Chapter 3

Existing Music Science

This is not the first book ever written about music science, and my theories aren't the first music theories either. This chapter summarises some of what has come before me.

Existing theories about music can be classified according to the assumptions that underlie them. The most common assumptions include: the Evolutionary Assumption (correct), the Music Assumption (incorrect), the Communication Hypothesis (incorrect), the Social Assumption (incorrect), the "In the Past" Assumption (incorrect), the Cultural Assumption (over-emphasised), the Cortical Plasticity Assumption (also over-emphasised), the Music-Language Assumption (correct but subject to misleading variations), and a few more technical assumptions about particular aspects of music (all of them probably incorrect). Although the Evolutionary Assumption is a good one to make, it has resulted in the development of many implausible evolutionary hypotheses about music.

3.1 Existing Literature

Each of the following five books is an edited collection of articles or papers written by different authors:

- *Handbook of Music Psychology* edited by Donald Hodges (Institute for Music Research 1996).

- *The Psychology of Music, 2nd Edition* edited by Diana Deutsch (Academic Press 1999).

- *The Origins of Music* edited by Nils Wallin, Björn Merker and Steven Brown (MIT Press 2000). These papers discuss different approaches to understanding the origins of music. Underlying most of them is the belief that we can understand more about music by understanding its origins.
- *Music and Emotion* edited by Patrik Juslin and John Sloboda (Oxford University Press 2001).
- *The Cognitive Neuroscience of Music* edited by Isabelle Peretz and Robert Zatorre (Oxford University Press 2003). This is the most recent music science book, although it is actually an expanded version of *The Biological Foundations of Music* (volume 930 of the Annals of the New York Academy of Sciences, June 2001).

For the purpose of quoting references, I will refer to these books as *Music Psych.*, *Psych. Music*, *Origins*, *Music & Emotion* and *Cog. Neuro. Music*. I am not going to attempt a full review of all the articles and papers—they are not light reading, and any attempts I make to clarify what I think they mean may not be all that helpful. If you are serious about learning all there is to know about music science, then you will probably want to read them yourself, and draw your own conclusions. In this chapter, I restrict myself to summarising existing work in music science as I understand it, and I give references where they seem relevant.

Some other books of interest include:

- *Emotion and Meaning in Music* Leonard B. Meyer (Univ. of Chicago Press 1956). Meyer, a professor of music, advances a theory of expectation, inhibition and completion, and discusses aspects of various musical items and excerpts in ways that match up with his theory.
- *Music and the Mind* Anthony Storr (Ballantine Books 1993). A partly philosophical, partly scientific book asking basic questions about the nature of music.
- *Music, the Brain and Ecstasy* Robert Jourdain (William Morrow 1997). A popularised introduction to music science.

For references to these books I will just quote the author's name.

3.2 The Origins of Music

Origins devotes itself to the origins of music, i.e. how and why did music come into existence? In practice this question is very closely related to the question of what music is now, and why it exists (now). In biology, the study of the present is inextricably linked to the study of the past. The current organism is the result of a history of evolutionary steps consisting of mutation and recombination (i.e. sex), and natural selection acting on the resulting genetic variation. At each point in time natural selection acts on the species, and at each point in time—including the present—one can explain the purposes inherent in an organism's structure and behaviour in relation to the selective pressures acting at that point in time.

In the first chapter of *Origins*, the editors explain how the study of the evolution of music became "unfashionable" some time after 1940, and compare this to the famous 1866 ban by the Linguistic Society of Paris on discussion of the origins of language.

As the editors of *Origins* point out, discussion of the origins of *music* has never been specifically banned by anyone. But it has suffered from the same difficulties as discussion of the origins of language—scholars can endlessly speculate about origins (of music or language), and there is little reason to reject or accept one speculation over another, as the hard evidence required to do so is lost in the past. The speakers of pre-language and the players of pre-music are long since dead, and their language-like and music-like activities have not left any identifiable remains, at least not that have been discovered. (The musical fossil remains that have been discovered, as discussed in the next section, are of such a nature that their owners may have had musical capacities already equivalent to those of modern humans.)

There is one significant difference between discussing the origins of language and the origins of music: *we know what language is and what it is for*. We can guess what the major selective pressures on the human species were that determined the evolution of the human capacity for language: the need to send information and the need to receive information. (We could just say the need to communicate, but "communication" refers to an activity involving at least two entities, whereas natural selection must act primarily via the reproductive success of the individual.) When we discuss the origins of music, we are discussing the origins of something that we don't know what it is. Even if we do find out what the origin of music is, we may be left not knowing what music is for *now*.

