[2] Milton, *Paradise Lost,* 148.

[3] http://www.jpl.nasa.gov/releases/2001/release_2001_186.html

ONE

The Pliocene: Something New Is Afoot

> That's one small step for a man, one giant leap for mankind.
>
> Neil Armstrong (1969)

We start with the Australopithecines,[1] the earliest hominids, that is, the earliest creatures clearly our relatives and not shared with chimpanzees. If we inquire into what was most like us about them, millions of years ago, we may discover what is most ancient in hominid heritage and perhaps what is the true essence of humanity. Were they bright – like us? (a question best asked while preening before a computer screen). No, their brains were only about a third the size of ours.

We make tools – spoons, forks, internal combustion engines, atomic energy plants – and expect our ancestors to have made

[1] I should point out that I will eschew whenever possible numerical dates, even those that allow for pluses and minuses of hundreds of thousands of years, and, with few exceptions, I will omit hominid species names as well. I don't want to pose as a paleoanthropologist nor do I want to become the innocent bystander so often injured in the combat of experts. I am interested in the chronological sequence of our ancestors and in their physical and mental capabilities, not dates or geneologies per se. I have my own fish to fry.

tools. Did Australopithecines make anything we recognize as even the crudest of tools, for instance, a chipped cobble with sharpish edges?[2] No, they didn't. They no doubt made use of rocks and branches at hand, which they may have modified slightly for the purpose, for instance, stripping bark from twigs to extract termites from logs. Chimps do that sort of thing, but have never elaborated on such behavior. Australopithecines or the species in hominid evolution that followed obviously did, but not to begin with.[3]

There is one feature of the Australopithecine skeleton that even a weekend paleontologist can spot immediately as prefiguring his or her own skeleton. It is the foot, which Dr. Frederic Wood, author of the classic *Structure and Function as Seen in the Foot,* celebrates as conferring "upon Man his only real distinction and provide his only valid claim to human status."[4]

The foot began as a hand, and its twenty-six bones – seven tarsals, five metatarsals, fourteen phalanges – are obviously versions of the bones of the hand: the thumb as the big toe, the four fingers as the other toes, the heel of the hand as the heel of the foot. The palm has lengthened into an arch, the toes have undergone abbreviation. The big toe has swiveled into line with the other toes and lost its vaunted opposability, and can no more reach the little toe than the stars.

The foot began as a hand, an organ of many capabilities, an organ for manipulation (a word derived from the Latin for hand). Making a foot of it would seem to be a case of making a sow's ear

[2] Bernard Wood, "The Oldest Whodunnit in the World," *Nature,* Vol. 385 (January 23, 1997), 292; Shanti Menon, "Hominid Hardware," *Discover,* Vol. 33 (May 1997), 34.

[3] Readers who want to sample the debates about who was and who was not ancestral to *Homo sapiens* should read David S. Strait, Frederick E. Grine, and Marc A, Moniz, "A Reappraisal of Early Hominid Phylogeny," *Journal of Human Evolution,* Vol. 32 (January 1997), 17–82.

[4] Frederic Wood, *Structure and Function as Seen in the Foot* (London: Bailliere, Tindall and Co., 1944), 2.

out of a silk purse. The sacrifice of function involved proclaims that the advantages in becoming bipedal (for that is what we are dealing with here) must have been immense.

The foot's job is to bear our weight and to get us around in this world. What a deflation, you may think, of its raison d'etre since its glory days as a hand. That, however, is like saying that a hammer is inferior to a Swiss Army knife because the former has one talent and the latter many. But the hammer can do one important thing much, much better than the Helvetian multipurpose jackknife. It can hammer.

The foot's function of bearing weight requires stability, but it must not be so solid as to transfer every shock with the ground to the delicate structure of the body above. The foot's function of providing locomotion involves thrusting down and back, that is, elasticity, but of course it must not be so elastic as to entail instability.

Take your choice: the foot is either a brilliant compromise fulfilling these contradictory requirements or a jerry-built improvisation put together with the parts available.

