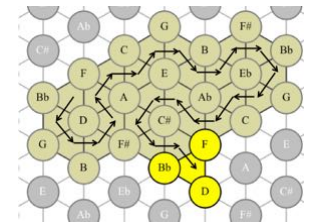


Modèles mathématiques et computationnels dans la chanson

Analyse de la musique et des répertoire III :
Musiques actuelles
(partie II : la représentation circulaire)



Moreno Andreatta

Equipe Représentations Musicales

IRCAM / CNRS UMR 9912 / Sorbonne Université

IRMA & GREAM, Université de Strasbourg

Structure du cours

Cours de Moreno Andreatta sur les modèles mathématiques et computationnels dans la chanson (Analyse de la musique et des répertoire III : Musiques actuelles)

Calendrier :

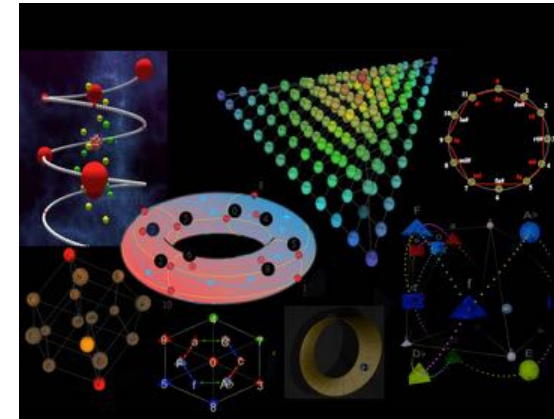
Chaque mardi, pour douze séances, à partir du 15 janvier 2019 et jusqu'au 9 avril 2019 (inclus) de 17h à 18h30 (Département de musicologie, université de Strasbourg - Le Portique, salle 18)

Page web :

<http://repmus.ircam.fr/moreno/chanson>

Quelques sujets abordés dans le cours :

- La chanson parmi les « musiques actuelles » (ou *popular music*)
- Le rapport entre la chanson et la poésie |
- La chanson d'auteur en France et en Italie
- Les tubes
- Outils théoriques pour l'analyse de la *popular music*
- Articulations musique savante / *popular music*
- Regards philosophiques et épistémologiques sur la *popular music*
- Modèles mathématiques et computationnels dans la *popular music*



De la musicologie systématique à la musicologie computationnelle

II. Systematisch.

Aufstellung der in den einzelnen Zweigen der Tonkunst zuhöchst stehenden Gesetze.

A. Erforschung und Begründung derselben in der

1. *Harmo-
nik*
(tonal od.
tonlich).
2. *Rhyth-
mik*
(temporär
oder
zeitlich).
3. *Melik*
(Cohärenz
von tonal
und tem-
porär).

B. Aesthetik der Tonkunst.

1. Vergleichung und Werthschätzung der Gesetze und deren Relation mit den apperzipirenden Subjecten behufs Feststellung der *Kriterien des musikalisch Schönen*.
2. Complex unmittelbar und mittelbar damit zusammenhängender Fragen.

C. Musikalische Pädagogik und Didaktik
(Zusammenstellung der Gesetze mit Rücksicht auf den Lehrzweck)

1. Tonlehre,
2. Harmonielehre,
3. Kontrapunkt,
4. Compositionslehre,
5. Instrumentationslehre,
6. Methoden des Unterrichtes im Gesang und Instrumentalspiel.

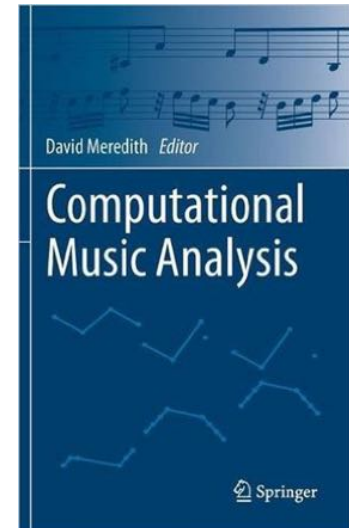
D. Musikologie (Untersuchung und Vergleichung zu ethnographischen Zwecken).

Hilfswissenschaften: Akustik und Mathematik.

Physiologie (Tonempfindungen).
Psychologie (Tonvorstellungen, Tonurtheile und Tongefühle).
Logik (das musikalische Denken).
Grammatik, Metrik und Poetik.
Pädagogik
Ästhetik etc.



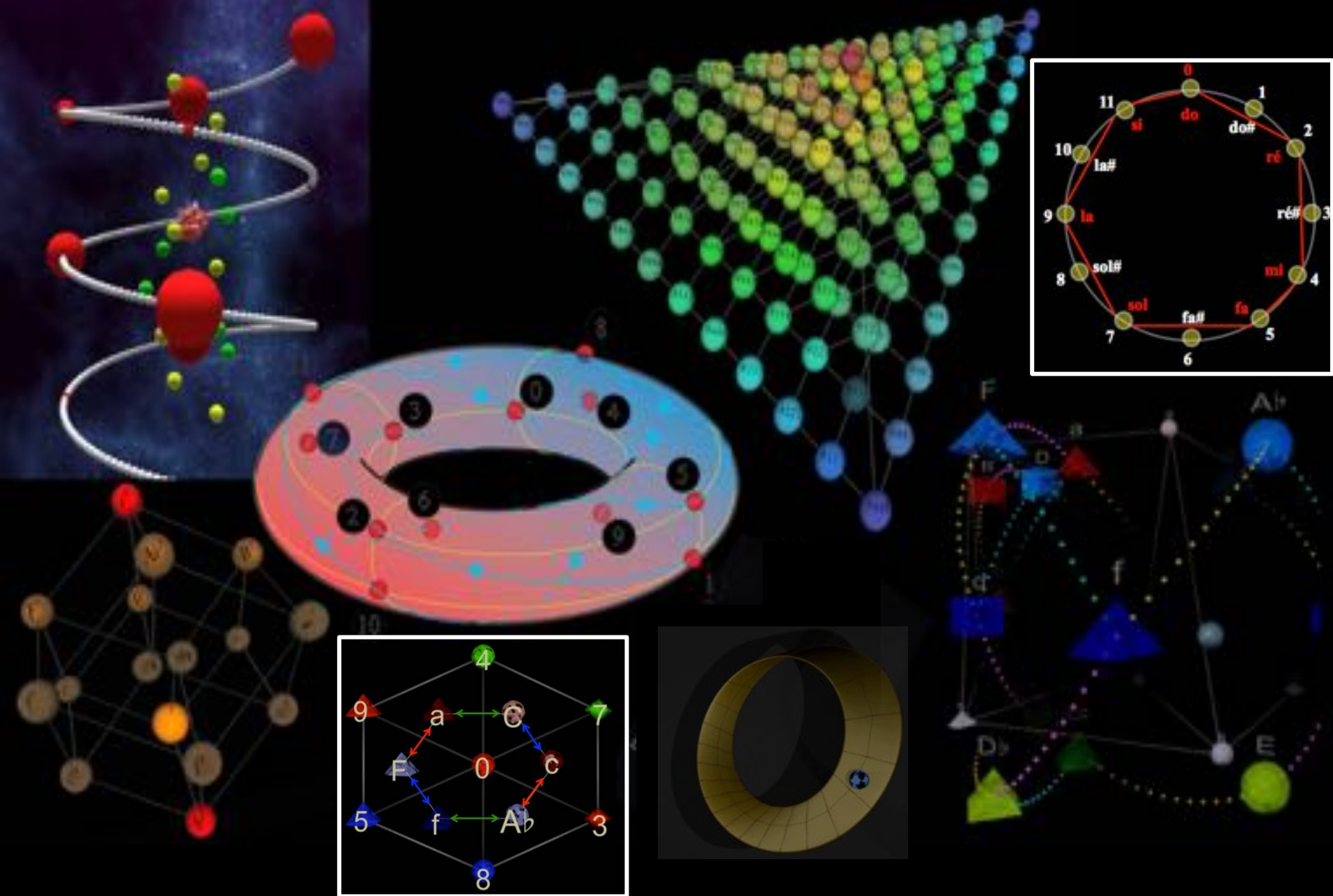
G. Adler (1855-1941)



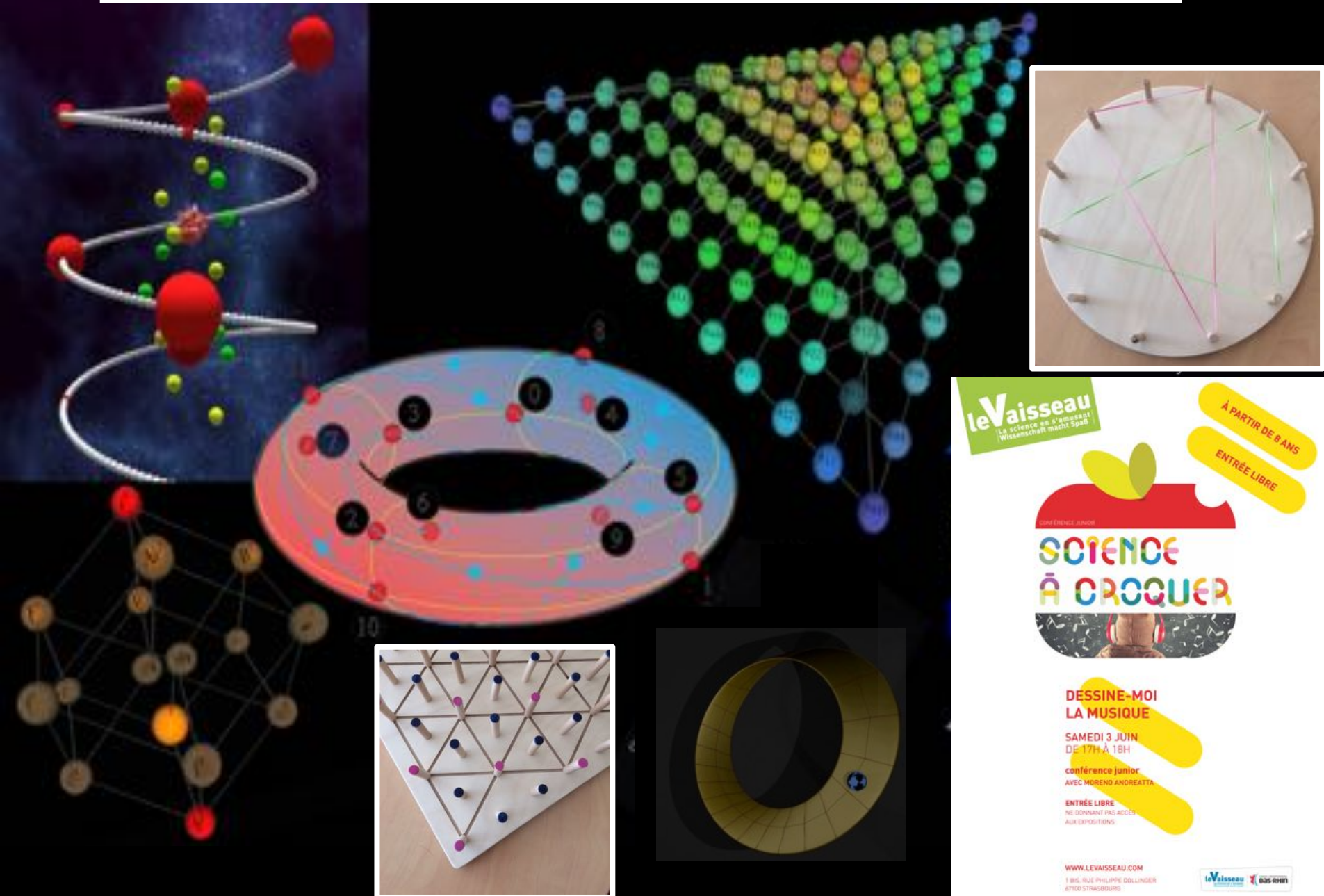
« La deuxième grande partie de la musicologie est la partie systématique; cette partie se base sur la partie historique. (...) L'accent de l'observation réside dans l'analogie de la méthode musicologique avec la méthode scientifique ».

