

An Abbreviated Brief History of Time (by kind permission of the author, Stephen Hawking)

1. In the Beginning

‘When asked: What did God do before he created the universe? Augustine replied that time was a property of the universe that God created, and that time did not exist before the beginning of the universe.’

2. The Big Bang

‘In 1929 Edwin Hubble made the landmark observation that wherever you look, distant galaxies are moving rapidly away from us. In other words, the universe is expanding. This means that at earlier times objects would have been closer together.’

‘In fact, it seemed that there was a time, about ten or twenty thousand million years ago, when they were all at exactly the same place and when, therefore, the density of the universe was infinite. This discovery finally brought the question of the beginning of the universe into the realm of science.’

‘Hubble’s observation suggested that there was a time, called the big bang, when the universe was infinitesimally small and infinitely dense.’

‘Under such conditions all the laws of science, and therefore all ability to predict the future, would break down. If there were events earlier than this time, then they could not affect what happens at the present time. Their existence can be ignored because it would have no observational consequences. One may say that time had a beginning at the big bang in the sense that earlier times simply would not be defined.’

3. Special Relativity and Time

‘The discovery that the speed of light appeared the same to every observer, no matter how he was moving, led to the theory of (special) relativity – and in that, one had to abandon the idea that there was a unique absolute time.’

‘Instead, each observer would have his own measure of time as recorded by a clock that he carried; clocks carried by different observers would not necessarily agree. Thus time became a more personal concept, relative to the observer who measured it.’

4. Space-Time

‘The theory of (special) relativity forces us to change fundamentally our ideas of space and time. We must accept that time is not completely separate from and independent of space, but is combined with it to form an object called space-time.’

5. General Relativity and Space-Time

‘Gravity is not a force like other forces, but is a consequence of the fact that space-time is not flat, as had been previously assumed: it is curved, or warped, by the distribution of mass and energy in it.’

6. Space-Time – Finite but No Boundary

‘It is possible for space-time to be finite in extent and yet have no singularities that formed a boundary or edge. Space-time would be like the surface of the earth (finite but with no boundary), only with two more dimensions.’

‘All the complicated structures that we see in the universe might be explained by the no (space-time) boundary condition for the universe together with the uncertainty principle of quantum mechanics.’

7. Imaginary Time

‘When one tries to unify gravity with quantum mechanics, one must introduce the idea of “imaginary” time. Imaginary time is indistinguishable from directions in space.’

‘If one can go north, one can turn around and head south; equally, if one can go forward in time, one ought to be able to go backward. This means that there can be no important difference between the forward and backward directions of imaginary time.’

8. Real Time

‘On the other hand, when one looks at real time, there’s a very big difference between the forward and backward directions, as we all know. Where does this difference between the past and the future come from? Why do we remember the past but not the future?’

9. Arrows of Time

‘There are at least three different arrows of time. First, there is the thermodynamic arrow of time, the direction of time in which disorder or entropy increases. Then, there is the psychological arrow of time. This is the direction in which we feel time passes, the direction in which we remember the past but not the future. Finally there is the cosmological arrow of time. This is the direction of time in which the universe is expanding rather than contracting.’

10. Pointing the Same Way

‘I have shown that the psychological arrow is essentially the same as the thermodynamic arrow. The no boundary proposal for the universe predicts the existence of a well-defined thermodynamic arrow of time because the universe must start off in a smooth and ordered state. And the reason we observe this thermodynamic arrow to agree with the cosmological arrow is that intelligent beings can exist only in the expanding phase.’

11. Putting the Bits Together

‘Ultimately, one would hope to find a complete, consistent, unified theory (of the universe) that would include all these partial theories. If we do discover a complete (unified) theory, it should in time be understandable in broad principle by everyone, not just a few scientists. Then we shall all, philosophers, scientists and just ordinary people, be able to take part in the discussion of the question of why it is that we, and the universe, exist. If we find the answer to that, it would be the ultimate triumph of human reason – for then we would know the mind of God.’