**PART 1: READING**

**MUSIC AND THE EMOTIONS**

***Neuroscientist Jonah Lehrer considers the emotional power of music***

Why does music make us feel? On the one hand, music is a purely abstract art form, devoid of language or explicit ideas. And yet, even though music says little, it still manages to touch us deeply. When listening to our favourite songs, our body betrays all the symptoms of emotional arousal. The pupils in our eyes dilate, our pulse and blood pressure rise, the electrical conductance of our skin is lowered, and the cerebellum, a brain region associated with bodily movement, becomes strangely active. Blood is even re-directed to the muscles in our legs. In other words, sound stirs us at our biological roots.  
  
A recent paper in Neuroscience by a research team in Montreal, Canada, marks an important step in repealing the precise underpinnings of ‘the potent pleasurable stimulus’ that is music. Although the study involves plenty of fancy technology, including functional magnetic resonance imaging (fMRI) and ligand-based positron emission tomography (PET) scanning, the experiment itself was rather straightforward. After screening 217 individuals who responded to advertisements requesting people who experience ‘chills’ to instrumental music, the scientists narrowed down the subject pool to ten. They then asked the subjects to bring in their playlist of favourite songs - virtually every genre was represented, from techno to tango - and played them the music while their brain activity was monitored. Because the scientists were combining methodologies (PET and fMRI), they were able to obtain an impressively exact and detailed portrait of music in the brain. The first thing they discovered is that music triggers the production of dopamine - a chemical with a key role in setting people’s moods - by the neurons (nerve cells) in both the dorsal and ventral regions of the brain. As these two regions have long been linked with the experience of pleasure, this finding isn’t particularly surprising.  
  
What is rather more significant is the finding that the dopamine neurons in the caudate - a region of the brain involved in learning stimulus-response associations, and in anticipating food and other ‘reward’ stimuli - were at their most active around 15 seconds before the participants’ favourite moments in the music. The researchers call this the ‘anticipatory phase’ and argue that the purpose of this activity is to help us predict the arrival of our favourite part. The question, of course, is what all these dopamine neurons are up to. Why are they so active in the period preceding the acoustic climax? After all, we typically associate surges of dopamine with pleasure, with the processing of actual rewards. And yet, this cluster of cells is most active when the ‘chills’ have yet to arrive, when the melodic pattern is still unresolved.  
  
One way to answer the question is to look at the music and not the neurons. While music can often seem (at least to the outsider) like a labyrinth of intricate patterns, it turns out that the most important part of every song or symphony is when the patterns break down, when the sound becomes unpredictable. If the music is too obvious, it is annoyingly boring, like an alarm clock. Numerous studies, after all, have demonstrated that dopamine neurons quickly adapt to predictable rewards. If we know what’s going to happen next, then we don’t get excited. This is why composers often introduce a key note in the beginning of a song, spend most of the rest of the piece in the studious avoidance of the pattern, and then finally repeat it only at the end. The longer we are denied the pattern we expect, the greater the emotional release when the pattern returns, safe and sound.  
To demonstrate this psychological principle, the musicologist Leonard Meyer, in his classic book Emotion and Meaning in Music (1956), analysed the 5th movement of Beethoven’s String Quartet in C-sharp minor, Op. 131. Meyer wanted to show how music is defined by its flirtation with - but not submission to - our expectations of order. Meyer dissected 50 measures (bars) of the masterpiece, showing how Beethoven begins with the clear statement of a rhythmic and harmonic pattern and then, in an ingenious tonal dance, carefully holds off repeating it. What Beethoven does instead suggest variations of the pattern. I want to preserve an element of uncertainty in his music, making our brains beg for the one chord he refuses to give us. Beethoven saves that chord for the end.  
  
According to Meyer, it is the suspenseful tension of music, arising out of our unfulfilled expectations, that is the source of the music’s feeling. While earlier theories of music focused on the way a sound can refer to the real world of images and experiences - its ‘connotative’ meaning - Meyer argued that the emotions we find in music come from the unfolding events of the music itself. This ‘embodied meaning’ arises from the patterns the symphony invokes and then ignores. It is this uncertainty that triggers the surge of dopamine in the caudate, as we struggle to figure out what will happen next. We can predict some of the notes, but we can’t predict them all, and that is what keeps us listening, waiting expectantly for our reward, for the pattern to be completed.

**Questions 27-31**  
Complete the summary below.  
Choose **NO MORE THAN TWO WORDS** from the passage for each answer.  
Write your answers in boxes **27-31** on your answer sheet.