Guido Adler : « Umfang, Methode und Ziel der Musikwissenschaft » (1885)

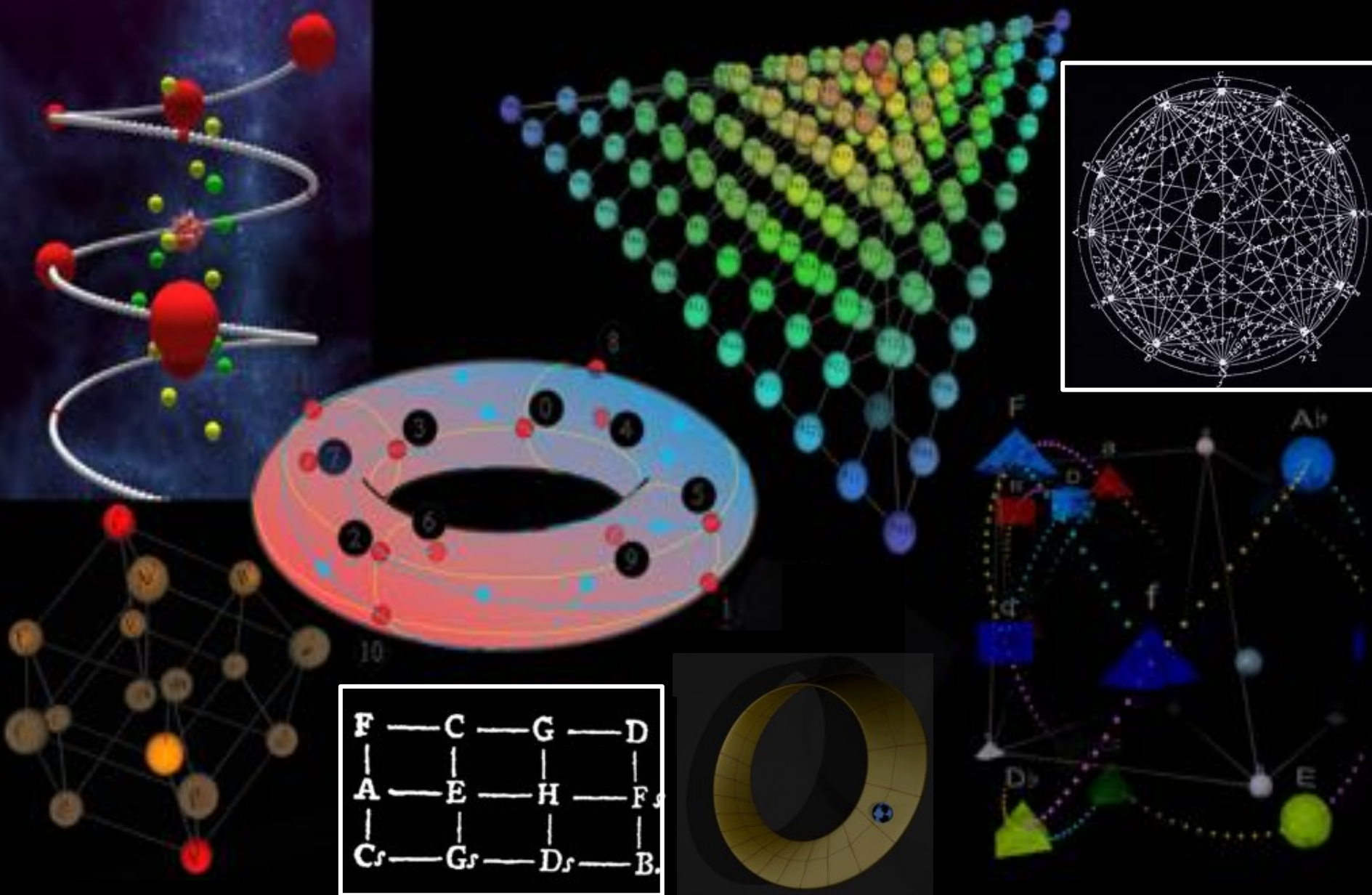
La galaxie des modèles géométriques au service de la musique



La galaxie des modèles géométriques au service de la musique



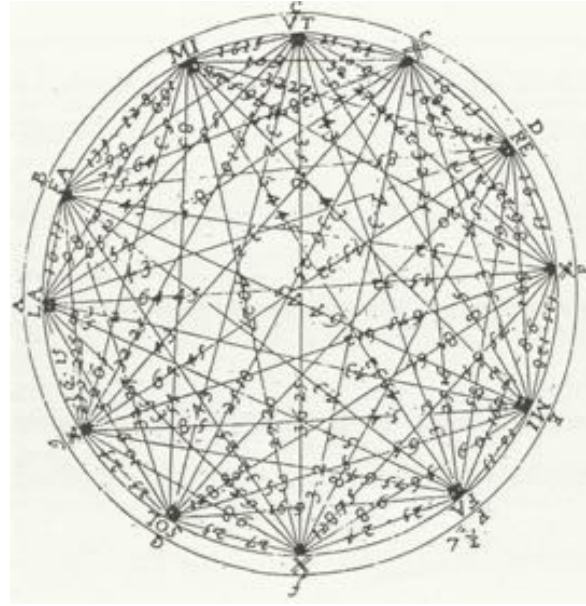
La galaxie des modèles géométriques au service de la musique



Mersenne et la naissance de la combinatoire

II 4. Marin Mersenne, *Harmonicorum Libri XII*, 1648

LIBER SEPTIMVS. DE CANTIBVS, SEV CANTILENIS, EARVMQ; NVMERO, PARTIBVS, ET SPECIEBVS.



Marin Mersenne

Tabula Combinationis ab 1 ad 22.

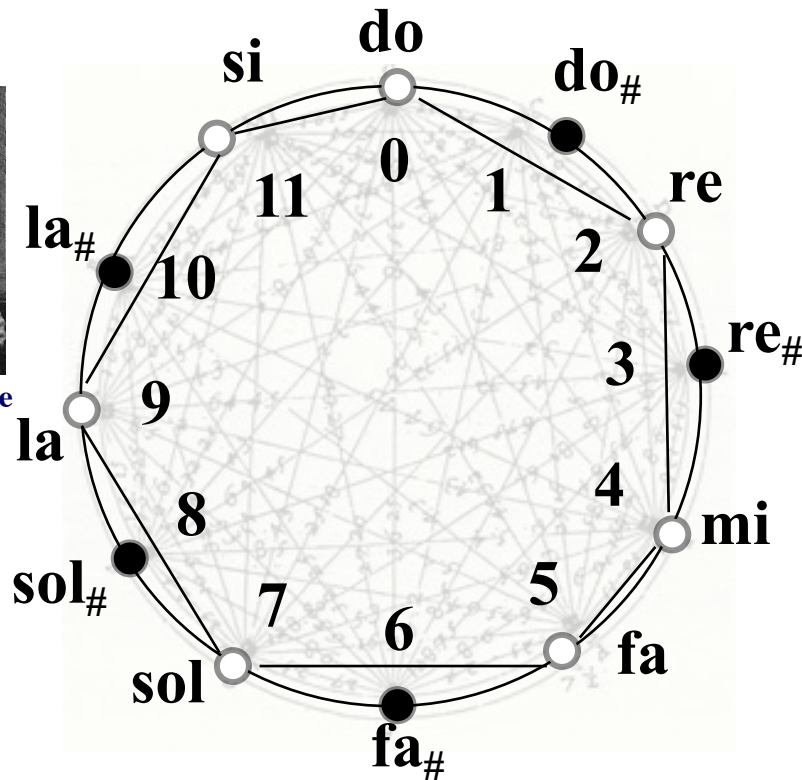
I	1
II	2
III	6
IV	24
V	110
VI	710
VII	5040
VIII	40310
IX	361880
X	3618800
XI	39916800
XII	479001600
XIII	6127016800
XIV	87178291200
XV	1307674368000
XVI	20912789888000
XVII	315687418096000
XVIII	6401373705718000
XIX	121648100408811000
XX	2431301008176640000
XXI	5090941171709440000
XXII	1114000717777607480000



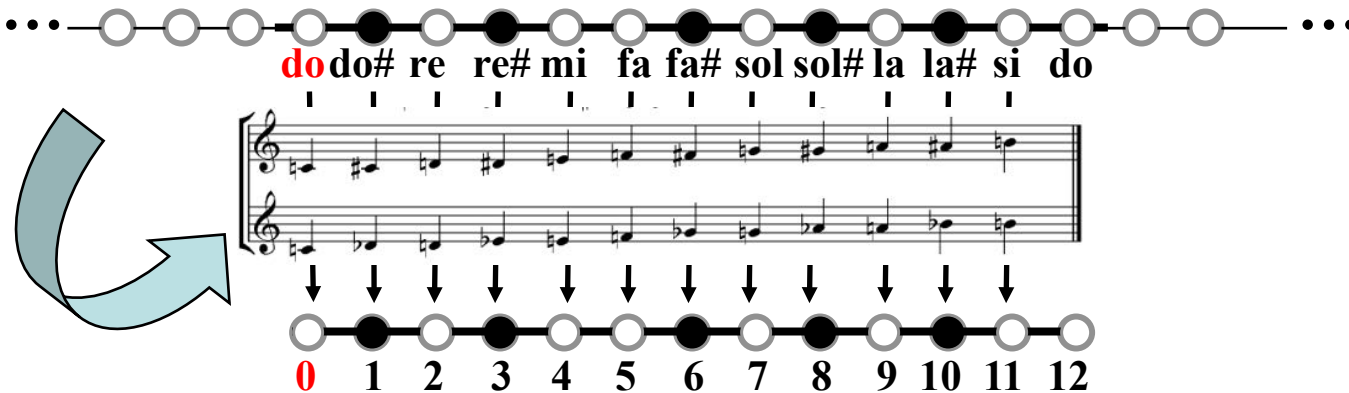
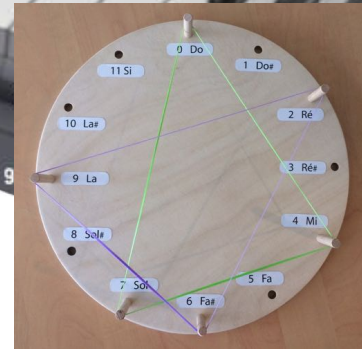
La représentation circulaire de l'espace des hauteurs



Marin Mersenne



Harmonicorum Libri XII, 1648



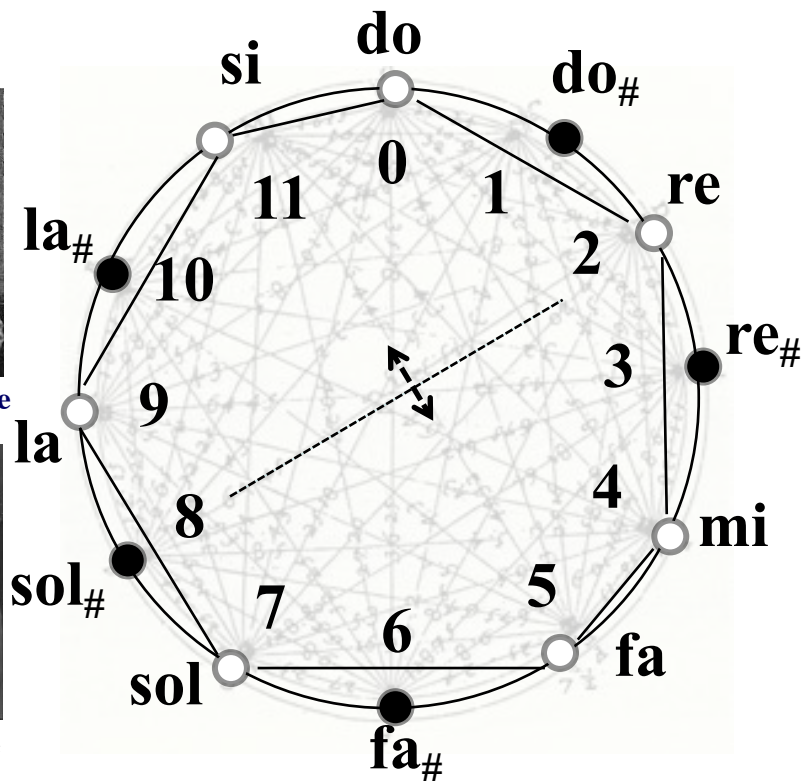
La représentation circulaire et l'idée de symétrie



Marin Mersenne



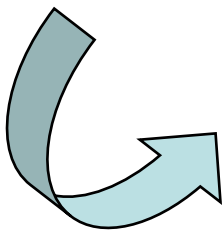
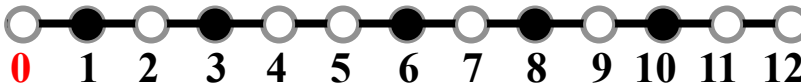
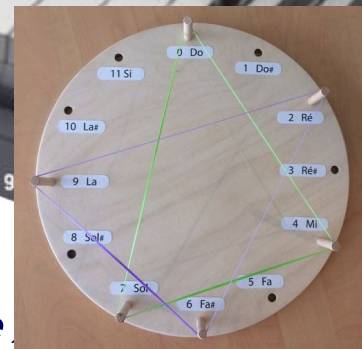
Camille Durutte



