Concept of Major and Minor Grooves in the DNA

Both the grooves are structural properties of the DNA and are formed by uneven intrinsic base pairing. The helical twist in the DNA provides structure, depth and width to both the grooves.

Both these grooves though arising from action of similar forces, are different in their properties especially structural properties which leads to unique features for each groove.

<u>Differences between DNA major & minor grooves:</u>

- Major groove is large in size, wider & deeper than minor groove which is smaller in size.
- Width of major groove is 22-26Å & in minor groove it is 12-15Å.
- Depth of major groove is 11Å and that of minor groove is 6Å.

A Comparative account of the major & minor grooves in different types of DNA is given below:

A form DNA:	**DNA major groove**	**DNA minor groove**
Size	14 to 15Å	7 to 8Å
Width	6 to 8Å	10 to 12Å
Depth	4 to 5Å	2 to 3Å
B form DNA:	**DNA major groove**	**DNA minor groove**
Size	22 to 26Å	12 to 15Å
Width	12 to 14Å	5 to 6Å
depth	11Å	6 to 7Å
Z form DNA:	**DNA major groove**	**DNA minor groove**
Size	9 to 10Å	3 to 4Å
Width	4 to 5Å	13 to 14Å
depth	7 to 8Å	1 to 2Å

From the above data, we can conclude that B-form of DNA has most distinctive major & minor grooves.

The major groove covers 10-12 bases per helix turn while minor groove covers 5-6 bases per helix turn. When taken together with the data regarding size, width & depth of the grooves, it becomes very clear that major groove is more accessible to various proteins & performs many important functions for DNA. Experimentally, it has been proven that major groove is more specific and gene rich while minor groove is relatively simple.

<u>Detailed discussion:</u>

Formation of major and minor groove is due to geometry of base pair. The angle between glycosidic bonds is 120^{o} for narrow angle and 240^{o} for the wide angle, so as the as the base pairs stack upon each other the narrow angle between the sugars on one edge generates minor groove while large angle generates the major groove.

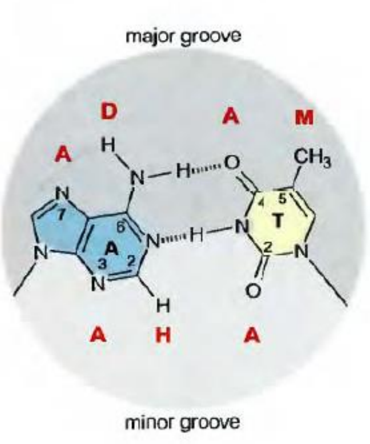
If sugars are pointed in a straight line i.e. at 180° from each other then the grooves will have equal dimensions and there will be no major and minor grooves.

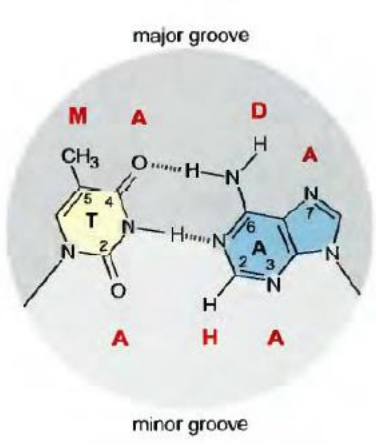
Richness of major groove in chemical information:

The edges of each base pair in grooves create a pattern of hydrogen bond donors and acceptors and of van der Waals surfaces that identify the base pair.

The edge of an A:T base pair in major groove displays chemical groups in the following order:

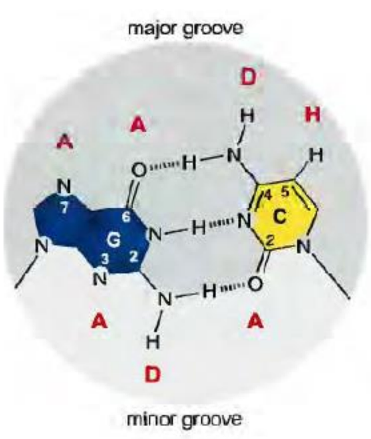
- N7 of adenine as H-bond acceptor.
- Exocyclic amino group on the C6 of the adenine as hydrogen bond donor.
- Carbonyl group on C4 of thymine as hydrogen bond acceptor.
- Methyl group on C5 of the thymine as bulky hydrophobic surface.

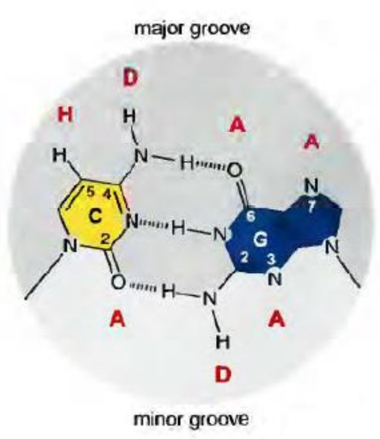




The edge of a G:C base pair in major groove displays chemical groups in the following order:

- N7 of guanine as hydrogen bond acceptor.
- Carbonyl on C6 of the guanine as hydrogen bond acceptor.
- Exocyclic amino group on C4 of the cytosine as hydrogen bond donor.
- Hydrogen at C5 of the cytosine as small nonpolar hydrogen.





Thus, we see characteristic patterns of the H-bonding and of overall shape that are exposed in the major groove and they can distinguish an A:T base pair from G:C base pair and also an A:T from T:A base pair and G:C from C:G base pair.

If we think of these features are as a code in which A is hydrogen bond acceptor, D is hydrogen bond donor, M is a methyl group and H is a nonpolar hydrogen then ADAM in major groove signals A:T base pair and AADH signals G:C base pair. Similarly, MADA signals T:A base pair and HDAA signals C:G base pair.

Thus, codes can specify the exact base pair in the major groove. This helps the proteins to specifically recognize the DNA sequences without opening & disrupting the double helix.

In contrast, the minor groove is not as rich in chemical information and available information is not sufficient for clear distinction between different base pairs. This can be understood from the discussion of groups given below:

An A:T base pairs displays following groups in the minor groove:

- N3 of adenine as hydrogen bond acceptor.
- Nonpolar hydrogen at N2 of adenine.
- Hydrogen bond acceptor at carbonyl on C2 of thymine.

Thus, the code is AHA but this code is same in both the directions and can`t differentiate between A:T and T:A base pairs.

A G:C base pair displays following groups in the minor groove:

- Hydrogen bond acceptor at N3 of guanine.
- Hydrogen bond donor in exocyclic amino group on C2 of guanine.
- Hydrogen bond acceptor on the C2 carbonyl of cytosine.

Thus, the code is ADA but this code is same in both the directions and can`t differentiate between G:C and C:G base pairs. However, at minor groove A:T and T:A base pairs can be distinguished from G:C and C:G base pairs as their codes are different.

DNA major vs minor Groove

DNA major groove	DNA minor groove
Larger, deeper, and wider	Smaller, shallow and short.
Allow wide-range of proteins involved in replication, transcription and translation.	Allow only specific proteins to interact with DNA.
Covers 10 to 12 bases per helix turn.	Cover 5 to 6 bases per helix turn.
The width of the major groove is ~22 to 26Å	The width of the minor groove is ~12 to15Å
The depth of the major groove is ~11Å	The depth of the minor groove is ~6Å
Common proteins that interact with the major groove DNA are restriction enzymes, transcriptional factors, zinc-finger proteins and homeodomain proteins etc.	Common proteins that interact with the minor groove DNA are helix motif proteins, basic, leucine zipper proteins and smaller peptides.
A good target for gene therapy.	A good target for drugs.