Unfortunately the best guesses about the origin of music are just that: guesses—some plausible, others wild—but guesses just the same. And if the Music-Language Assumption is correct, and music is related to language, then we would expect the precursor of music to be related in an analogous way to the precursor of language. But, as the Paris ban implied, speculations about the precursor to language are also just wild guesses, and we are left with nothing very firm to hold on to.

3.3 The Archaeology of Music

The study of the archaeology of music consists almost entirely of the study of ancient musical instruments, and in particular the study of instruments made from materials likely to fossilize (such as bone).

The most famous prehistoric musical artefact is the Divje bone "flute", as described in "New Perspectives on the Beginnings of Music: Archeological and Musicological Analysis of a Middle Paleolithic Bone 'Flute'", Drago Kunej and Ivan Turk (*Origins*). It was found in a cave in Divje, Slovenia in 1995. The dating of this fossil strongly suggests that it is a Neanderthal artefact: it was found in a deposit layer dated 50,000 BP (before present) to 43,000 BP, which was quite distinct from another layer dated 35,000 BP which was the most recent layer at the site containing **Aurignacian** artefacts. (Aurignacian culture is a European stone age culture going back to 40,000 BP at the very earliest, and is strongly associated with "modern" humans, with a degree of innovation in art and tool manufacture that contrasts somewhat with that of the **Mousterian** Neanderthal culture.)

Given that it is now believed that modern humans are not all that closely related to Neanderthals, the Divje flute appears to push the origin of music a long way back in time: the common ancestor of Neanderthals and modern humans could have lived as long ago as 400,000 BP.

Much depends, however, on this one piece of evidence. One major uncertainty is that the object may not be a flute. The artefact is a broken piece of a cave bear thigh bone, with two holes in a line, and signs of two other holes on each of the broken ends, and another hole underneath. There may have been some other reason why the artefact's creator decided to drill holes in a bone. But given that it is difficult to think of any other practical purpose for a bone with holes in it, one would be forced to attribute some symbolic significance to it, and there is very little evidence that Neanderthals created artefacts with symbolic meaning (the evidence that does exist is ambiguous and controversial, and contrasts with overwhelming evidence of symbolic artefacts created by modern humans who lived in Europe at the same time as the Neanderthals).

A second uncertainty is that the holes might not have been the result of human activity, the most plausible alternative being that some carnivore bit down on the bones. However, the number of holes and partial holes, and the regularity of their placement, is just a bit too much coincidence for this explanation to be believable. (The paper by Kunej and Turk contains a detailed analysis of the nature of the holes and different cutting processes that could have created them, with the conclusion that the holes were most probably the result of deliberate human manufacture, and very probably not the result of a large carnivore biting on the bone.)

The next oldest known fossil flute is one found in a cave at Geissenklösterle, Germany, dated to 30,000 BP–37000 BP (found by a team from the University of Tübingen).[1] This is associated with the Aurignacian culture, and thus reflects the capabilities and musical preferences of prehistoric modern

[1] **http://www.uni-tuebingen.de/uni/qvo/pm/pm2004/pm824.html** (University of Tübingen press release)

humans, not necessarily much different from those of modern humans living today.

3.4 Common Assumptions

Although there are many different theories of music, and many different approaches that have been taken by those trying to understand music, a relatively small number of basic assumptions underlie most of these theories.

3.4.1 The Evolutionary Assumption

One assumption that I do not dispute is the requirement that music must be explained within the framework of evolution by natural selection.

It's one thing to suppose that music evolved by natural selection as a result of satisfying some biological purpose. It's another thing to determine what that purpose is. Possibilities that have been considered by music scientists include the following:

- Young men sing to attract young women. In *The descent of man, and Selection in relation to sex* (1871), Charles Darwin considered the possibility that music had evolved as a result of sexual selection. **Sexual selection** is where a female has to choose a male according to the same preferences as other females, otherwise her own sons will not have the genes required to make them attractive to the next generation of females. In this way sexual selection can create and maintain preferences that do not serve any other useful purpose, or which may even be counterproductive, like the peacock's tail, which just gets in the way. In "Evolution of Human Music through Sexual Selection" (*Origins*), Geoffrey Miller reviews evidence for and against sexual selection as an explanation for music, his conclusion being that the hypothesis is at least plausible.