Harmonicorum Libri XII, 1648



M. Andreatta, C. Agon,
« La musique mise en algèbre »
Pour la Science, 2008



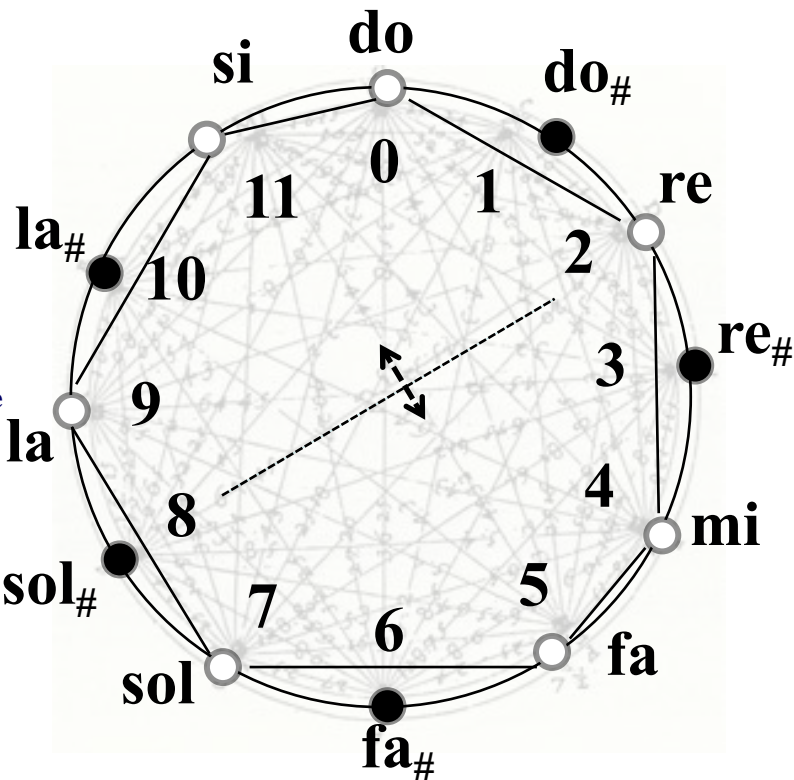
Symétrie et perception/cognition musicales



Marin Mersenne



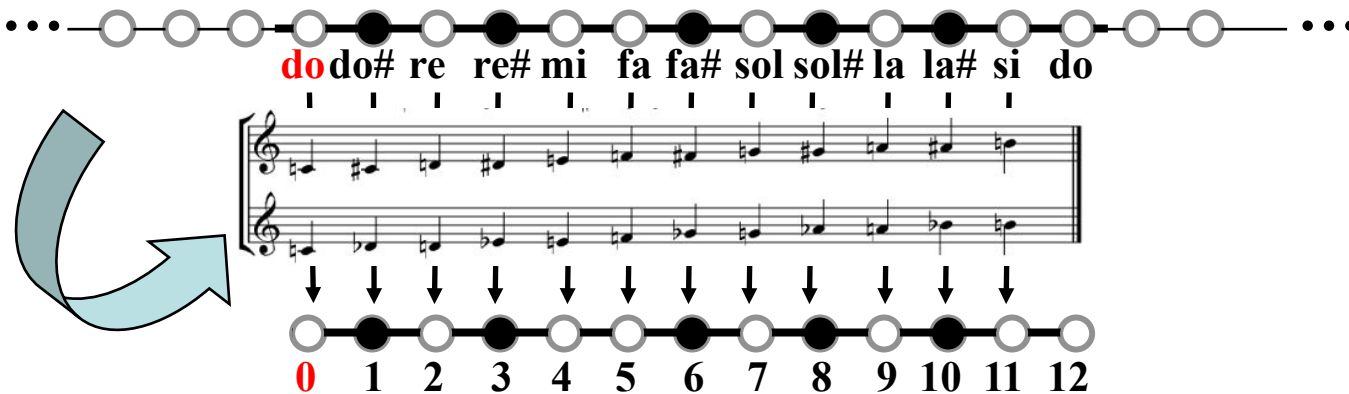
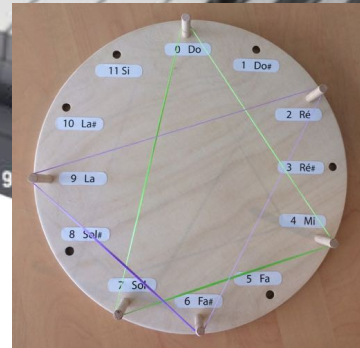
Camille Durutte



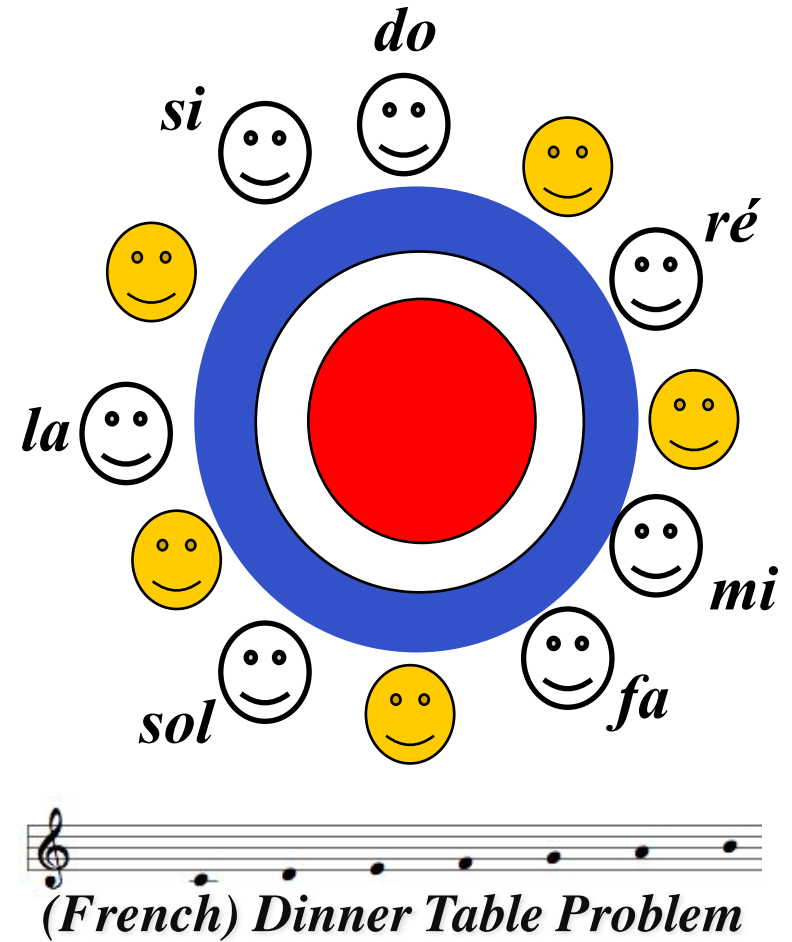
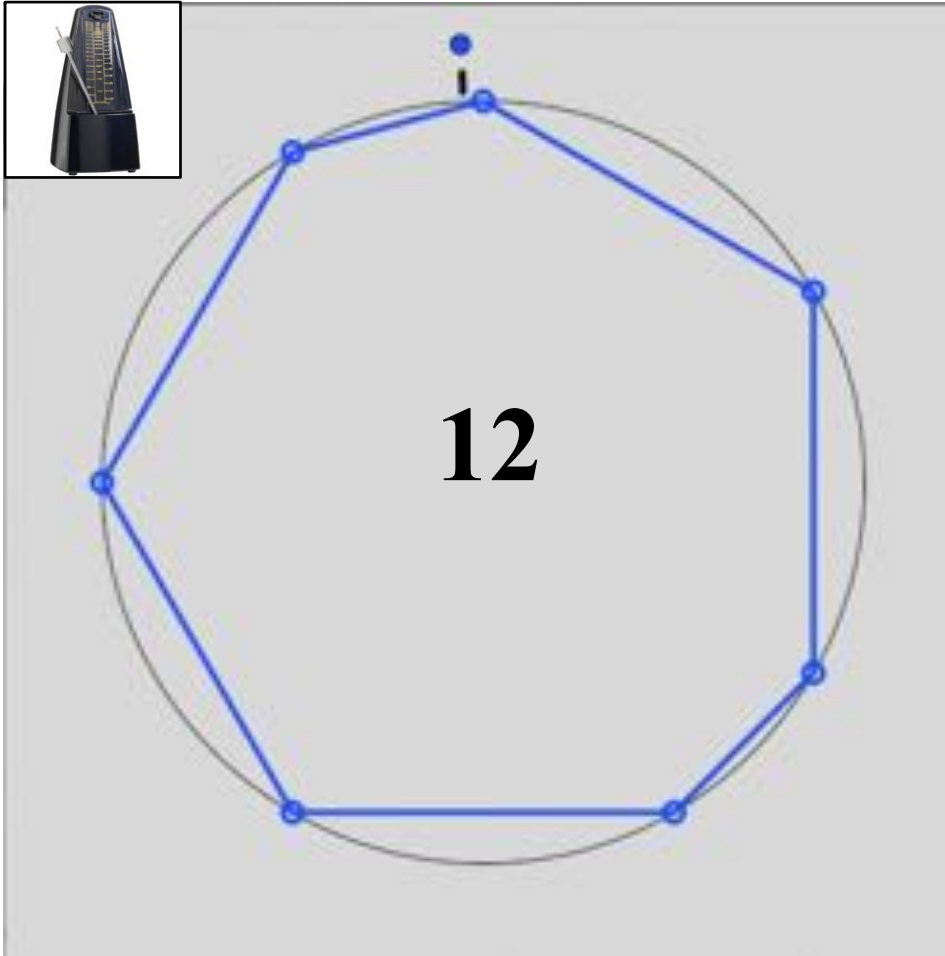
Harmonicorum Libri XII, 1648



M. Andreatta, C. Agon,
« Algèbre et géométrie :
sont-elles inscrites dans le
cerveau ? »,
Pour la Science, 2018

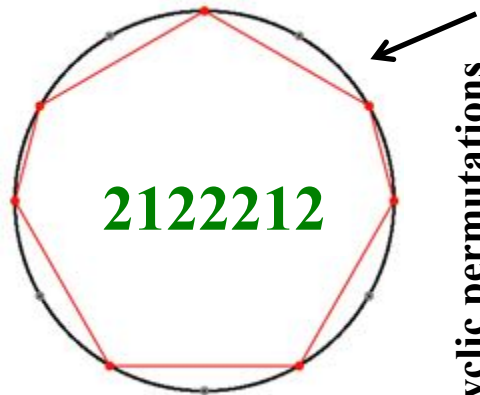
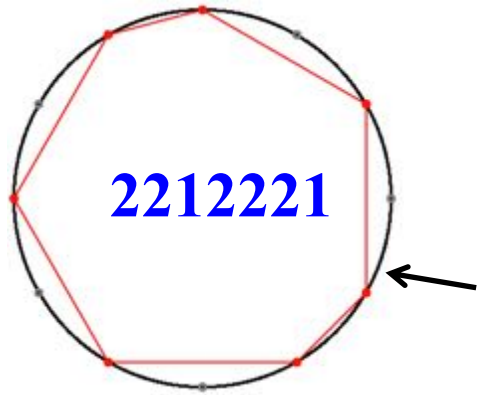


Représentation circulaire des rythmes



Abadja ou Bembé

Isomorphisme cognitif entre rythmes et hauteurs



cyclic permutations

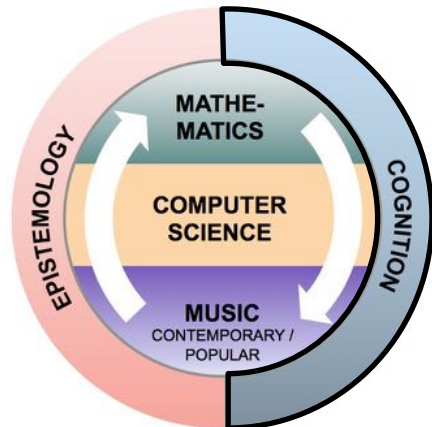


TABLE I

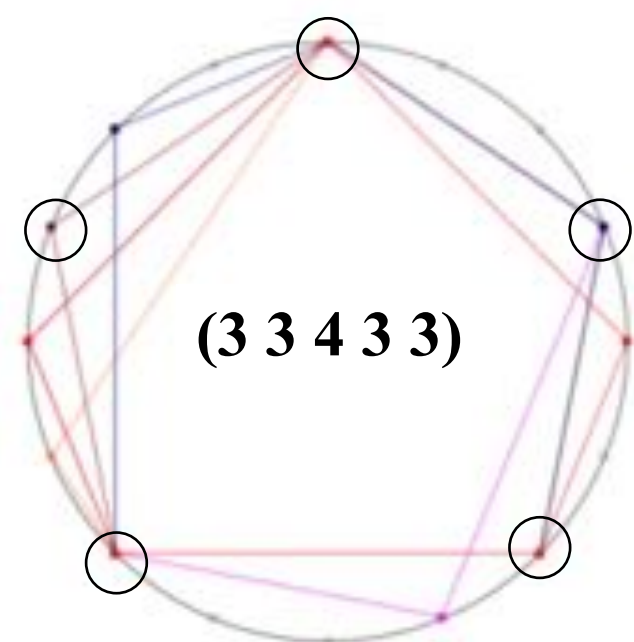
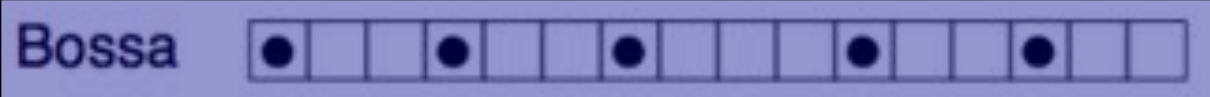
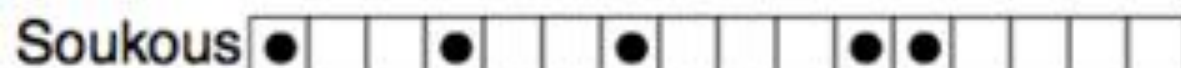
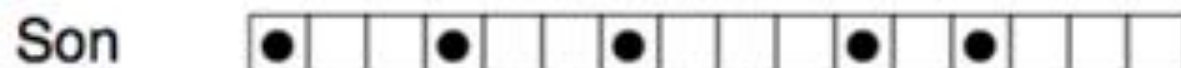
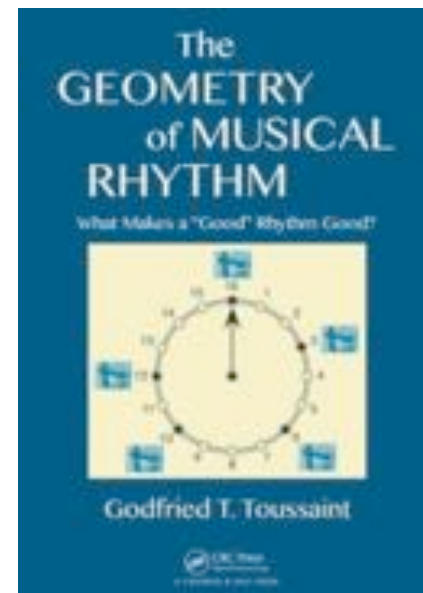
Comparison of M = 7, L = 12 patterns for pitch (scales) and rhythm (time-lines)

