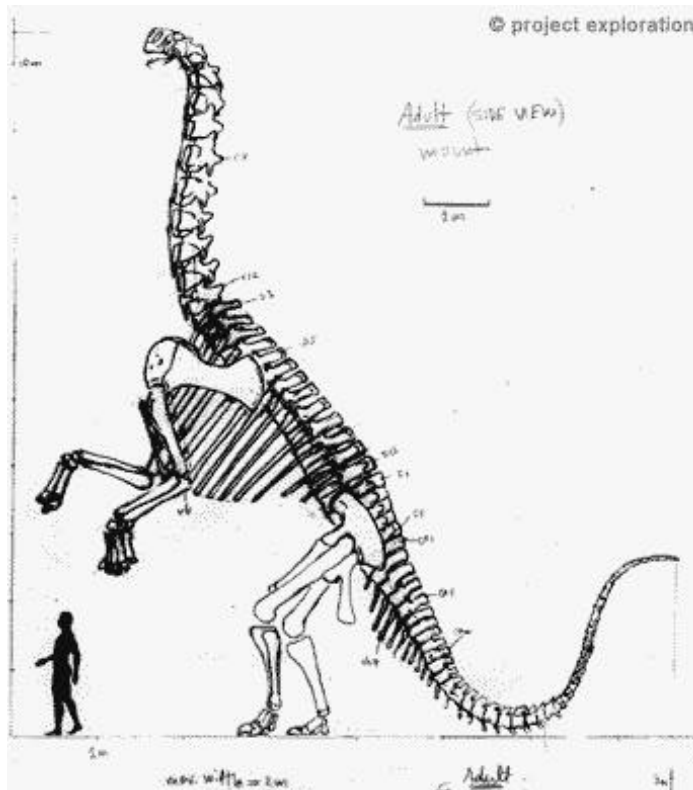


## JOBARIA AND THE ELEPHANT



Dr. Sereno's sketch of an adult *Jobaria* posed in a hind-limb stand. The human silhouette establishes scale.

When paleontologists mount dinosaur bones they try to capture what the dinosaurs would have looked like when they were alive. That's why almost all dinosaurs are mounted in dynamic poses: walking, running, attacking or defending.

When Sereno's team prepared the bones of the juvenile *Jobaria*, a surprising discovery came to light: something had bitten the juvenile and left tooth marks on its ribs!

*Afrovenator* was the dominant predator in the region at that time and its teeth were found at the theropod site. Dr. Sereno concluded it was likely the bite marks were made by *Afrovenator*, the "African Hunter", that had attacked the juvenile.

Based on this fascinating discovery, Dr. Sereno decided to mount a juvenile skeleton of *Jobaria* alongside an adult skeleton warding off an attack by *Afrovenator*.

Not that long ago, paleontologists would have rejected the notion that a 20-ton sauropod like *Jobaria* could rear up on its hind legs.

Paleontologists argued that these giant animals - the largest sauropod probably weighed about 80 tons - lived their whole lives in the water, where they could wade around with less effort. Paleontologists couldn't believe that such big and heavy animals could support their own weight.

Today we know that Sauropods could support their weight and did walk on land. While it's true that Sauropods are very heavy, their bones are also much more robust than similar bones in today's large living animals such as elephants. Furthermore, sauropod skeletons like *Jobaria* are found in land, not water, deposits. But the most convincing evidence comes from sauropod trackways: these preserved footprints show that sauropods must have walked on land.

But could 20-ton *Jobaria* stand on its hind legs, supporting all that weight on just two legs? To answer that question Dr. Sereno turned to today's largest living four-footed animal, the African elephant.

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## JOBARIA AND THE ELEPHANT



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*The talented 20-year-old elephant, Angus, who helped Dr. Sereno. Angus is under the care of gifted animal trainer Michael Hackenberger.*

directly. To determine the elephant's center of mass, Dr. Sereno needed to find out how much weight was on the forelimbs vs. the hind limbs of an elephant.

