

THE RESONANCE OF JERICHO

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The story of the fall of the walls of Jericho notes that the Israelites walked around the city walls, blew their horns, and roared in unison, procedures which fashioned the miraculous outcome of Jericho's fate. However, in an age without modern technology, how could a series of seemingly random and weak measures have caused the destruction of the walls of Jericho? Below is the text of the Biblical narrative in which it is clearly evident that no use of "traditional" weapons was used to invade the city – not even a bow and arrow.

"You and your marching men should march around the town once a day for six days. Seven Priests will walk ahead of the Ark, each carrying a ram's horn. On the seventh day you are to march around the town seven times with the priests blowing the horns. When you hear the priests give one long blast on the ram's horns, have all the people shout as loud as they can. Then the walls of the town will collapse" (Joshua 6: 3-5).

If we dig through the *pesukim* for evidence of some type of "weapon," we could withdraw some insight into the type of force that the Israelites used as they approached Jericho, a city having "walls that reached to the sky" (Deuteronomy 9:1). The three instructions that G-d listed for Joshua involve some sort of mechanical force (thousands of men marching around the city) and acoustic force (priests continually blowing the *shofarot* and thousands of men yelling in unison). Actually, the narrative references what very well might have been both mechanical and acoustic *resonance* [1].

In physics, resonance is the tendency of an object to oscillate at larger amplitude at preferred frequencies. These preferred frequencies are the object's resonant frequencies. Every object, no matter how flexible or stiff it may be, has a natural frequency of vibration. If a periodic series of driving forces is applied to an object, the object will eventually begin to vibrate with the frequency of the driving force instead of its own natural frequency of vibration. If the driving frequency is close to the natural frequency, then this driving frequency is a resonant frequency, and the object will vibrate with larger amplitude. The object will vibrate with smaller amplitude if the driving frequency is different from the natural frequency of vibration of the object [2].

There are various types of resonance, one type of which we have all had experience with – mechanical resonance. A common example of mechanical resonance is pushing a swing. A swing is a sort of pendulum with a natural frequency that is dependent upon the radius of the pendulum. If a series of regularly spaced pushes is applied to the swing with a frequency that matches the natural frequency of the swing, the motion of the swing, as we know from experience, will be quite large. If the frequency of the pushes is different from the natural frequency of the swing or the pushes are irregularly spaced, then the motion of the swing will not be as large and not as fun [2].

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Under certain circumstances, if the frequency of the driving force is the same as the natural frequency of the object to which the force is applied, the object could vibrate at amplitude that is dangerously high. If soldiers march in lockstep over a bridge and their footsteps have a frequency equal to one of the natural frequencies of the bridge, the bridge may begin to oscillate treacherously. This is why soldiers are ordered to march in break step when crossing a bridge [2].

While the Biblical narrative of Jericho does not indicate *how* the men marched around the city, theoretically they may have marched around the city in lockstep, generating a frequency of vibration equal to the natural frequency of the walls. Thus, thousands of men marching in lockstep once a day for six days around the city walls, and seven times on the seventh day may have weakened the wall due to mechanical resonance [1].

Furthermore, the priests continually blew the *shofarot* as they marched around the city, once each day for six days. During

the seventh circle around the city on the seventh day the priests blasted the *shofarot*, and the nation shouted in unison immediately thereafter. This may have generated acoustic resonance with the city walls which had already endured a week of mechanical resonance. The acoustic resonance may have caused further vibrations resulting in the walls falling to the ground. This hypothesis may seem unlikely, but if you think about it, the destructive consequences of acoustic resonance are not so unfamiliar. If a person sings at the appropriate pitch such that the frequency of the notes being sung matches the natural frequency of a glass, the glass will vibrate and could shatter [1].

Various theories have been proposed to explain how the walls of Jericho fell down. The wording of the 20th *pasuk* in the 6th *perek* may provide a clue. "...it came to pass, when the people heard the sound of the horn that the people shouted with a great shout, and the wall fell down flat, so that the people went up into the city, every man straight before him, and they took the city." According to one theory, the words, "*every man straight before him,*" suggest that not only one section of the wall shattered but that the entire wall shattered at once, similarly to the manner in which glass shatters under acoustic resonance [1].

However, this theory, which proposes that the walls shattered like glass, is not as compelling as an alternative theory which is supported by other textual clues, as well as archaeological evidence. Evidence gathered from these aforementioned sources, in fact, suggest that the earth itself vibrated at the time of the attack on Jericho. When the fate of Jericho ensued, the Biblical text uses the word "*tach'teba*" to describe how the walls fell down. "*Tach'teba*" literally means "underneath it," the subject of which is the city wall. This translation does not suggest that the walls themselves were breached, but that they sank into the earth as a result of the ground opening up beneath them. This would certainly support the earthquake theory. However, modern excavations do not show evidence of the walls having sunk into the earth, but rather that the walls fell down flat, a hypothesis which still sides with the earthquake theory. Interestingly, many Biblical translations actually do interpret "*tach'teba*" to mean that the walls fell down flat.