pattern	pitch domain name and notation (in C)	rhythm domain notation	examples from West Africa	references
1. 2212221	major scale (Ionian) CDEFGAB	♪ ♪ ♪ ♪ ♪ ♪ ♪	Ewe (Atsiabek , Sogba, Atsia) also Yoruba	Jones (1959), C. K. Ladzekpo, S. K. Ladzekpo and Pantaleoni, Locke
2. 2122212	Dorian CDE ^b FGAB ^b	♪ ♪ ♪ ♪ ♪ ♪ ♪	Bemba—Northern Rhodesia	Jones (1965), (Ekwueme)
3. 1222122	Phrygian CD ^b E ^b FGA ^b B ^b	♪ ♪ ♪ ♪ ♪ ♪ ♪	—	—
4. 2221221	Lydian CDEF [#] GAB	♪ ♪ ♪ ♪ ♪ ♪ ♪	Ga-Adangme (common) also common Haitian pattern, Akan (Ab fo)	C. K. Ladzekpo, Combs (1974), R. Hill, Asiama
5. 2212212	Mixolydian CDEFGAB ^b	♪ ♪ ♪ ♪ ♪ ♪ ♪	Yoruba sacred music from Ekiti	King
6. 2122122	Aeolian CDE ^b FGA ^b B ^b	♪ ♪ ♪ ♪ ♪ ♪ ♪	Ashanti (Ab fo , Mpre)	Koetting
7. 1221222	Locrian CD ^b E ^b FG ^b A ^b B ^b	♪ ♪ ♪ ♪ ♪ ♪ ♪	Ghana*	Nketia (1963a)
8. 2121222	(#2 Locrian) CDE ^b FG ^b A ^b B ^b	♪ ♪ ♪ ♪ ♪ ♪ ♪	Ashanti (Asedua)	C. K. Ladzekpo
9. 2112123	— CDD [#] EF [#] GA	♪ ♪ ♪ ♪ ♪ ♪ ♪	Akan (juvenile song)	Nketia (1963b)

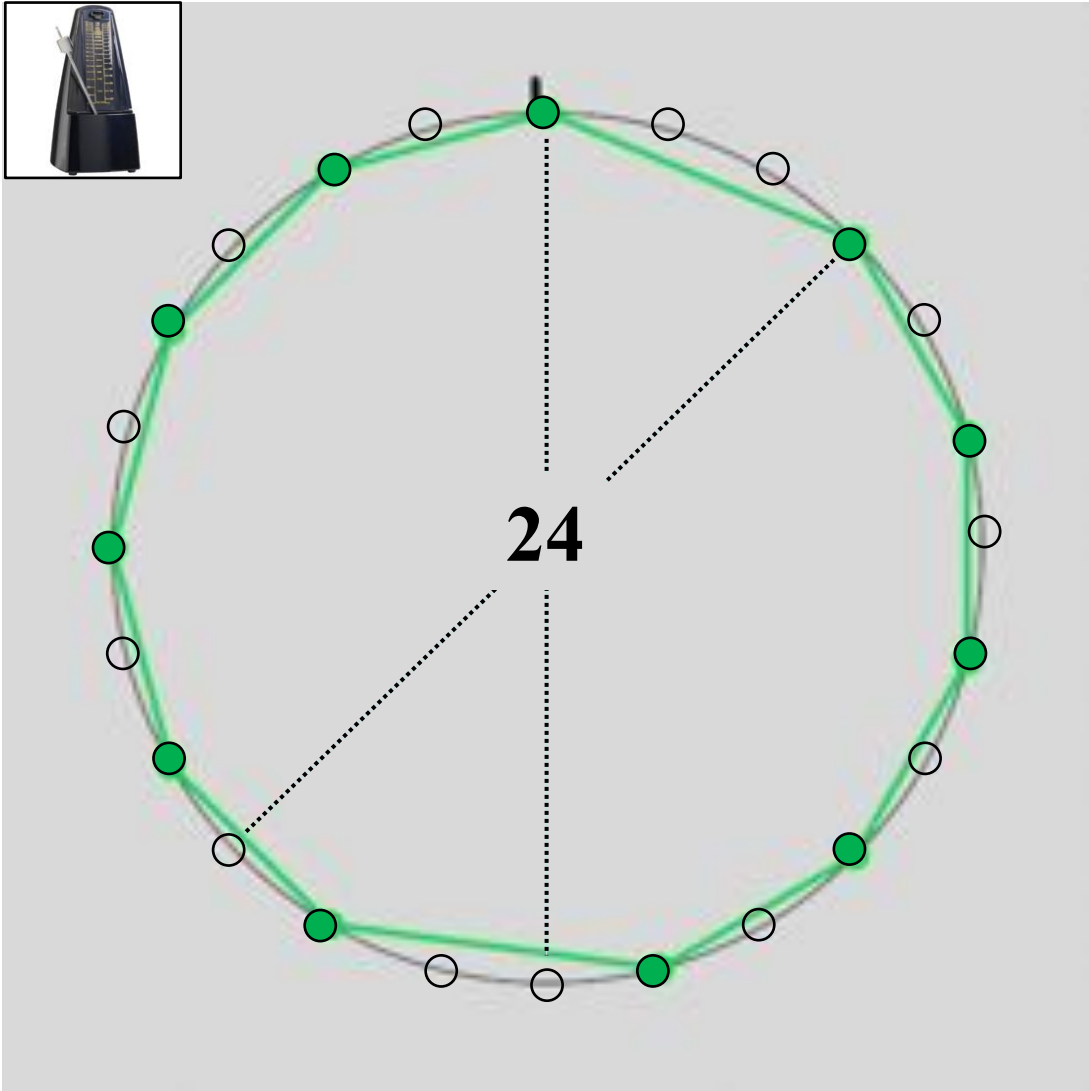
* clap pattern
† mute stroke on bell

J. Pressing, "Cognitive isomorphisms between pitch and rhythm in world musics: West Africa, the Balkans and Western tonality", *Studies in Music*, 17, p. 38-61

La géométrie des rythmes afro-cubains



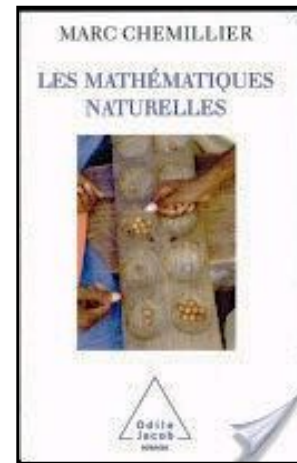
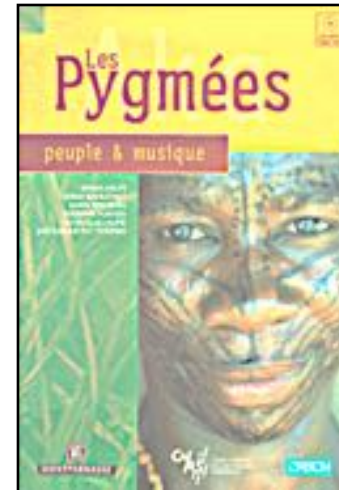
Imparité rythmique et traditions orales



Simha Arom



Marc Chemillier

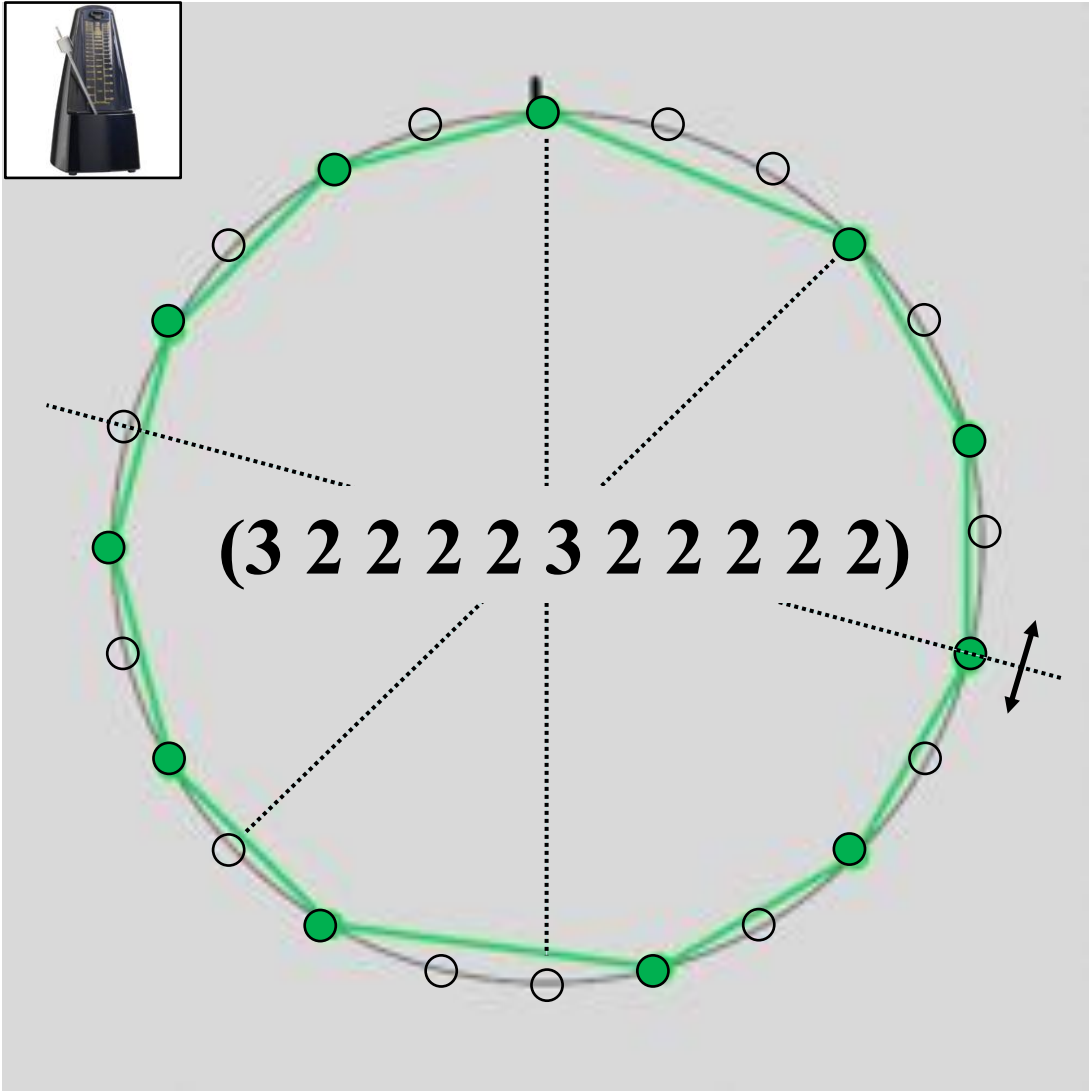


musimédiane

publiée avec le concours de la SFAM

revue audiovisuelle et multimédia d'analyse musicale

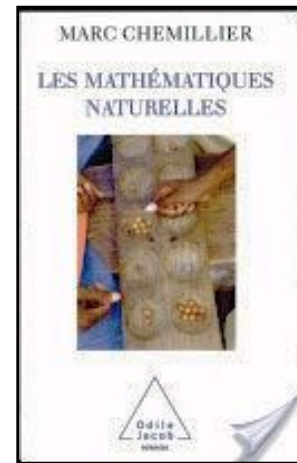
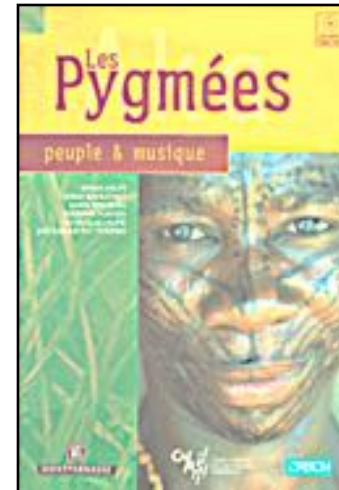
Imparité rythmique et traditions orales