That's when Dr. Sereno decided to weigh Angus the elephant. At 12,800 pounds, Angus is the largest African elephant in captivity. He resides at the Bowmanville Zoo, just outside Toronto, Canada.

But where do you weigh an elephant?

Why compare *Jobaria* to an elephant?

Elephants rear on their hind limbs occasionally in the wild. They perform this feat regularly in captivity. By studying how an elephant rears on it's hind legs, Dr. Sereno hoped to better understand how *Jobaria* would stand on it's hind legs.

To rear up and to hold a hind leg stand, the center of mass of the elephant (or of *Jobaria*) must be balanced over the hind limbs.

But where is the center of mass of an elephant? No one had ever measured this

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## JOBARIA AND THE ELEPHANT



*Bringing the elephant to the weigh station.*

A good place to weigh really heavy things is the scale at a weighing station for trucks. In fact, the scale is designed to weight front and hind axles separately. Angus only needed to stand on the scale and Jeff Ogradnik and Dr. Sereno would have an answer to their question: Where is Angus' center of mass?

Dr. Sereno discovered that Angus carries almost 60% of his weight on his front feet and only 40% on his hind feet. The forefeet, carry about 7,600 pounds, or almost 4,000lbs (2 tons) **each!**

Based on the weight report, Dr. Sereno knew that Angus' center of mass was forward in his body, closer to his front feet than his back feet. Angus has a large head and a puny tail, so it makes sense that his hind legs carry less weight than his front legs. To confirm this finding, Sereno and Ogradnik measured elephant limb bones and found that the circumference of the front leg bone (the humerus) was one and a half times bigger than the circumference of the back leg bone (femur).

Dr. Sereno compared this with the circumference of *Jobaria's* leg bones. He concluded *Jobaria* has the **opposite** weight distribution than Angus the elephant, carrying more weight on the hind legs and less on the front legs. *Jobaria's* leg bones measured as the reverse of Angus' bones: *Jobaria's* back leg bone (femur) has a circumference of about 1.5 times that of *Jobaria's* front leg bone (humerus).



*The weight report from the weigh station.*

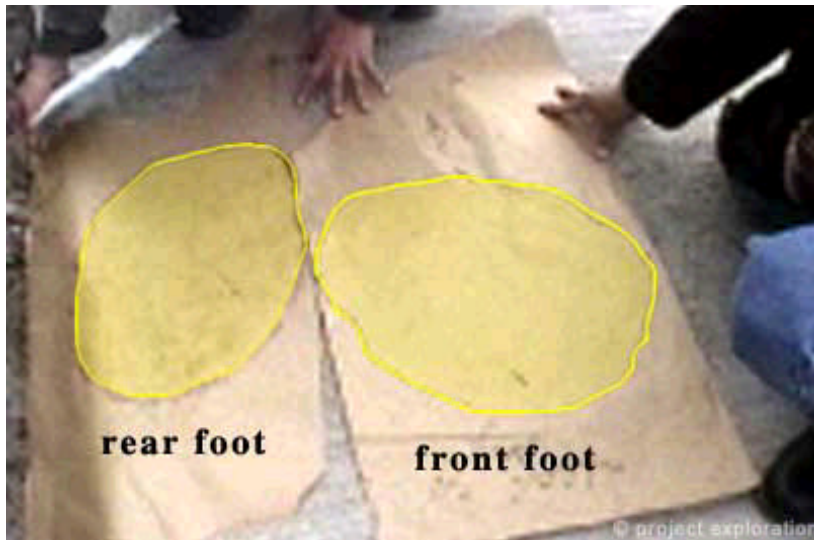
*Jobaria's* center of mass was therefore closer to its rear feet than its front feet. And the closer the center of mass is to the rear feet, the shorter the center of mass has to travel to be above the rear feet to allow the animal to stand on its back legs. So if an elephant (which has its center of mass near the front) could move its center of balance far enough back to rear on its hind legs, it logically follows that a sauropod like *Jobaria* - whose center of mass is already near its hind legs - would have an even easier time rearing on its hind legs than the elephant.