- Young women sing to attract young men. Sexual selection does operate in both directions: a male must choose a female mate according to the same preferences as other males, otherwise his daughters will not have the genes required to make them attractive to the next generation of males. Men are generally less choosy about who they have sex with, which implies that sexual selection will not influence male choice as much as it does female choice. But men are reasonably choosy about who they form long-term relationships with, and we do observe that men are apparently more obsessed with physical attractiveness than women are (although it is debatable as to what proportion of the attributes that determine physical attractiveness are the result of sexual selection). So if sexual selection can plausibly explain the musical abilities of males, it can just as plausibly explain the musical abilities of females.

- It's easier to remember something if you sing it as lyrics in a song. See "How Music Fixed 'Nonsense' into Significant Formulas: On Rhythm, Repetition and Meaning" (Bruce Richman, *Origins*) and "Synchronous Chorusing and Human Origins" (Björn Merker, *Origins*).

- Performing music as part of a group improves one's membership within the group—the "social bonding" theory. See "A Neurobiological Role of Music in Social Bonding" (Walter Freeman, *Origins*).

One difficulty with all of these theories is that they allow for music to be completely arbitrary, and therefore say nothing about why music is like it is.

A recent review of evolutionary theories is found in "Is Music an Evolutionary Adaptation?" (David Huron, *Cog. Neuro. Music*). See also "Human Musicality" (Donald Hodges, *Music Psych.*).

Some evolutionary theories of music are stated in terms of what music evolved *from*. Music evolved from something else, where the something else had or has a discernible purpose, and somehow this something else evolved into music. Unfortunately A cannot evolve into B unless B itself has some purpose. Otherwise there is nothing to drive the evolution required. To put it another way, the fact that A might have been a precursor of B does nothing to explain why B exists. It's like explaining what wings are good for by saying that they evolved from legs, and that legs serve the purpose of getting the animal from one place to another by walking or running: we still don't know what the wings are good for.

A list of things that music might have evolved from includes:

- Mothers making communicative noises and gestures to their babies, and babies to their mothers. See "Antecedents of the Temporal Arts in Early Mother-Infant Interaction" (Ellen Dissanayake, *Origins*).

- Language, or specific aspects of language, such as the rhythm and melody of language.

- Alternatively, language evolved from music, and music just carried on existing as well. See "The 'Musilanguage' Model of Music" (Steven Brown, *Origins*), which lists various models of language/music evolution.

The language-related evolutionary explanations are a subset of those explanations subject to the Music-Language Assumption (see below).

3.4.2 The Music Assumption

Perhaps the most dominant and yet unjustified assumption in the field of music science is the assumption that it is *music* that must be explained. Within the framework of evolutionary theory, this translates into an assumption that music has a biological purpose—that music somehow contributes to reproductive success. Many of those studying the evolutionary theory of music seem to make this assumption implicitly, without even considering the alternative: that the human tendencies that cause people to compose, perform and/or appreciate music can serve some biological purpose, but music itself does not serve any such purpose, rather music is just a side-effect of those tendencies.

On the other hand, sometimes it is recognised that music does not appear to serve any useful purpose, but this is presented as a fatal difficulty within the evolutionary framework.

Musical activity can be divided roughly into three activities:

- Composing
- Performing
- Listening

For each of these activities we can suppose that there exists a corresponding tendency to engage in that activity. My theory not only rejects the Music Assumption, it also supposes that only the tendency to *listen* to music requires biological explanation, because the other activities, i.e. composition and performance, are ultimately motivated by the desire to listen to music. Composers compose and performers perform in order to satisfy their own desire to listen to good music, and to satisfy the desire of their audience to listen to good music.

3.4.3 The Communication Hypothesis

The Communication Hypothesis depends on the Music Assumption—that music must be explained—and states that the explanation for music is that it is a form of communication. The problem is to determine what it is that is being communicated. Given the observed effects of music on listeners, we might suppose that one or more of the following is being communicated:

- Emotional quality
- Dance! (as a command)
- Feel good! (as a command)

There are several major objections to this hypothesis:

- The amount of information inherent in a piece of music far exceeds what is necessary to impart information on any of these topics. “Dance” and “Feel good” are just simple commands, and there are not that many distinct emotional qualities in the world that are worth communicating. Yet music has a level of complexity, even in the simplest of tunes, which seems out of proportion to what is required to communicate any of these items of information.

- Composing music is not easy to do. How can you musically communicate anything if you don't know how to compose music? At best you can make use of the repertoire available to the culture you live in. Compare this to language: we all know a "repertoire" of words and syntax, but we do not rely on a "repertoire" of sentences, rather we freely compose our own sentences as the need arises.