Simha Arom



Marc Chemillier

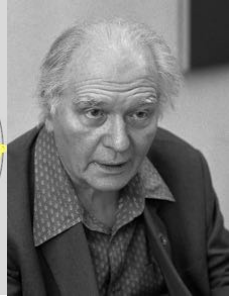
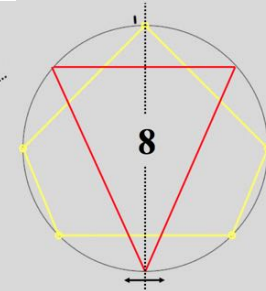
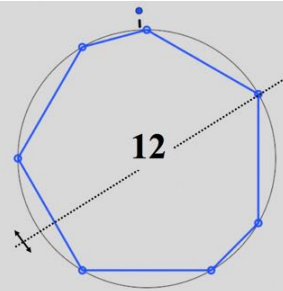
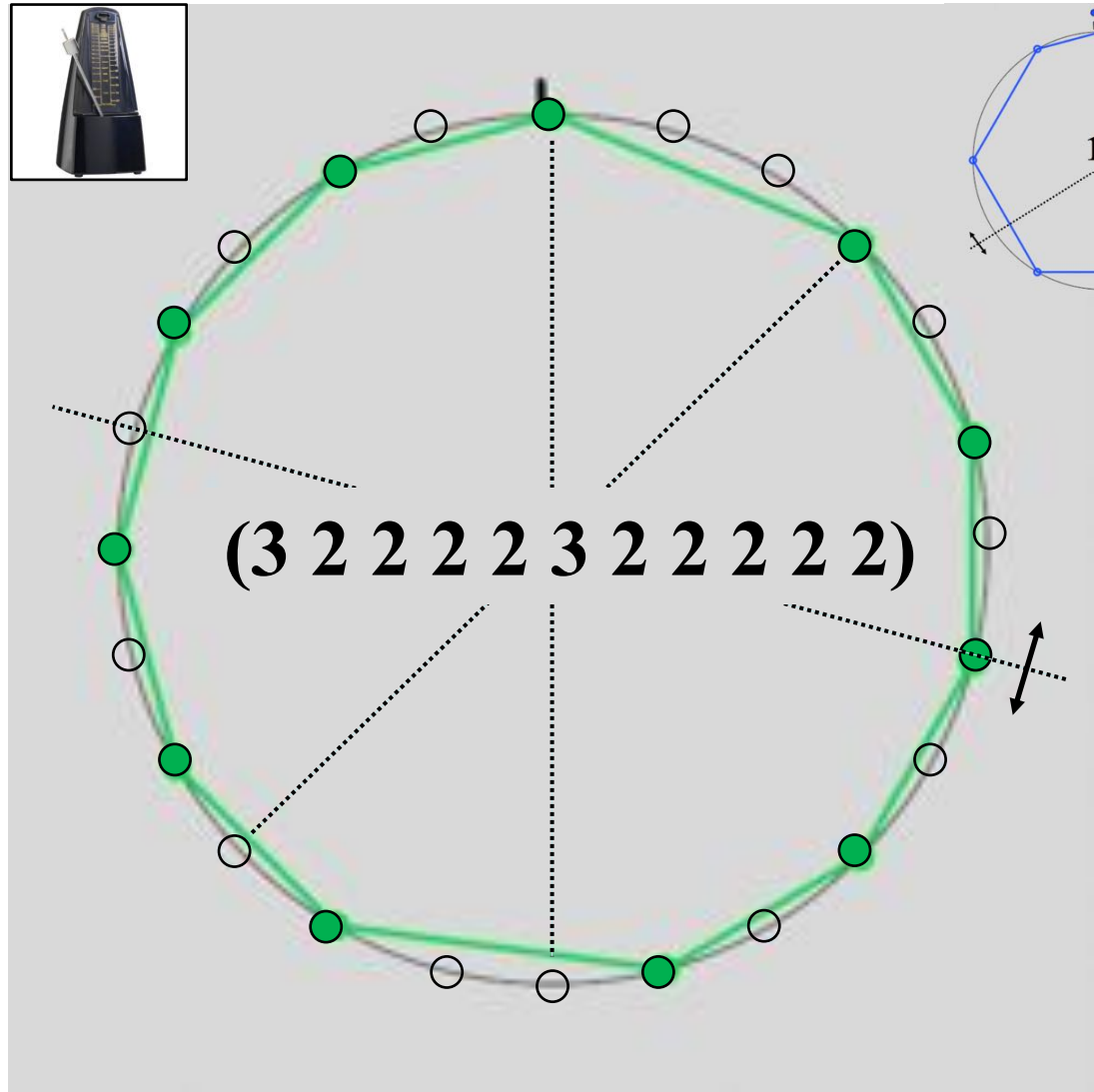


musimédiane

publiée avec le concours de la SFAM

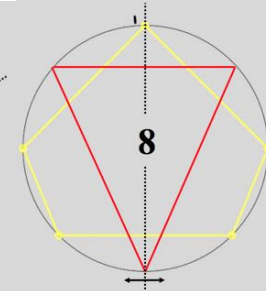
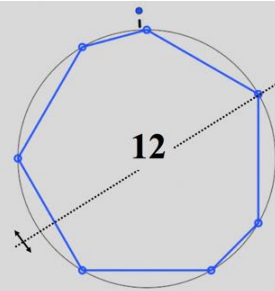
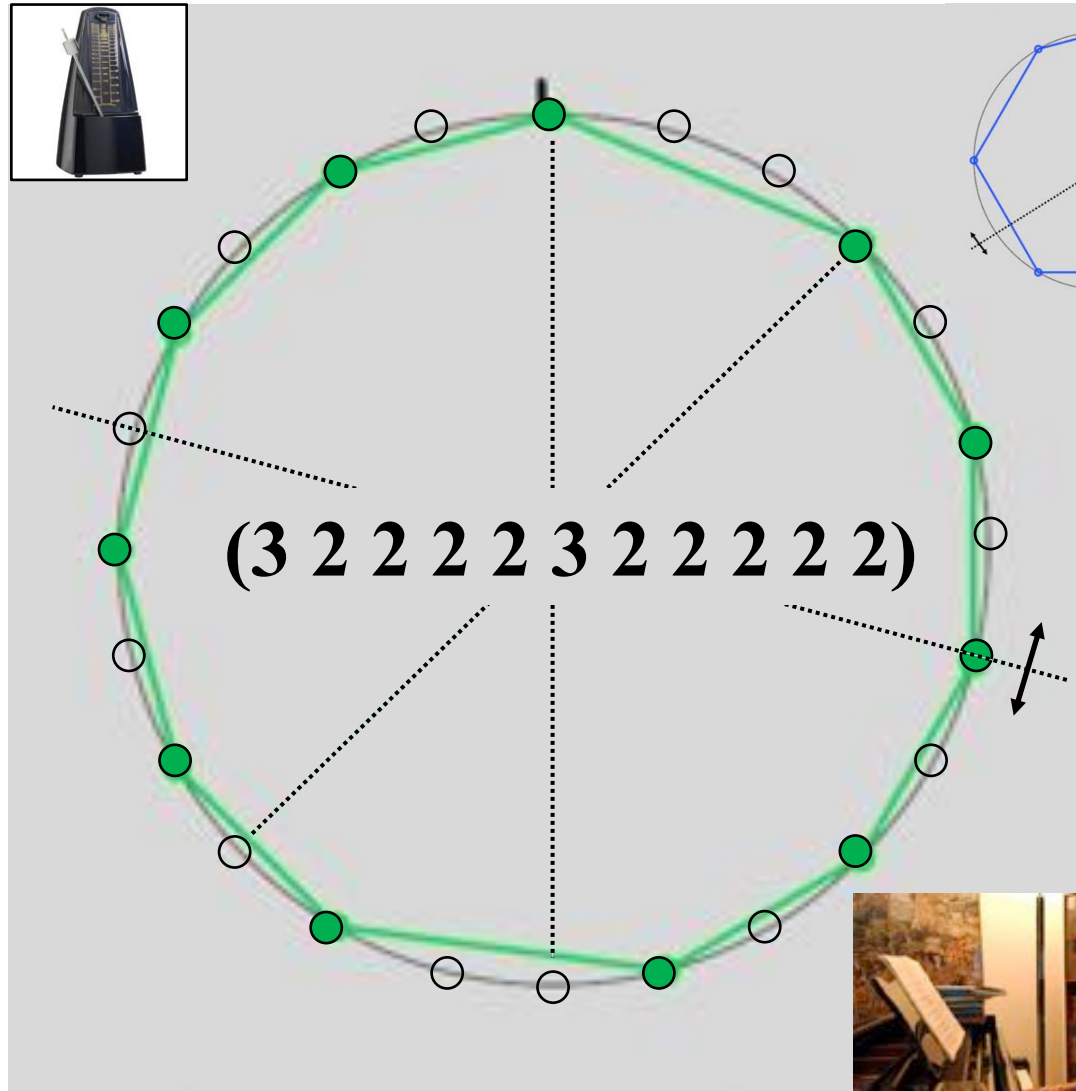
revue audiovisuelle et multimédia d'analyse musicale

Rythmes non-retrogradables d'Olivier Messiaen

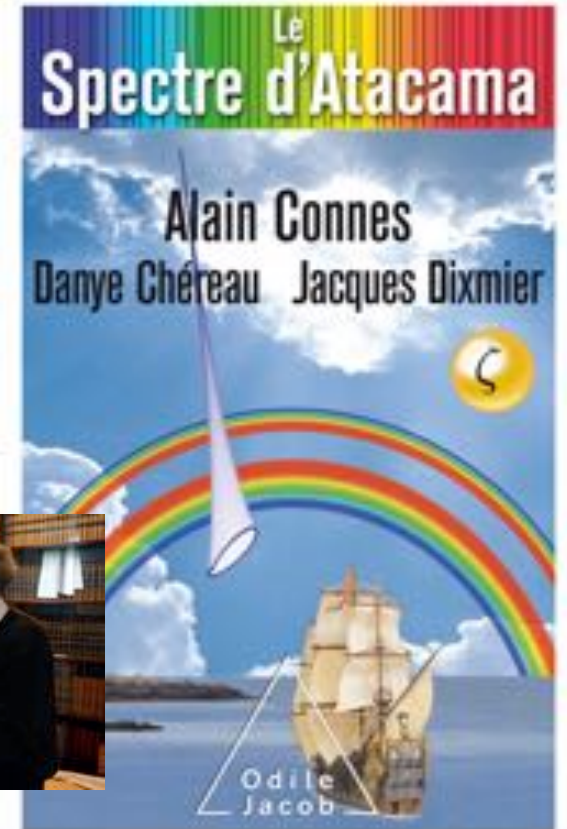


Olivier Messiaen

Rythmes non-retrogradables d'Olivier Messiaen



Olivier Messiaen



Alain Connes

Le « cercle rythmique » et ses rotations

CLAPPING MUSIC

FOR TWO PERFORMERS

J. 004-100

CLAP 1
CLAP 2

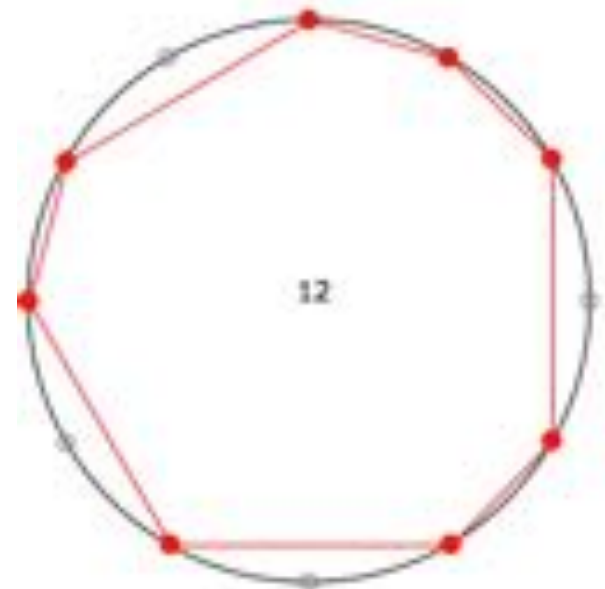
Repeat back to 1, then end

The performers begin and end with both performers in unison at bar ①. The number of repeats of each bar should be fixed at twelve repeats per bar. Since the first performer part does not change, it is up to the second performer to ease from one bar to the next. The second performer should try to keep his or her clapping where it is written, i.e. on the first beat of each measure (not on the first beat of the group of three claps), so that his clapping always falls on a new beat of his or her unchanging pattern.