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## JOBARIA AND THE ELEPHANT



*Tracings done around the elephant's feet, showing their relative sizes.*

footprints show the opposite condition to elephants. The hind print is much larger than the foreprint, confirming that most of the body mass of a sauropod like Jobaria was in the rear, borne by the hind limbs.

While working with Angus, Dr. Sereno and Jeff Ogradnik noticed that the sole of the forefoot was much larger than the sole of the hind foot. The difference was nearly 1.5 times - the same difference they measured for the weight of the limb supported. That means that each sole is designed to carry the same load per unit area.

Footprint size, therefore, is a good estimator for the amount of total body weight carried by a limb.

As with limb circumference, sauropod

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# JOBARIA AND THE ELEPHANT



*The elephant's forefoot.*

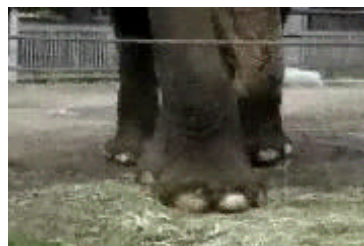
same sense of balance for sauropods.

Dr. Sereno's objectives with the mounts of *Jobaria* is to create realistic poses that capture something important about the athletic capability of *Jobaria*. The hind leg stand for the adult seems quite possible, based on a comparison with Angus the elephant.

What about the pose of the juvenile skeleton? Here we see an animal at a stiff walk. Notice how closely the feet are positioned under the body. Dr. Sereno was particularly impressed by the speed, agility and balance of Angus, the 12,800 pound elephant. His great sense of balance is shown by how close his feet are to a midline when he walks. Sauropod trackways, likewise, are narrow and suggest the

Dr. Sereno is convinced that *Jobaria* was capable of walking faster than a human being can run, rearing on its hind legs, and moving with a great sense of agility and balance.

The old view of sauropods as clumsy, water-bound behemoths is wrong, as are museum skeletons that pose sauropods as if they were wide-legged.



*Click the play button to see a quicktime movie of the elephant walking.*

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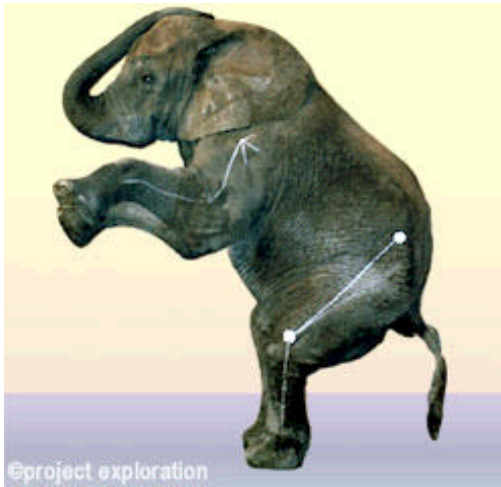
*Animation of the foot order of a preserved sauropod trackway.*

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## JOBARIA AND THE ELEPHANT



*Angus, the bull African elephant, performing the rear leg stand. White dots and lines indicate joints and bones, respectively.*

Having figured out the location of the elephant's center of mass, Dr. Sereno and Jeff Ogradnik were finally ready to watch an elephant perform the hind leg stand.

Dr. Sereno and Angus' trainer, Michael Hackenberger, drew straight chalk lines down the elephants' legs to represent the underlying bones and allow calculation of their position during rearing.

As you can see in the quicktime movie, the elephant moved into his rearing pose very carefully. First Angus shifted his center of mass backward by bending his knees.

Now Angus can lift his front legs and stand in the rearing position. Notice also that Angus uses his long trunk and short tail to try to help maintain his balance. By moving them Angus ever-so-slightly shifts his center of balance backward.