- It does not feel subjectively that we perform music to communicate. We perform to entertain (ourselves or others), or because the occasion demands it. When we do want to communicate, we generally speak, and this is often supplemented by other forms of communication, such as facial expression, body language, and non-linguistic vocalisations such as laughing and crying. But we do not sing.

The first part of *Origins* consists of articles about animal calls and songs and their relationship to human language and music. Given that almost all animal calls are believed to be some type of communication, it would follow that if human music evolved from non-human animal calls, then music must also be a type of communication.

Patrik Juslin in "Communicating Emotion in Music Performance: A Review and Theoretical Framework" (*Music & Emotion*) presents a theory of how music communicates the emotions of the performer to the listeners.

3.4.4 The Social Assumption

The Social Assumption is the assumption that music plays some crucial role in creating and maintaining human society. It is true that people gather together to make music, and to listen to music, and to respond in other ways such as dancing. And people often sing songs or make music that reflects membership in their society or religion.

But none of these observations are really evidence that music exists *for the purpose* of maintaining social connections or increasing social bonding. People listen to music together, but they also drink alcohol together. One would hardly say that the purpose of alcohol is to increase social bonding. In Western society our use of alcohol and other recreational drugs is fairly informal (and even legally prohibited in some cases). In other societies particular drugs may play a central role in the formal rituals of those societies. But we would still not say that the *purpose* of mind-altering drugs is to facilitate social bonding. Rather we would say that the drugs have effects on their users which lead to them being chosen as a component of social rituals. Similarly for the use of alcohol at a party. And similarly for the performance and appreciation of music, whether in a formal ritual or at an informal party—it is the effects of music that encourage its use in those situations.

Humans are very social animals—almost anything they do can be done socially.[2] So just because an activity occurs in social situations, that is no reason to suppose that the activity in question serves a social purpose.

This reasoning applies even where the performance of music *requires* group activity, like a choir singing in harmony, or a band playing different instruments. It typically requires group activity to make a house. But it is not the purpose of house-building to bond society together—the purpose of building a house is to make a house that someone can live in.

3.4.5 The "In the Past" Assumption

Reference to the past is a general strategy for solving hard problems about evolutionary human biology: the thing to be explained doesn't serve any useful purpose now, but it was very useful in the past when we were all hunter gatherers living in small tribes. The technical name for this past life that explains everything about us is the **environment of evolutionary adaptedness**[3] (**EEA**). Now it is true that there was a time when all of our ancestors lived in this environment, and currently many of us don't live in such an environment. *Some* evolutionary problems can be solved by comparing the past with the present. A good example is the set of desires that cause us to eat more of certain foods than are good for us. In the EEA these foods were not freely available, and when they were occasionally available, the short-term benefits of eating them outweighed the long-term costs. Most people were going to die early anyway, and malnutrition presented a much greater immediate threat than cancer, diabetes and circulatory disease.

But EEA-based explanations must be used with caution, and here is a list of problems that can arise:

- Some EEA-based explanations make further suppositions about the nature of human culture in the EEA. But the big thing about human culture is that it *varies*. Culture is a manner of creating and passing on variation that operates somewhat independently of genetic evolution, and also considerably faster. Any evolutionary explanation that assumes some particular and peculiar characteristics of primitive human culture is ignoring this intrinsic tendency towards variation.

- There are still people living today in circumstances that approximate the EEA. That is, they live in small tribes and feed themselves by hunting wild animals and gathering wild plant foods. If you were invoking the EEA, hoping that your theory could not be tested against a real live stone age hunter-gatherer culture (and found wanting), you could be out of luck.

- Even if a theory of musical behaviour depends on characteristics of life in an environment and culture that no longer exists, the human

[2] Although there are *some* activities that we mostly prefer to do in private.

[3] A term invented by John Bowlby, the psychiatrist who developed Attachment Theory.

musical tendencies that the theory is trying to explain do still exist. Any theory must be consistent with our *current* experience of those tendencies. If, for example, music was used by males to flirt with females in the past, are modern day males observed to flirt with females by singing to them? Do they show even a tendency to behave in this way? (There are indeed circumstances where young men are observed to sing or perform music to females in the hope of creating or enhancing romantic interest, but there is no real evidence that this is an *instinctive* behaviour. Rather it appears to result from a conscious plan based on a conscious understanding of the likely effects of such performance.)