According to diagrams of Jericho designed by archaeologists, Jericho was fortified by a retaining wall 12-15 feet high on top of which stood an outer city wall reaching 20-26 feet above the retaining wall. Uphill from the outer city wall stood an inner city wall with similar dimensions. Even after the city walls fell down, the Israelites still had to climb over the towering retaining wall. Excavations have revealed that bricks from the fallen walls

fell at the base of the retaining wall forming a ramp on which the Israelites could climb up and over. In fact, this archaeological finding matches the precise description in the Biblical text which describes how the Israelites entered Jericho: "The people *went up* into the city, every man straight before him" [3].

As a result of his excavation in Jericho in 1930-1936, Professor John Garstang emphasized that the city walls fell *outward*, such that the Israelites were able to climb over the retaining wall and up into Jericho. All archaeological sites of ancient cities in the Middle East, except for Jericho, revealed that besieged city walls fell inward simply because when invaders besiege a city they are aiming to get into the city, not out of the city. Interestingly though, Jericho's walls fell outward [4].

The Israelites did not besiege the city in the normal fashion, and thus, even had the walls fallen inward, the event would have been no less a miracle. However, the direction in which the walls fell was still an obvious convenience to the Israelites in their attack on Jericho. Was it possible for the Israelites to have caused the walls to fall in this preferred direction using resonance? Assuming that resonance caused the *walls* to shatter, it would depend on the mode of oscillation of the wall being excited by the driving force. If the walls formed a circular ring, a breathing mode of oscillation would entail radial expansion and contraction. The wall could technically break in the expansion part of the cycle or in the contraction part of the cycle, and thus, the wall could fall outward or inward respectively. However, other modes of oscillation would not result in the breaking of the wall in any preferred direction, and the wall would randomly fall in either direction. The sounds of the *shofarot* used in the attack would have had to have a frequency value much larger than the frequency of sounds within the audible range (10Hz-10kHz) since the value of the Young's modulus for stone is enormous. (The Young's modulus is a measure of how stiff an object is.) Thus, it is very unlikely that the Israelites would have been able to excite a breathing mode within the walls, and therefore, could not have made the walls fall in any preferred direction [5]. On the other hand, archaeology shows that the walls were made of baked mud [3], which may be weaker and more brittle than the kind of stone we are familiar with today. But, assuming that the walls were still too stiff to excite a breathing mode within them, the walls could still have fallen outward due to chance.

Here is another theory that is simpler and assumes that resonance caused the *earth* to vibrate. According to diagrams of Jericho that were produced based on archaeological excavations, the city was built on top of a hill, and the fortifying walls were built

around the city on the hill [3]. If this is indeed the case, then the location of the center of mass (or the center of gravity, which can be used synonymously in a uniform gravity field) would have predicted that the walls fall outward. The center of mass is the mean location of the object's total mass and can be used to explain how that object will respond to certain forces and torques [6]. If an inclined surface beneath a standing object were to shake, the object would fall in the direction in which gravity exerts the most force. On Earth, gravity would exert the most force on the side of the object where the center of mass lies. Likewise, the walls of Jericho, which stood on a vibrating inclined plane, fell outward because their centers of mass experienced the force of gravity most powerfully in the "outward direction."

Actually, excavations show evidence of earthquake activity at the time of the attack on Jericho. However, is it physically possible that the Israelites used resonance to induce an earthquake? According to the work performed by Nikola Tesla, a great Austrian inventor who lived in the 19th and 20th centuries, resonance can indeed cause vibrations in the earth like those from the effect of an earthquake. Tesla was prone to conjuring up very strange ideas, one of which materialized into an invention called the "Tesla Oscillator," also known as the "Earthquake Machine." Tesla performed his first experiments with resonance technology in his New York laboratory where he excited his little oscillating device causing vibrations in Manhattan for miles around his laboratory [7]. It follows, Tesla claimed, that by finding the most suitable fre-

quency, *any* structure can be destroyed. Tesla once even "joked" that he could crack the earth using his device [8].

Tesla's experiment also showed that resonance waves become stronger the more distant they are from their source [7]. This explains how the Israelites were able to produce strong resonance effects while still maintaining a safe distance from the city walls so as not to be in danger when the walls would fall down. However, we should be careful not to place too much emphasis on the hypothesis regarding resonance as the cause of an earthquake at the time of the attack. It is mere speculation, but nonetheless, it raises an interesting topic for discussion.

Still, archaeological evidence and physical probabilities in addition to the Biblical text, suggest that resonance might have somehow played a role in the attack on Jericho. If the walls of Jericho indeed fell due to resonance, was the event any less of a miracle? Absolutely not – the probability of thousands of men walking in lockstep together and at the same frequency as one of the natural frequencies of vibration of the earth or the city walls (depending on which hypothesis you accept) is quite small. Furthermore, the event of all the priests blowing the *shofarot* and the thousands of men yelling at the same frequency as one of the natural frequencies of vibration of the earth or the walls is also a small probability occurrence. Thus, even had the walls fallen due to resonance, the event is no less a miracle. And, although the event is considered a miracle, it does not necessarily follow that it occurred contrarily to the laws of nature. ■

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