Passage 3 Information theory -the big idea

Information theory Lies at the heart of everything-from DVD players and the genetic code of DNA to the physics （ ） of the universe （ ） at its most fundamental （ ）. It has been central to the development of the science of communication, which enables （ ） data to be sent electronically and has therefore had a major impact on our lives

A

In April 2002 an event took place which demonstrated （ ） one of the many applications of information theory. The space probe,（ ） Voyager（ ） I, launched （ ）in 1977, had sent back spectacular （ ） images of Jupiter（ ） and Saturn（ ） and then soared（ ） out of the Solar System on a one-way mission to the stars. After 25 years of exposure （ ） to the freezing temperatures of deep space, the probe was beginning to show its age. Sensors （ ） and circuits （ ） were on the brink （ ） of failing and NASA experts realised that they had to do something or lose contact with their probe forever. The solution was to get a message to Voyager I to instruct（ ） it to use spares（ ）to change the failing parts. With the probe 12 billion kilometres from Earth, this was not an easy task. By means of a radio dish belonging to NASA'S Deep Space Network, the message was sent out into the depths of space. Even travelling at the speed of light, it took over l1 hours to reach its target, far beyond the orbit（ ） of Pluto（ ）. Yet, incredibly, the little probe managed to hear the faint（ ） call from its home planet, and successfully made the switchover.（ ）

B

It was the longest-distance repair（ ）job in history, and a triumph（ ） for the NASA engineers. But it also highlighted the astonishing （ ） power of the techniques developed by American communications engineer Claude Shannon, who had died just a year earlier. Born in 1916 in Petoskey, Michigan, Shannon showed an early talent for maths and for building gadgets, and made breakthroughs （ ）in the foundations of computer technology when still a student. While at Bell Laboratories, Shannon developed information theory, but shunned（ ） the resulting acclaim.（ ） In the 1940s, he single-handedly（ ） created an entire （ ） science of communication which has since inveigled （ ）its way into a host of applications, from DVDS to satellite （ ） communications to bar codes-any area, in short, where data has to be conveyed （ ）rapidly yet accurately.

C

This all seems light years away from the down-to-earth uses Shannon original had for his work, which began when he was a 22-year-old graduate engineering student at the prestigious（　　　　）Massachusetts Institute of Technology in 1939. He set out with an apparently simple aim: to pin（　　　　）down the precise（　　　　）meaning of the concept（　　　　）of 'information'. The most basic form of information, Shannon argued, is whether something is true or false-which can be captured（　　　　）in the binary（　　　　）unit, orbit, of the form 1 or 0. Having identified this fundamental unit, Shannon set about defining otherwise vague ideas about information and how to transmit（　　　　）it from place to place In the process he discovered something surprising: it is always possible to guarantee（　　　　）information will get through random（　　）interference-'noise'-intact.（　　　　）

D

Noise usually means unwanted sounds which interfere（　　　　）with genuine（　　　　）information. Information theory generalises this idea via theorems（　　　　）that capture the effects of noise with mathematical precision.（　　　　）In particular, Shannon showed that noise sets a limit on the rate at which information can pass along communication channels while remaining error-free（　　　　）. This rate depends on the relative strengths of the signal and noise travelling down the communication channel, and on its capacity (its bandwidth（　　　　）) The resulting limit, given in units of bits per second, is the absolute maximum rate of error-free communication given signal strength and noise level. The trick, Shannon showed, is to find ways of packaging up-coding'- information to cope with the ravages of noise, while staying within the information-carrying capacity bandwidth'-of the communication system being used.

E

Over the years scientists have devised（　　　　）many such coding methods, and they have proved crucial in many technological feats.（　　　　）The Voyager spacecraft transmitted data using codes which added one extra bit for every single bit of information; the result was an error rate of just one bit in 10, 000-and stunningly（　　　　）clear pictures of the planets. Other codes have become part of everyday life-such as the Universal Product Code, or bar code, which uses a simple error-detecting system that ensures supermarket check-out lasers（　　　　）can read the price even on, say, a crumpled（　　　　）bag of crisps.（　　　　）As recently as 1993, engineers made a major breakthrough by discovering so-called turbo（　　　　）codes-which come very close to Shannon's ultimate（　　　　）limit for the maximum rate that data can be transmitted reliably, and now play a key role in the mobile videophone revolution.

F

Shannon also laid the foundations of more efficient ways of storing information, by stripping（　　　　）out superfluous（　　　　）('redundant')（　　　　）bits（　　　　）from data which contributed little real information. As mobile phone text messages like 'I CN C U' show, it is often possible to leave out a lot of data without losing much meaning. As with error correction, however, there's a limit beyond which messages become too ambiguous. Shannon showed how to calculate this limit, opening the way to the design of compression（　　　　） methods that cram（　　　　） maximum information into the minimum space.