3.4.6 The Music-Language Assumption

At its most general, the Music-Language Assumption states that music and language have some relationship to each other. It is an assumption that I agree with, and if you read on you will see that my theory of music quite explicitly relates the perception of music to the perception of language.

There are, however, many different ways that music and language can be related. There are also many different choices to make as to which aspects of language relate to which aspects of music, and why. For example, some authors relate musical harmony to linguistic syntax—an analogy not included in my theory.[4]

Papers that relate music to language include "Comparison between Language and Music" (Mireille Besson and Daniele Schön, *Cog. Neuro. Music*), "Toward an Evolutionary Theory of Music and Language" (Jean Molino, *Origins*) and "The 'Musilanguage' Model of Music Evolution" (Steven Brown, *Origins*).

Poetry is one phenomenon whose characteristics place it in the gap that lies between music and language, and some authors consider the relationship between poetry and music, for example, Fred Lerdahl in "The Sounds of Poetry Viewed as Music" (*Cog. Neuro. Music*).

3.4.7 The Cultural Assumption

Music is a cultural phenomenon, and people respond primarily to music from their own culture. Some conclude from this that the evolution of music is subject only to laws of cultural evolution, and that it is not appropriate or relevant to explain music in terms of genetic evolution by natural selection.

[4] A **syntax** is formally defined as a set of rules for accepting a sequence of symbols. Thus a syntax of English would be a mathematical description of what constituted a grammatically correct English sentence. Although the syntaxes of natural human languages have so far defied complete formal description, there are approximate descriptions that are convincingly close, and good enough to enable computers and people to chat on some level (usually bounded by the limitations on the computer's ability to handle semantics rather than by its inability to deal with syntax).

It is true that culture strongly affects the musical behaviour and the musical tastes of individuals. But the existence of human culture does not remove the need to explain human behaviour in a biological evolutionary framework. Human culture exists because there are human tendencies to copy attitudes, preferences and behaviours from other people. These tendencies to copy are themselves necessarily determined by our genes, and are subject to natural selection just like any other genetically determined aspect of human nature.

Human culture is not a simple fixed attribute of human behaviour. There are many possible variations in the way that information is copied from one person to another. You can pay more or less attention to the attitudes and behaviours of other people, according to any number of relevant criteria: whether or not another person is admirable in some way, whether they are successful, whether they belong to your family group, whether they are the same gender as yourself.

Different *kinds* of information can be copied in different ways. There are almost certainly special mechanisms that exist for learning and reproducing natural language. At the same time, many behaviours are not substantially determined by cultural transmission, behaviours such as running, walking, eating and breathing (the basic mechanics of these behaviours are not culturally determined, although culture may still affect some peripheral aspects of them).

There also exist specific "anti-culture" mechanisms, which have the effect of negating or reversing culturally determined attitudes. In particular there is teenage rebellion, where at a certain age the individual goes out of their way to behave in ways consistent with their peers but inconsistent with the mores of their parents and the larger society they live in.

And, as a final complication, different individuals have varying tendencies to copy or not copy the attitudes and behaviours of others. Some people have a strong tendency to "fit in", even where this conflicts with common sense. Others live in a world of their own, yet may still make a useful and unique contribution to the society they live in, perhaps as a result of their individualism.

It is very likely that separate genes affect each of these different mechanisms and aspects of the transmission of culture. So we can't just say "Music is determined by culture, so forget about the biology". We still have to ask what the cultural mechanisms are that cause music to propagate from one generation to the next, and perhaps change along the way, and what the biological purpose is of those cultural mechanisms (i.e. what the forces of natural selection are that act on the genes that affect those mechanisms).

3.4.8 The Cortical Plasticity Assumption

I investigate **cortical plasticity** in more detail in Chapter 10. Cortical plasticity refers to the brain's ability to rewire itself to process whatever type of information it needs to or wants to process. In the context of music science, the concept allows us to believe that the brain rewires itself however much is necessary to process the patterns and structures of music. The problem with this belief in flexibility is that it distracts us from an opposite possibility: that aspects of music evoke a response in cortical maps which already exist for some other purpose, and these cortical maps exist independently of any exposure to music.

The Cortical Plasticity Assumption is related to the Cultural Assumption, in that it is generally assumed that a person's brain adapts to the music of their culture by means of cortical plasticity.

In "Musical Predispositions in Infancy" (*Cog. Neuro. Music*), Sandra Trehub reports on studies of the musical capabilities of infants. The results show that many aspects of music perception are already found in infants, even though they are so young that their previous exposure to music must be very limited. The conclusion is that we come into this world to some extent already "wired" for music perception.