The choice of a particular clapping sound, i.e. with cupped or flat hands is left up to the performers, whichever sound is chosen, both performers should try to get the same one so that their two parts will blend to produce one overall exciting pattern.

Clapping Music de Steve Reich (1972)

Steve Reich 1972
12 repeats 1972



Le « cercle rythmique » et ses rotations

CLAPPING MUSIC

FOR TWO PERFORMERS

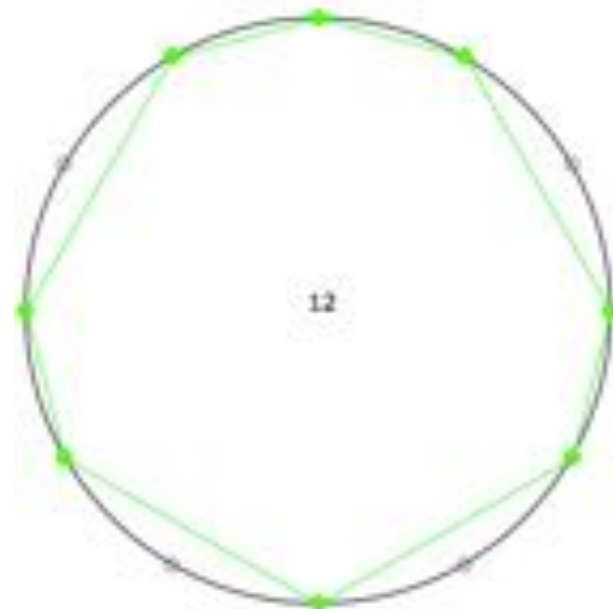
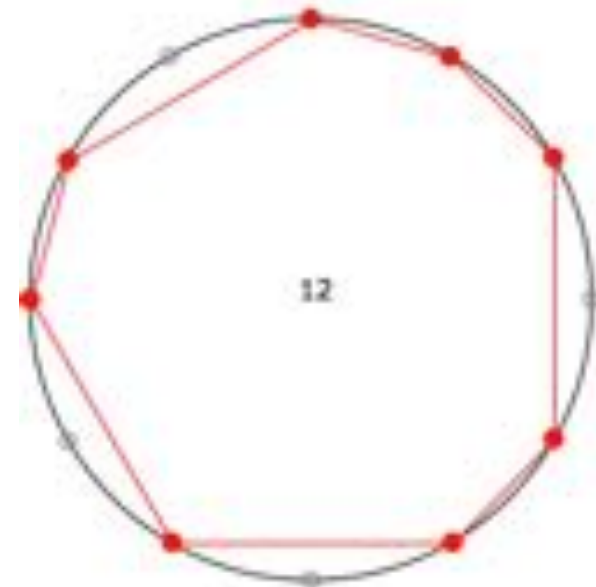
CLAP 1
CLAP 2

J. 044-168

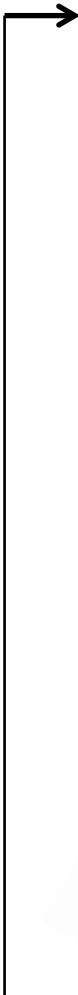
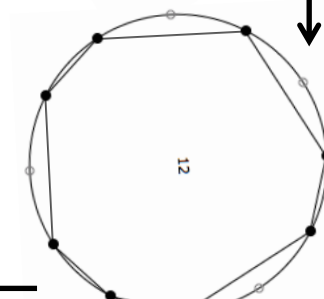
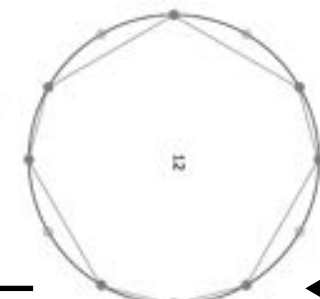
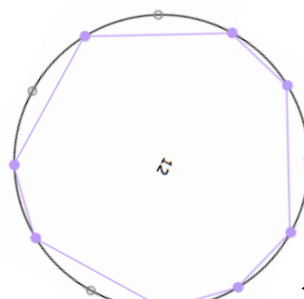
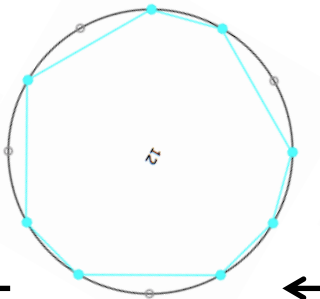
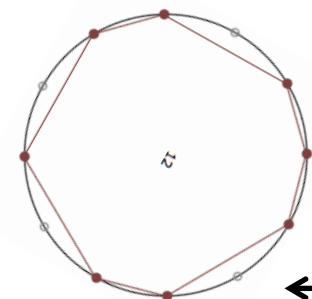
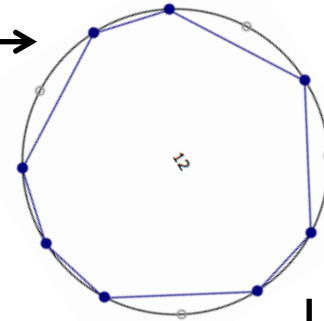
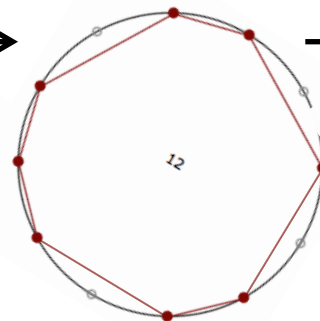
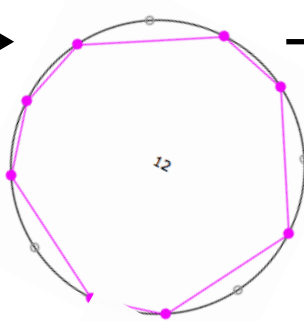
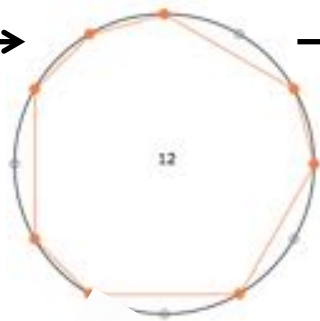
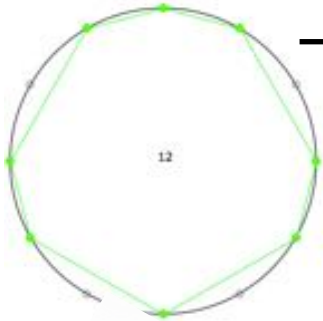
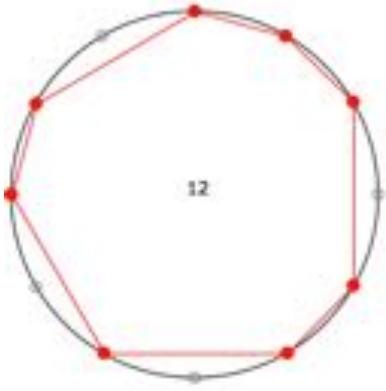
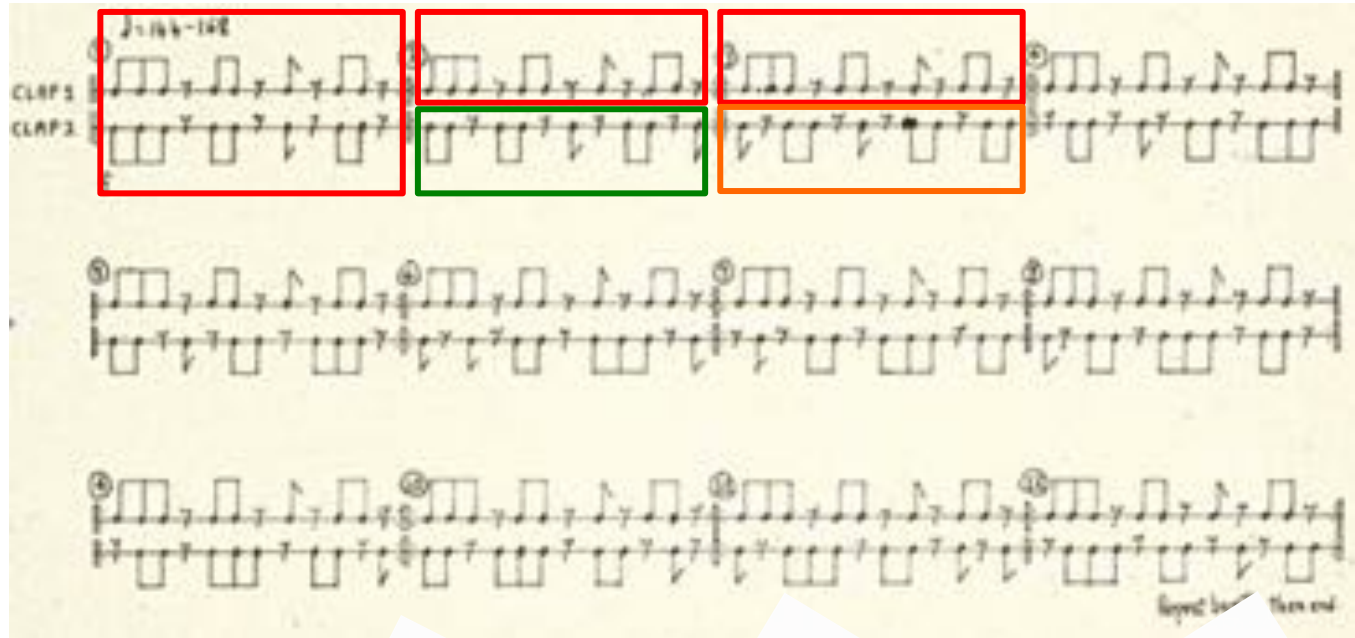
Repeat last 8, then end

The performers begin and end with both performers in unison at bar ①. The number of repeats of each bar should be fixed at twelve repeats per bar. Since the first performer part does not change, it is up to the second performer to ease from one bar to the next. The second performer should try to keep his or her direction where it is written, i.e. on the first beat of each measure (not on the first beat of the group of three claps), so that his direction always falls on a new beat of his or her unchanging pattern.

The choice of a particular clapping sound, i.e. with cupped or flat hands is left up to the performers, whichever sound is chosen, both performers should try to get the same one so that their two parts will blend to produce one overall rhythmic pattern.



Un exercice minimaliste sur les permutations circulaires



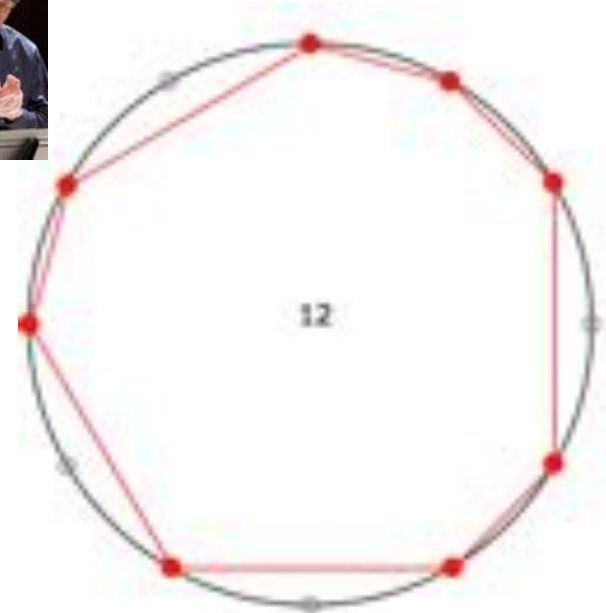
Le « cercle rythmique » et ses rotations

CLAPPING MUSIC

FOR TWO PERFORMERS



Handwritten musical score for two clappers. The score is written on a single sheet of paper with two staves per system. The first system is highlighted with red, green, and orange boxes. The tempo is marked 'J. 164-168'. The score consists of three systems of music, each with four measures. The first measure of each system is circled in red. The score is titled 'CLAPPING MUSIC FOR TWO PERFORMERS'.



The performers begin and end with both performers in unison at bar ①. The number of repeats of each bar should be fixed at twelve repeats per bar. Since the first performer part does not change, it is up to the second performer to cause five bar to the next. The second performer should try to keep his or her downbeat where it is written, i.e. on the first beat of each measure (not on the first beat of the group of three claps), so that his downbeat always falls on a new beat of his or her unchanging pattern.