### The Montreal Study

Participants, who were recruited for the study through advertisements, had their brain activity monitored while listening to their favourite music. It was noted that the music stimulated the brain’s neurons to release a substance called 27 in two of the parts of the brain which are associated with feeling **(28)** **...........................** .  
  
Researchers also observed that the neurons in the area of the brain called the **(29)** **...........................**were particularly active just before the participants’ favourite moments in the music - the period known as the **(30)...........................**. Activity in this part of the brain is associated with the expectation of ‘reward’ stimuli such as **(31)** **........................... .**

**Questions 32-36** Choose the correct letter, **A**, **B,** **C** or **D**.   
Write the correct letter in boxes **32-36** on your answer sheet  
  
**32.** What point does the writer emphasise in the first paragraph?  
    A. how dramatically our reactions to music can vary  
    B. how intense our physical responses to music can be  
    C. how little we know about the way that music affects us=  
    D. how much music can tell us about how our brains operate  
**33.** What view of the Montreal study does the writer express in the second paragraph?  
    A. Its aims were innovative.  
    B. The approach was too simplistic.  
    C. It produced some remarkably precise data.  
    D. The technology used was unnecessarily complex.  
**34.** What does the writer find interesting about the results of the Montreal study?  
    A. the timing of participants’ neural responses to the music  
    B. the impact of the music on participants’ emotional state  
    C. the section of participants’ brains which was activated by the music  
    D. the type of music which had the strongest effect on participants’ brains  
**35.** Why does the writer refer to Meyer’s work on music and emotion?

    A. to propose an original theory about the subject  
    B. to offer support for the findings of the Montreal study  
    C. to recommend the need for further research into the subject  
    D. to present a view which opposes that of the Montreal researchers  
**36.** According to Leonard Meyer, what causes the listener’s emotional response to music?

    A. the way that the music evokes poignant memories in the listener  
    B. the association of certain musical chords with certain feelings  
    C. the listener’s sympathy with the composer’s intentions  
    D. the internal structure of the musical composition

**Questions 37-40** Complete each sentence with the correct ending, **A-F**, below.  
  
Write the correct letter, **A-F**, in boxes **37-40** on your answer sheet.  
**37.** The Montreal researchers discovered that  
**38.** Many studies have demonstrated that  
**39.** Meyer’s analysis of Beethoven’s music shows that  
**40.** Earlier theories of music suggested that

**A.** our response to music depends on our initial emotional state.  
**B.** neuron activity decreases if outcomes become predictable.  
**C.** emotive music can bring to mind actual pictures and events.  
**D.** experiences on our past can influence our emotional reaction to music.  
**E.**emotive music delays giving listeners what they expect to hear.  
**F.**  neuron activity increases prior to key points in a musical piece.

**READING PRACTICE 2**

**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 11 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 originally 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, or ‘bit’, 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 .

**Questions 1-6**

Reading Passage has six paragraphs, A-F. Which paragraph contains the following information?

Write the correct letter, A-F, in boxes 1-6 on your answer sheet.

1..................... an explanation of the factors affecting the transmission of information

2..................... an example of how unnecessary information can be omitted

3..................... a reference to Shannon’s attitude to fame

4..................... details of a machine capable of interpreting incomplete information

5..................... a detailed account of an incident involving information theory

6..................... a reference to what Shannon initially intended to achieve in his research

**Questions 7-11.** Complete the notes below.

Choose NO MORE THAN THREE WORDS from the passage for each answer.

Write your answers in boxes 7-11 on your answer sheet.

**The Voyager 1 Space Probe**

• The probe transmitted pictures of both 7....................., then left the 8.....................

• The freezing temperatures were found to have a negative effect on parts of the space probe.

• Scientists feared that both the 9..................... were about to stop working.

• The only hope was to tell the probe to replace them with 10..................... – but distance made communication with the probe difficult.

• A 11..................... was used to transmit the message at the speed of light.

• The message was picked up by the probe and the switchover took place.

**Questions 12-14: TRUE, FALSE, NOT GIVEN**

Do the following statements agree with the information given in Reading Passage? Write

12..................... The concept of describing something as true or false was the starting point for Shannon in his attempts to send messages over distances.

13..................... The amount of information that can be sent in a given time period is determined with reference to the signal strength and noise level.

14..................... Products have now been developed which can convey more information than Shannon had anticipated as possible.