3.4.9 The Simultaneous Pitch Assumption

Compared to the assumptions I have discussed so far, the Simultaneous Pitch Assumption is quite a technical assumption. It is assumed that, to understand the basis of musical harmony, we must understand how the brain processes perception of simultaneous notes with pitch values related (or not related) to each other by consonant intervals.

This may seem almost common sense, since harmony is by definition the performance of different notes simultaneously in music. However, this assumption is a subtle corollary of the Music Assumption—the assumption that we must explain music, as opposed to explaining human musical tendencies.

Harmony is one aspect of music where this assumption makes a large difference. One form of harmony is **chords**: groups of notes related by consonant intervals. It is an empirical fact that the listener to music can perceive chords as groups of notes played simultaneously, but can also perceive chords as groups of notes played sequentially. It may be that the response to sequential notes is what actually matters and requires explanation in an evolutionary framework, and that the response to simultaneous notes is an accidental side-effect of the ability to respond to notes of a chord sequentially.

An example of research into harmony and the perception of consonance and dissonance is "Neurobiology of Harmony Perception" (Mark Tramo, Peter Cariani, Bertrund Delgutte & Louis Braida *Cog. Neuro. Music*).

Tramo *et al.* conclude from their research that consonance and dissonance of simultaneous tones are encoded in the form of **interspike interval**[5] (**ISI**) distributions as measured in the auditory nerve of a cat (there is no claim

[5]The **interspike intervals** are intervals between action potentials. Calculating the distribution of intervals is equivalent to calculating the **autocorrelation** function of the signal, and doing so extracts periodic features from the signal.

that cats perceive music, but it is reasonable to presume that this aspect of auditory perception is not too different from what occurs in humans).

This encoding would be an example of **temporal coding**, i.e. encoding of information in the precise *timings* of neural activity. The paper does not make any suggestions as to how such an encoding might be translated into other forms of encoding, such as position within a cortical map. However, it seems likely that temporally encoded information must eventually be re-encoded into a positional form if it is to be integrated and processed with all the other information that the brain processes.

Tramo *et al.*'s research is part of a long history of attempting to determine neurophysiological correlates of the subjective perception of consonance and dissonance, which includes the work of scientists such as Hermann von Helmholtz, Carl Stumpf, and R. Plomp and J.M. Levelt (the last two developed the **critical band theory** of consonance). Although consonance and dissonance appear to be major aspects of music, there are difficulties that arise in interpreting these attempts to understand the perception of consonance and dissonance:

- Most experiments in this field involve asking subjects to judge the consonant/"pleasant"/"non-rough" quality of pairs of tones, which are usually played simultaneously. But our knowledge of the relationship between subjectively perceived consonance and musicality is very limited: we observe that dissonant chords tend to "resolve" into consonant chords, and that's about it. So even if we determine that neurophysiological phenomenon X is perfectly correlated with the perception of consonance and dissonance, we still don't know what, if anything, phenomenon X has to do with musicality.

- As already mentioned above, harmonic relationships matter both between simultaneous tones and sequential tones. The ISI distribution measured by Tramo *et al.* is quite explicitly dependent on the simultaneity of the tones: the distribution is a function only of the *current* tone or tones being perceived. An observation readily made by anyone who has played music with different types of accompaniment (including no accompaniment at all) is that very often the difference between simultaneous and sequential has only a minor effect on how the harmonic relationships between notes contribute to the musicality of the music. In many cases the harmonic relationships are already found *in the melody* (which is sequential), and playing an explicit accompaniment at most helps to emphasise those relationships.

3.4.10 Other Musical Aspect Assumptions

The Simultaneous Pitch Assumption is just one of a group of technical assumptions that derive from the Music Assumption. A brief description of some of these other assumptions is:

- **Scale Assumption:** that there is some part of the brain that responds to musical scales, and the purpose of this part of the brain is to perceive musical scales. A common follow-on conclusion is that scales exist so that the brain can *categorise* pitch values, similarly to how it categorises other continuums into discrete values, as happens with vowel sounds and colours. For example, see "Intervals, Scales and Tuning" (Edward Burns, *Psych. Music*).

- **Regular Beat Assumption:** that the occurrence of regular beat in music relates to the importance of regular beats from some other source or sources. One popular candidate for this is the human heart, either the person's own heart, or their mother's heart which they heard before they were born. In either case it is not clear why hearing a regular beat under particular circumstances should result in the development of our appreciation of the complex rhythms of music. Nor is it clear why there should be a major perceptual system devoted to listening to heart beats: the infant in the womb cannot do much in response to its mother's heart beats, and even when we do hear our own hearts beating, we do not normally act on the information in any significant way. Our bodies have other ways of providing and processing information relevant to the functioning of the heart (like wanting to rest when we get tired from doing too much exercise).