The outside of the foot, the part in contact with the ground that runs from the ball of the foot around to the heel, is a static supportive organ. But we do not stump through the world: the toes and the arch from the ball behind the big toe back to the heel are elastic, mobile, and dynamic and provide propulsion. The longitudinal arch and the less obvious transverse arch between the inside to outside of the foot absorb the shocks that flesh (certainly the foot) is heir to.[5]

The foot is only one part of what we need to move about while upright. Above it is the ankle, a joint that experiences the shock of the foot's contact with the ground and must be supple enough to swivel forward and back, left and right, in order to accommodate to variations in that surface and the shifts, to and fro, side to side, of the weight above it. The knees likewise suffer pounding and also

[5] Wood, *Structure,* 247, 259, 261.

swivel forward and back (but not otherwise, if all is well). The hip joints also get pounded and must allow for rotation of the leg as well as its swing forward and back. In between the hip and the knee the thigh bone, the femur, tilts inward from the former joint to the latter. We are all skeletally knock-kneed. Otherwise we would waddle. Try walking with your feet exactly under the hip joint. Awkward. Widen the placement of your feet only a bit more and you will have the gait of a movie monster.

There are also our shoulders and arms, swiveling and swinging in opposition to the movement of our legs. They supplement our knock-kneed femurs in damping the sway from side to side. There is our back, arranged not in an arch, the architecturally sturdy form favored by other quadrupeds, including apes, but in an S-curve, the bottom half curving in and the top half out. We thus have managed to retain a central column with which to brace a torso and also to stand up straight (if you won't quibble about calling S a straight line) and to twist and sway whichever way is needed from moment to moment. Backaches and displaced disks are the price.

And, on top of the flexible neck, which is on top of everything else, is the head, that boulder whose misdirected mass can send the whole assemblage veering off in unexpected directions.

Myriad bundles of muscles connect and surround the hard bones. The exquisitely sequenced and coordinated contractions and relaxations of these soft tissues enable us to move like good animals rather than bad machines. Imagine the human body as a stick figure with each major flexible boney connection – two ankles, knees, hips, shoulders, elbows, one back, one neck – capable of only five positions each. How many positions is this simplified version of ourselves capable of assuming? That would be five times five eleven times over. The final total is 488,281,125. The total if calculated on the full range of the body's possible postures would be – literally – beyond calculation.

It is the functions of our muscles (and the nerves that direct them and transmit their return messages) that we find so difficult

to reproduce in robots and why it is so much easier to produce one that rolls than one that walks on two or even four feet. The lurch of the movie's Frankenstein (any able-bodied child could thumb his or her nose and skip away from that monstrosity) is about as good as our engineers have managed with walking machines.[6]

Let us consider the miracle of getting around on two feet. We will ignore running, which involves having both feet off the ground part of the time. Let us consider unspectacular walking, the merest example of which turns out to be more complicated neuromuscularly than a Beethoven symphony is musically. Walking is the process of leaning forward to fall on your face and then interrupting that mistake by stepping forward – and then proceeding on with the next mistake and the next interruption for as long as it takes to get where you want to go. When you catch your toe on a curb the interruption is delayed and you complete your sprawl.

Walking, the linear movement of the body forward, involves the shifting of the weight from one base, the left foot, let us say, to the right and then back. To avoid sprawl, the body's center of gravity must shift back and forth, keeping up with and above the supporting foot. That could be accomplished by placing each foot with each step directly in line with the other foot's last placement, which would have us walking as if on a tightwire, about to topple laterally, and would require considerable expenditure of energy to swing each foot around the other with every step.