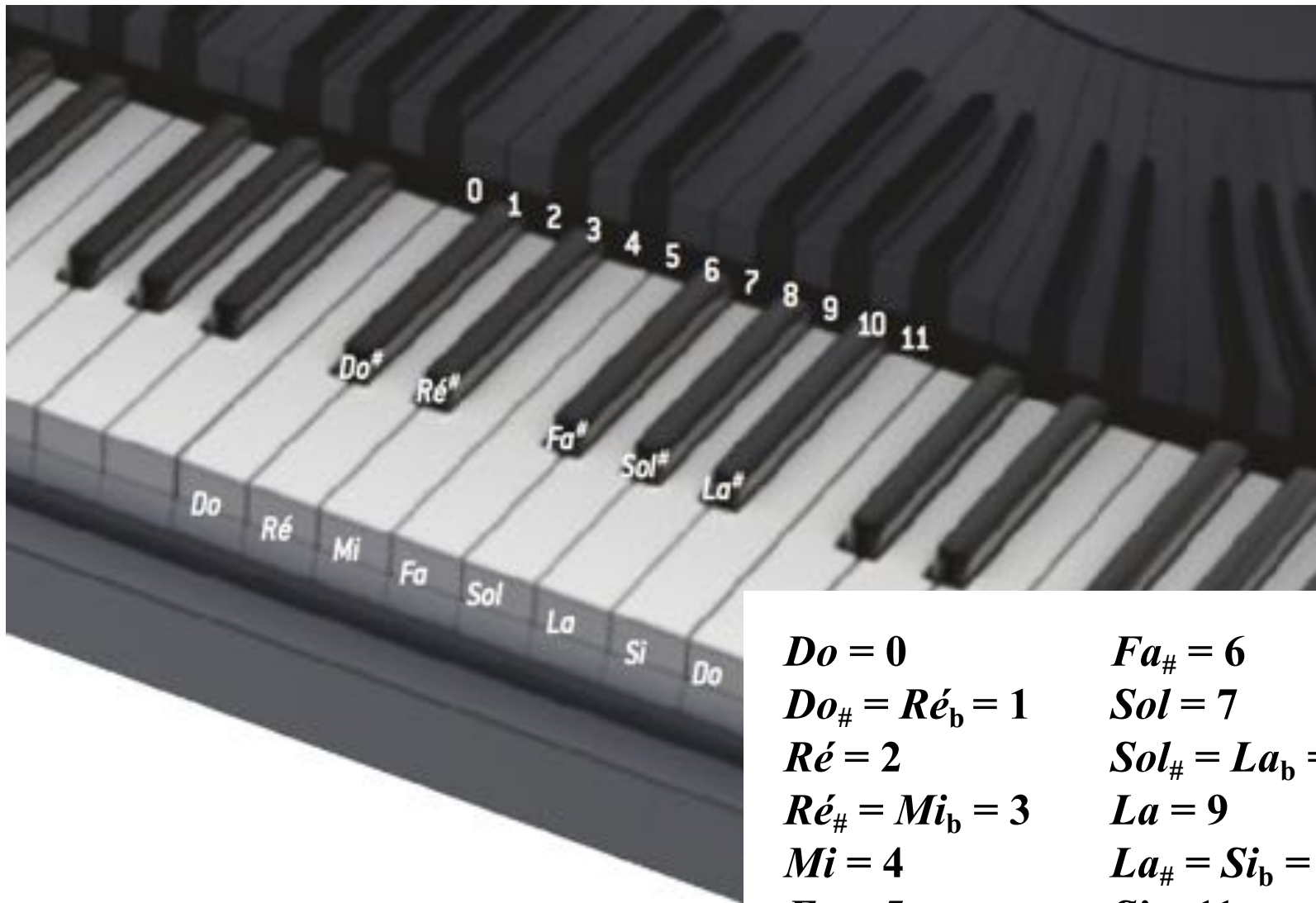
The choice of a particular clapping sound, i.e. with cupped or flat hands is left up to the performers, whichever sound is chosen, both performers should try to get the same one so that their two parts will blend to produce one overall exciting pattern.

Clapping Music (1972)

Steve Reich 1972
revised 1979

Gerubach's Scrolling Score Project
<http://www.gerubach.com>

Le piano : douze notes = douze nombres



Do = 0

*Do*_# = *Ré*_b = 1

Ré = 2

*Ré*_# = *Mi*_b = 3

Mi = 4

Fa = 5

*Fa*_# = 6

Sol = 7

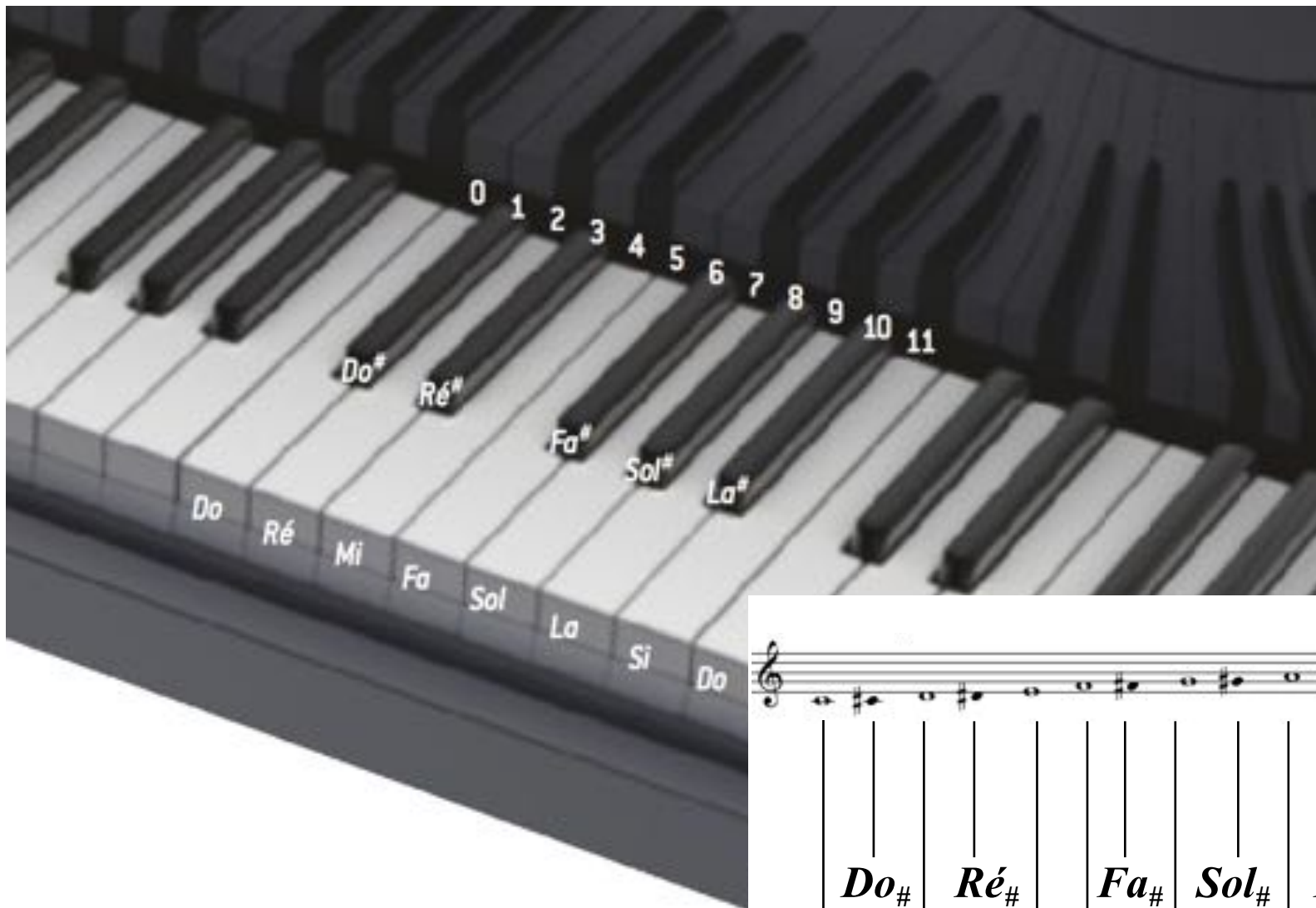
*Sol*_# = *La*_b = 8

La = 9

*La*_# = *Si*_b = 10

Si = 11

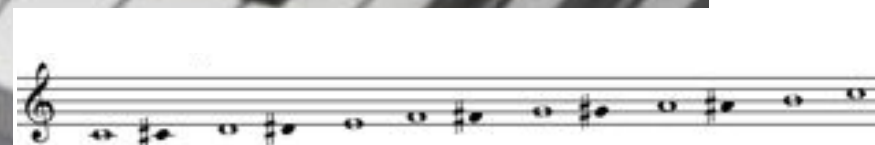
Le piano : douze notes = douze nombres








A musical staff showing the twelve chromatic notes. The notes are: Do#, Ré#, Fa#, Sol#, La#, Si, and Do. Below the staff, the names are listed in two rows: *Do# Ré# Fa# Sol# La#* and *Ré_b Mi_b Sol_b La_b Si_b*. Vertical lines connect the notes on the staff to their names below. A dotted line is shown at the end of the staff.

Do Ré Mi Fa Sol La Si do

Le piano : douze notes = douze nombres



					
<i>Do_#</i>	<i>Ré_#</i>	<i>Fa_#</i>	<i>Sol_#</i>	<i>La_#</i>	
<i>Ré_b</i>	<i>Mi_b</i>	<i>Sol_b</i>	<i>La_b</i>	<i>Si_b</i>	

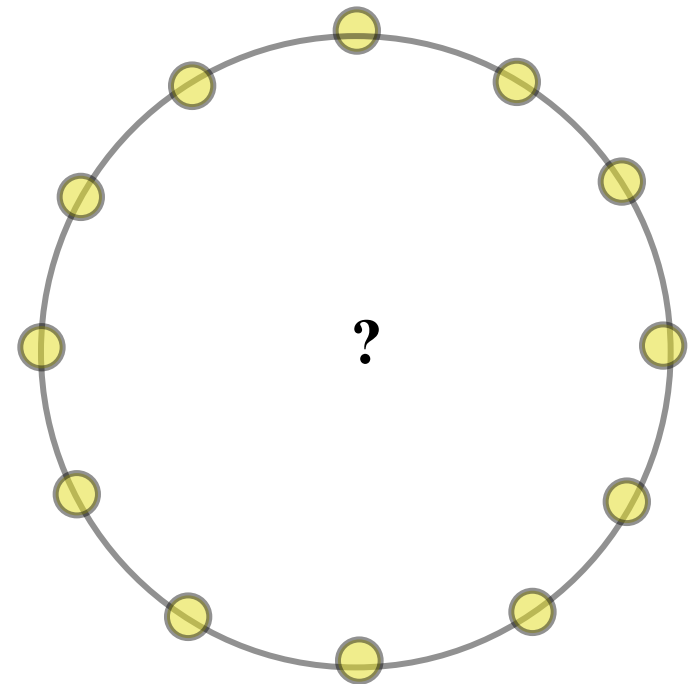
Do Ré Mi Fa Sol La Si Do

Du piano à l'horloge musicale



Do = 0
*Do*_# = *Ré*_b = 1
Ré = 2
*Ré*_# = *Mi*_b = 3
Mi = 4
Fa = 5

*Fa*_# = 6
Sol = 7
*Sol*_# = *La*_b = 8
La = 9
*La*_# = *Si*_b = 10
Si = 11

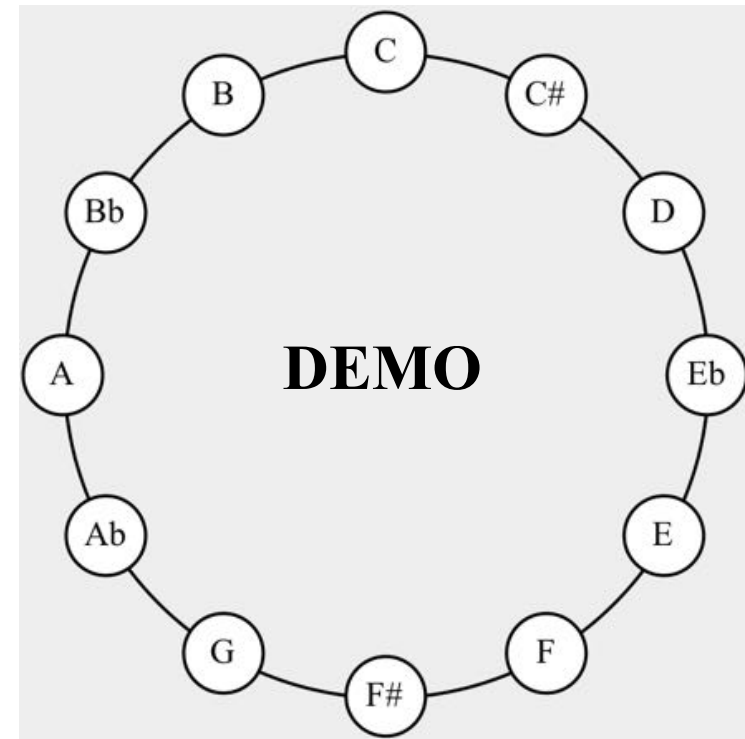
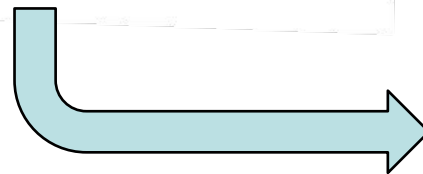


Du piano à l'horloge musicale (via le software *Hexachord*)