- **Hierarchical Segmentation Assumption:** I originally made this assumption myself, that, to understand music, we must understand how the brain processes hierarchically organised data, because music has a hierarchical structure. In particular musical time has a hierarchical structure.

  Musical time is hierarchical in the sense that a tune consists of bars, which—assuming for instance typical 4/4 time—sub-divide into half bars and then into counts and then half counts and finally quarter counts. Often the hierarchy of grouping also proceeds in the opposite direction: bars are grouped into groups of bars and even into groups of groups, in a way that matches the phrasal structure of the melody. A natural mathematical representation of this hierarchical division is a discrete N-dimensional space, where N is the number of hierarchical levels. Unfortunately, cortical maps in the brain are only 2-dimensional (with the 3rd physical dimension being too small to represent information values), so there is no "natural" way to represent this N-dimensional space in the brain.

> When I developed a full understanding of the **regular beat cortical map** (see Chapter 10) and how it processes information about rhythm and tempo, I found that the hierarchical nature of musical time is a consequence of the constraint that musical rhythm should contain multiple regular beats, so there is no need to make specific assumptions about the existence and perception of hierarchy just to explain this feature of musical time.
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> The regular beat cortical map may not account for musical hierarchy that exists on a time scale greater than bar lengths, and large scale hierarchy may result from constraints determined by other aspects of musicality. One such aspect is repetition: components of music within an observable hierarchy are often repetitions or partial repetitions of previous components of the same music.
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> *A Generative Theory of Tonal Music* by Fred Lerdahl and Ray Jackendoff (MIT Press 1983) describes a formal system for analysing music into strict hierarchies.

3.5 Questions That Have to be Answered

Perhaps the biggest problem with most theories of music is that they fail to confront *all* the questions that can be asked about music.

There are many things that we know about music—most of these become obvious to anyone who learns to perform music. A complete theory of music must explain all of these things that we know about music, not just some of them. The theory must explain why music is what it is, and why it isn't what it isn't.

One point of view is that many aspects of music are culturally determined, and for any such aspect one can specify "culture" as being the reason for that aspect's existence. A corollary of this view is that only those features observed across all or most cultures need to be explained.

I have already discussed this issue in the previous chapter, in the section on Universality. In developing my own theory of music I have decided to take what might be called the strong approach, and I assume that in the first instance a theory of music should be capable of explaining all observed features of music, whether or not those features are found across all cultures, as long as it can be established that the features contribute substantially to the musicality of music for a substantial number of listeners. This implies that you cannot dismiss a feature of music from the scope of a general theory just because there are some listeners who do not respond to that feature or to music containing that feature.

Even if we don't accept this strong approach, and instead settle for a weaker approach of only requiring explanation for those features that are universal, or at least found across a large proportion of all musical cultures, there are still many questions that need to be answered.

The questions in this first list relate to universal or near universal aspects of music:

- What selective pressures have resulted in the human capacity to respond to music?
- Why do melodies consist of notes with constant pitch values taken from scales, where a scale consists of a finite set of possible pitch values?
- Why are notes sometimes “bent” (breaking the rule about constant pitch values stated in the previous question)?
- Why do scales usually repeat every octave?
- Why are notes separated by multiples of an octave perceived as having a similar quality? (And this is not true for other consonant intervals.)
- Why do scales usually contain 5 to 7 notes per octave?
- Why are scales usually uneven?
- Why does melody mostly go up and down the scale one step at a time?
- Why is the musical quality of music invariant under transposition into a different key?
- Why do consonant intervals play such an important role in music?
- Why is musical beat usually completely regular?
- Why is musical beat sometimes *not* completely regular (e.g. irregular bar lengths found even in popular music, and polyrhythm found in some types of non-Western music)?
- Why is musical time consistently divided up into intervals by factors of 2 (mostly) or 3 (sometimes)?
- How are we able to recognise the same rhythm played at different tempos?
- Why does music have an emotional effect? Why does it sometimes cause goosebumps or shivers down the spine?
- Why do we enjoy music?
- Why do we like some music more than we like other music?
- Which parts of the brain respond to music, and do different parts respond to different aspects of music?

- Do the parts of the brain that respond to music serve some other purpose, or have they been specifically recruited as a result of exposure to music?