We compromise. The advancing foot lands ahead of the other with its inside edge close to or on the inside edge of a line drawn directly forward of the other foot, which at the moment is supporting the body's weight. All this involves a wagging about of

[6] J. Furusho and A. Sano, "Development of Biped Robot" in *Adaptability of Human Gait: Implications for the Control of Locomotion,* ed. Aftab E. Patla (Amsterdam: Elsevier Science Publishers, 1991), 301.

practically everything, feet, legs, hips, shoulders, arms, in whatever direction is required to keep the whole on an even keel.[7]

If we had observed an Australopithecine proceeding across the landscape of Ethiopia some three and a half million years old, we would have seen that it walked more like a modern human than a chimpanzee. The bones of its arms, pelvis, and knee joint indicate that. Even better evidence of that gait turned up in 1976 in Tanzania: the footprints of three individuals as they walked across a moist layer of volcanic ash one day long, long ago.

These individuals walked on two feet. There are no indications of knuckle-dragging whatsoever. The print of each step lies just off the line of the previous step. The mark of the big toe (the former thumb) is about twice as big as that of the toe next to it, like ours, and the spacing between the toes no greater than between those of people today who usually go barefoot or of even many habitual wearers of shoes. The big toe print is parallel with the others. On each stride the heel clearly struck the ground first, then the body weight rolled forward along the outside of the arch to the outside of the ball and then across to the ball to the big toe. Then the toes and forefoot thrust back against the ash for the stride forward, pushing up a bit of the ash back against the ball.

These footprints would not attract our attention if found in the sand of a beach today.[8] The stride that made them was, like ours, a pas de deux for one person's two feet more complicated than any ever choreographed for two dancers.

[7] Marion Broer, *Efficiency of Human Movement,* 3rd ed. (Philadelphia: W. B. Saunders Co., 1973), 145, 151, 153.

[8] *Laetoli, A pliocene Site in Northern Tanzania,* eds. M. D. Leakey and J. M. Harris (Oxford: Oxford University Press, 1987), 498, 500; R. H. Crompton et al., "The Mechanical Effectiveness of Erect and Bent-hip, Bent-Knee' Bipedal Walking in *Australopithecus afaransis,*" *Journal of Human Evolution,* Vol. 35 (July 1998), 71; Richard L. Hay and M. D. Leakey, "The Fossil Footprints of Laetoli," *Scientific American,* Vol. 246 (February 1982), 51. For another interpretation, see Ian Tattersall and Jeffrey Schwartz, *Extinct Humans* (New York: Neuramont Publishing Co., 2000), 95.

I know of only a single appreciation in literature of that peculiar gait, and it is worth pausing for. Aldous Huxley described it in his flapper-generation novel, *Antic Hay,* with gentle recognition that sometimes the survival of the species may require momentary inattention to firm footing in favor of sexual signaling. His heroine, Myra Viveash,

> crossed the dirty street, placing her feet with a meticulous precision one after the other in the same straight line, as though she were treading a knife edge between goodness only knew what invisible gulfs. Floating she seemed to go, with a little spring at every step and the skirt of her summery dress – white it was with a florid pattern printed in black all over it – blowing airely out around her swaying march.[9]

The Australopithecines' feet were no doubt better for climbing than Myra Viveash's, and they probably fled to the trees when lions prowled and may have spent their nights there, but, like Myra, clearly they had rejected two hands good for a thousand purposes and turned them into feet at least as good, perhaps better, for locomotion on the level than for climbing trees. The Australopithecines were on their way down to the ground where their teeth and claws (mere fingernails!) were inferior to those of rivals and enemies, where these bipeds were easy to tip over and couldn't run as fast or jump as far as any of the large or even medium-sized predators.

It would seem that our ancient relatives went to enormous trouble to move from a desirable neighborhood to a very dangerous one. But sometimes the new kid on the block works up a new set of tricks. He has to. As Darwin put it a century and a quarter ago, it may "have been an immense advantage to man to have sprung from some comparatively weak creature."[10]

[9] Aldous Huxley, *Antic Hay* (New York: The Modern Library, 1923), 98.

[10] Charles Darwin, *The Origin of Species by Means of Natural Selection and The Descent of Man and Selection in Relation to Sex* (New York: The Modern Library, n.d.), 443.