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Contact: Robert Shepherd  
1-978-985-2008  
rshepherd@bobshepherdonline.com

## IdeaLog No. 1 | Combinatorial Explosion | We Are the World

Years ago a girlfriend dragged me to a psychic in New York City who interviewed me in a room hung with beads and told me I was descended from Genghis Khan. Gee, I could have told her that. Chances are I'm descended from Cleopatra and Julius Caesar, too, and so, illustrious reader, are you. Why this is so has to do with something called *combinatorial explosion*.

There's an old story about the guy who invented chess. He took the game to the Shah, who loved games and war. The Shah was so pleased to see his two favorite pastimes combined that he offered the inventor anything he wanted. The inventor replied, "I'm a simple man. Just give me two grains of wheat on the first square and double them on each square after that."

"Done," said the Shah, in the decisive way of Shahs, not realizing that he was bankrupting himself, for numbers doubled in each generation get big very quickly. By the time you get to the last square on the board, square 64, the number of grains of wheat tops 18 quadrillion—more than the grains of sand on all the beaches of the world!

Like everyone else on this planet, you have two parents, four grandparents, eight great grandparents, sixteen great-great grandparents, and so on. The number doubles with each generation that you go back. Go back 32 generations to AD 1200, when Genghis

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Khan was slaying or bedding everyone in Asia, and you will find, by this method of counting, that you have 4,294,967,296 direct ancestors! But that isn't possible. According to the Population Reference Bureau, there were only about 450 million people alive in AD 1200. How can you have more ancestors 32 generations ago than there were people on earth at that time?

The answer is that you had relatives who married relatives. In the distant past, there were fewer people around from whom to choose mates, so cousins often married cousins, meaning that they shared some of the same grandparents. Your family tree, as you go back in time, gets bigger and bigger. Then, as the number of cousin marriages starts increasing, the number of ancestors in a given generation gets smaller, and your ancestral tree starts looking more like a diamond than like a tree or pyramid. So, there's good news and bad news. The good news is that you are descended from just about everyone ever alive, including lots and lots of philosophers, scientists, poets, artists, kings, and queens. The bad news is that many of your ancestors were keeping it in the family.

Scientists have recently figured out other ways to show that we are all related. Inside all your body cells are little organelles called mitochondria. These mitochondria have their own DNA, separate from the DNA in your cell nuclei. You get your nuclear DNA from both your mother and father, but your mitochondrial DNA all comes from your mother. So, theoretically, mitochondrial DNA would pass down, unchanged, from mother to mother, through the generations. But that's not what happens. Random

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accidents cause mutations in mitochondrial DNA, and since we know the rate at which these mutations occur, by comparing people's mitochondrial DNA, we can tell how long ago they had a common female ancestor. By this means scientists have figured out that everyone now alive on planet earth has a common ancestor in a woman who lived in East Africa about 125,000 years ago. Scientists call this woman Mitochondrial Eve. Another line of research, based on differences in Y chromosomes, traces all people back to a single male ancestor who lived in Africa only about 75,000 years ago.

So, not only are you descended from royalty, but you're also African. Even if you're not.

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