The next list consists of questions that relate more specifically to popular forms of Western music, but I would still expect a complete theory of music to answer them:

- Why does the well-tempered diatonic scale work as well as it does?
- Why do chords change mostly at the beginning of a bar?
- Why do the more strongly emphasised notes in the melody usually correspond to notes in the current chord?
- Why are there home chords, and why are they almost always either C major or A minor (on the white notes scale)?
- Why is the final home chord often preceded by a dominant 7th chord, i.e. G7 precedes a final C major, or E7 precedes a final A minor?
- Why is there a bass line which generally starts with the root note of the chord when there is a new chord?
- What determines the minimum number of chords found in popular tunes: very rarely less than 3, and usually at least 4?
- Why are syncopated melodies so common in modern popular music?
- Why do listeners prefer music containing singing?
- Why do song lyrics almost always rhyme (although sometimes the rhymes are weak)?
- Why do melodies contain repeated components, or components that repeat some but not all aspects of the music (e.g. rhythm only)?
- Why do certain instrumental timbres work better with certain genres of music? (A good example of this is the over-driven electric guitar, which appears to be entirely responsible for the previously unknown genre of heavy metal, elements of which are contained in much of modern popular music.)
- Why do we like to watch groups of people dancing synchronously in time to music (but not the synchronous motion of anything else)?
- What are the constraints, as yet undetermined, which make it non-trivial to compose original commercial quality music, even if one knows all the “rules” of musical composition?

(Some of these questions contain technical musical terms that some readers may not be familiar with. These will be explained as necessary in the next chapter on “Sound and Music”.)

3.6 Approaches to Studying Music

When no one has any idea what the answer is, there aren't any rules about what is the correct way to attack the question, and as a consequence there are many different approaches that music scientists (and philosophers and theorists) have taken in their efforts to solve the basic mystery of music.

Here is a list of research and analysis methods that I am aware of:

- Cognitive and perceptual experimentation that attempts to discern the processes involved in music perception and related types of perception including language cognition. This experimentation may be combined with the use of brain imaging techniques that measure the intensity and location of neural activity in the brain while a subject performs certain cognitive tasks.

- Comparison of human music to various kinds of animal "song".

- Comparison of music to language.

- Studying the development of musical competence in the growing child. (At a given point in time, some aspects of music perception may be well developed and others may not be—so studying development can help to analyse music perception into its components.)

- Studying the archaeology of music, in particular fossil musical instruments such as the Divje bone flute.

- Formulation of hypotheses about how music contributes to reproductive success.

- Analysis of individual musical items, attempting to explain the subjective effects of the music being analysed. Most such analysis is done within the discipline of traditional music theory, which unfortunately tends to be somewhat unscientific: the "theories" are not formulated as proper scientific theories, and the theorists do not treat the study of music as a sub-discipline of biology.

- Statistical analysis of either individual items (small or large) or of collections of different musical items.

  Hit Song Science (*http://www.hitsongscience.com/*) is a commercial service that claims to be able to distinguish hits from non-hits based on a statistical analysis of a large historical database of hit music.

- Mathematical modelling of music perception. Many such models are based on neural networks (which are in effect mathematical models of networks of neurons in the brain). For example, in "Tonal Cognition" (*Cog. Neuro. Music*), Carol Krumhansl and Petri Toiviainen describe a neural network model that perceives key changes.

- General philosophical discussions of music and any aspects of the human condition assumed to be relevant to an understanding of music—in particular human emotion. Unfortunately such philosophical discussions suffer the same problems as traditional music theoretic analysis: they are usually not very scientific.

- Investigation into the differences between the brains of musicians and non-musicians. Learning to play music well enough to make a living from it causes significant and observable changes in the brain. For example, see *Cog. Neuro. Music*, “The Brain of Musicians” (Gottfried Schlaug), “Representation Cortex in Musicians” (Christo Pantev, A. Engelien, V. Candia and T. Elbert) and “The Brain that Makes Music and is Changed by it” (Alvaro Pascual-Leone).

  Of course it is likely that reorganisation of the brain occurs with many types of specialist; for example, the way that mathematics is represented in the brains of mathematicians may be different to how it is represented in the brains of non-mathematicians. And the representation of information about driving in a racing car driver’s brain may be different to the representation of the same information in the brain of an ordinary driver. Thus the reorganisation of cortical maps in the brains of musicians is interesting, but it may tell us more about the consequences of becoming a specialist in something than it tells us about what music is.