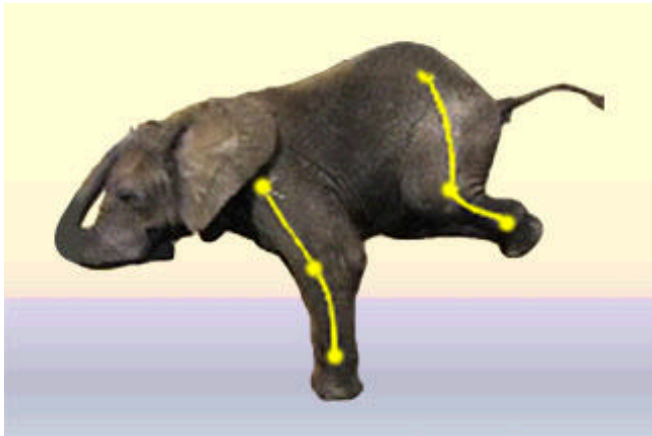
*Click the play button to see a quicktime movie of the elephant rearing.*

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## JOBARIA AND THE ELEPHANT



*Angus performing the front leg stand.*

weight is concentrated in the back of *Jobaria's* body.

Elephants are so front heavy that they can perform an amazing feat - a front leg stand. This is a pose that would have been impossible for *Jobaria* .

The elephant, in one view, is like a sauropod turned around. Look at the picture above and imagine a sauropod with its tail in the position of the elephant's head, and the head in the position of the tail. It is a fitting comparison because the head of the elephant and the tail of the sauropod are the heaviest extensions from the body. As a result, the forelimbs of the elephant are more robust while the hindlimbs of the sauropod are more robust.

Furthermore, the tail of the elephant that is very light, as is the neck and head of the sauropod. (Keep in mind that the neck of the sauropod is filled with large air spaces that connect to the lung (trachea, airsacs). This makes it much less massive than it appears to be).



*Click the play button to see a quicktime movie of the elephant "fronting".*

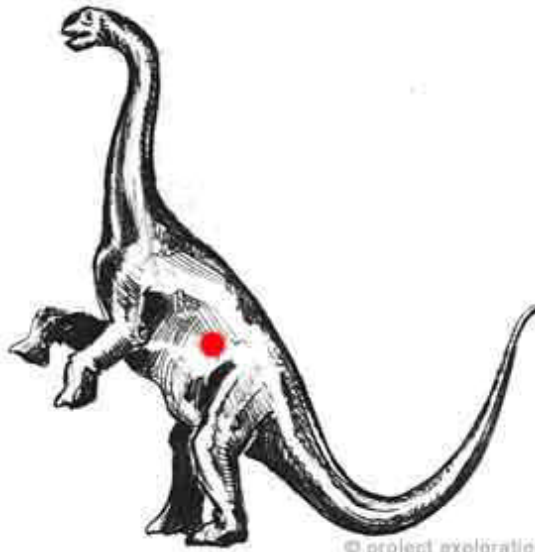
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## JOBARIA AND THE ELEPHANT

An elephant has a more difficult task in performing a hind leg stand than *Jobaria*. The elephants' center of mass is closer to the forelimbs than the hindlimbs - exactly the



*Illustration of Jobaria rearing (by Dr. Sereno).  
The red dot shows the center of mass, which is  
located directly above the hind feet.*

opposite of *Jobaria*. Bone measurements and footprint size confirm that *Jobaria* would have had to move its center of mass only a short distance backward in order to rear up on its hind legs.

But could its main hind leg bone - the femur - withstand the bending force generated by the hind leg stand? Or would it snap? Using a computer-modeled sauropod and a bent-knee pose similar to that of an elephant (shown in the illustration here), Jeff Ogradnik was able to show that the bones of *Jobaria* were up to the task. It would take a mass almost **three times greater** to snap *Jobaria*'s femur.

Dr. Sereno's research has led him to conclude sauropods like *Jobaria* were agile, graceful, and much more flexible than paleontologists have traditionally thought.

So look at *Jobaria* in its rearing pose: you are seeing a snapshot of how this dinosaur could move.

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