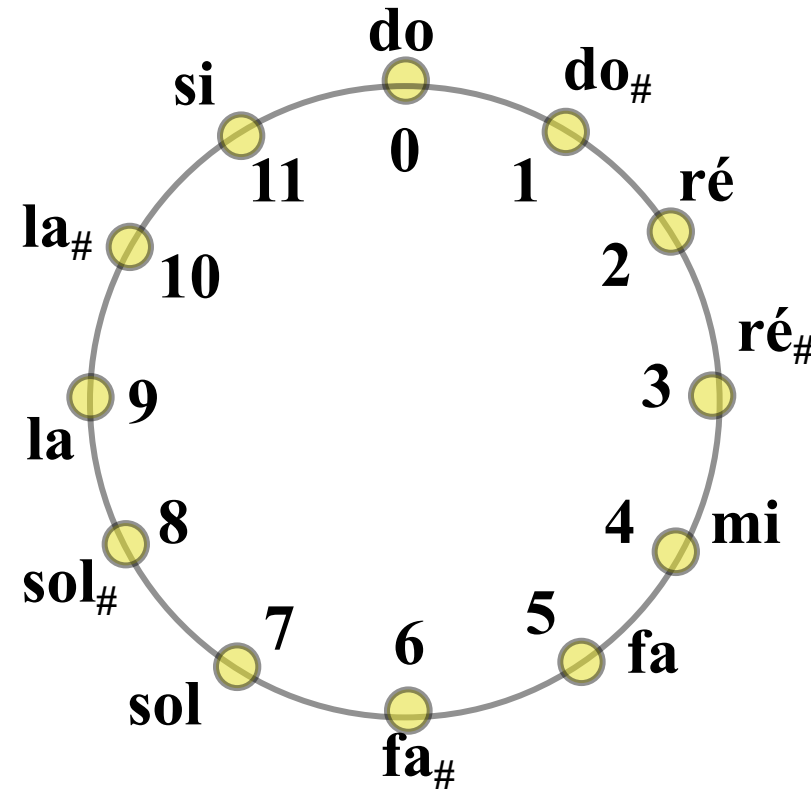


***Do* = 0**
***Do*_# = *Ré*_b = 1**
***Ré* = 2**
***Ré*_# = *Mi*_b = 3**
***Mi* = 4**
***Fa* = 5**

***Fa*_# = 6**
***Sol* = 7**
***Sol*_# = *La*_b = 8**
***La* = 9**
***La*_# = *Si*_b = 10**
***Si* = 11**



Du piano à l'horloge musicale



La réduction à l'octave et le cadran d'horloge



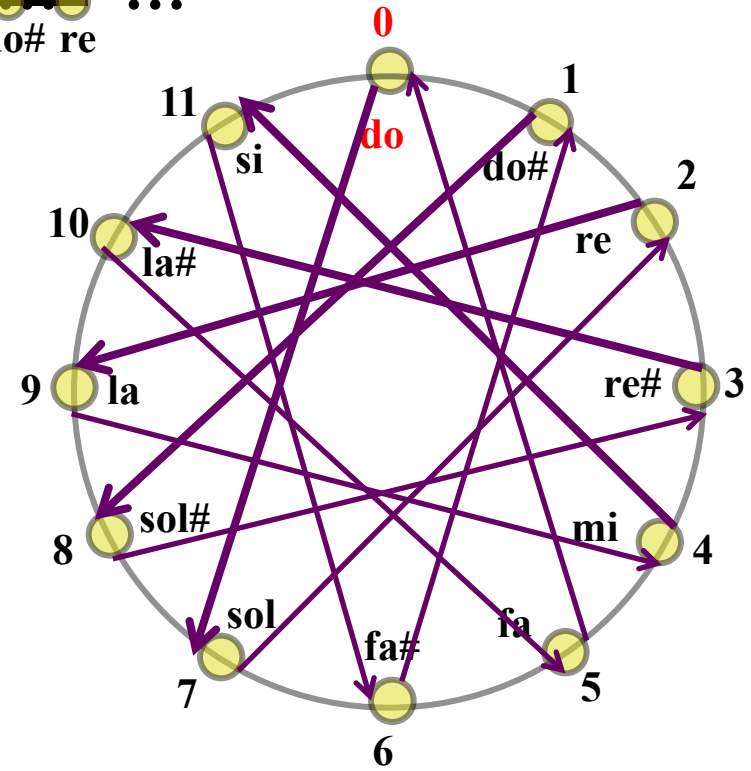
7

... do do# re re# mi fa fa# sol sol# la la# si do do# re ...



0 1 2 3 4 5 6 7 8 9 10 11 12

Cycle des quintes



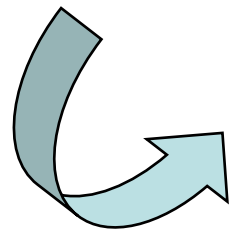
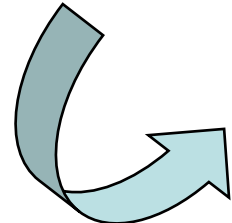
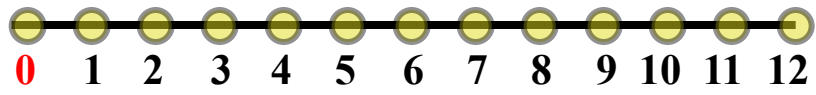
La réduction à l'octave et le cadran d'horloge



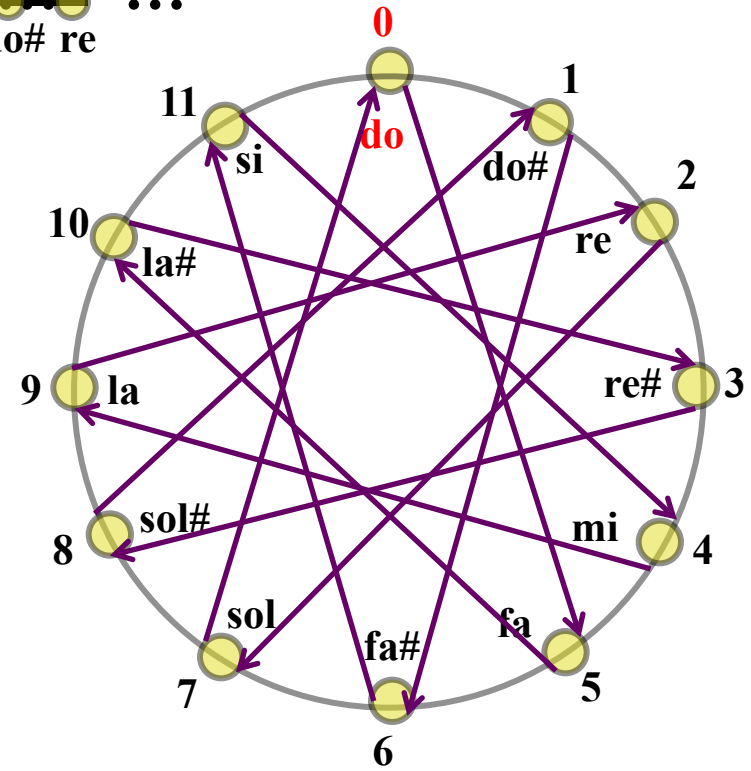
5



do do# re re# mi fa fa# sol sol# la la# si do do# re



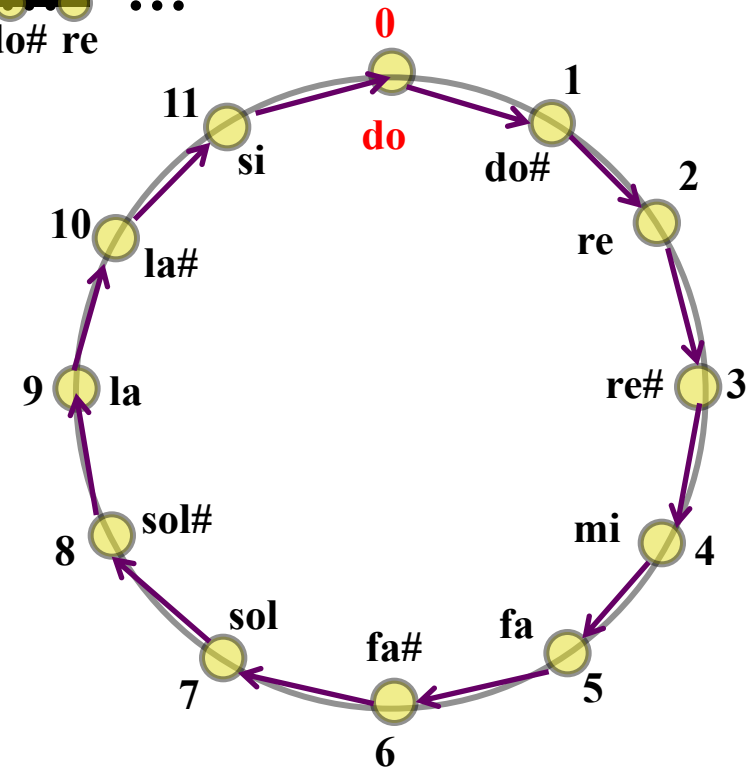
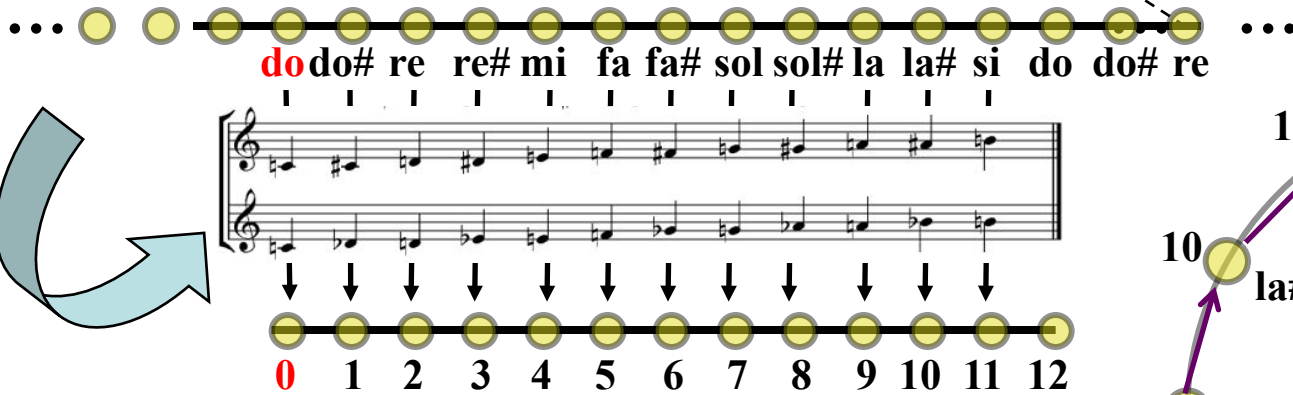
Cycle des quartes



La réduction à l'octave et le cadran d'horloge



1



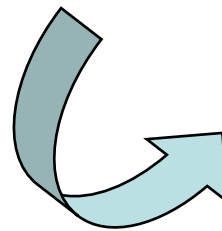
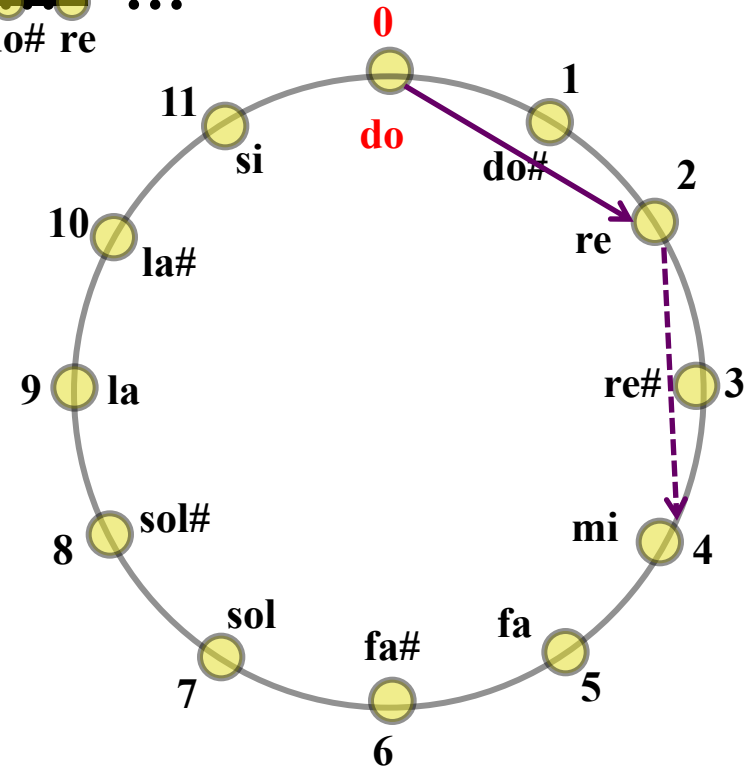
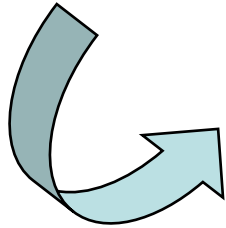
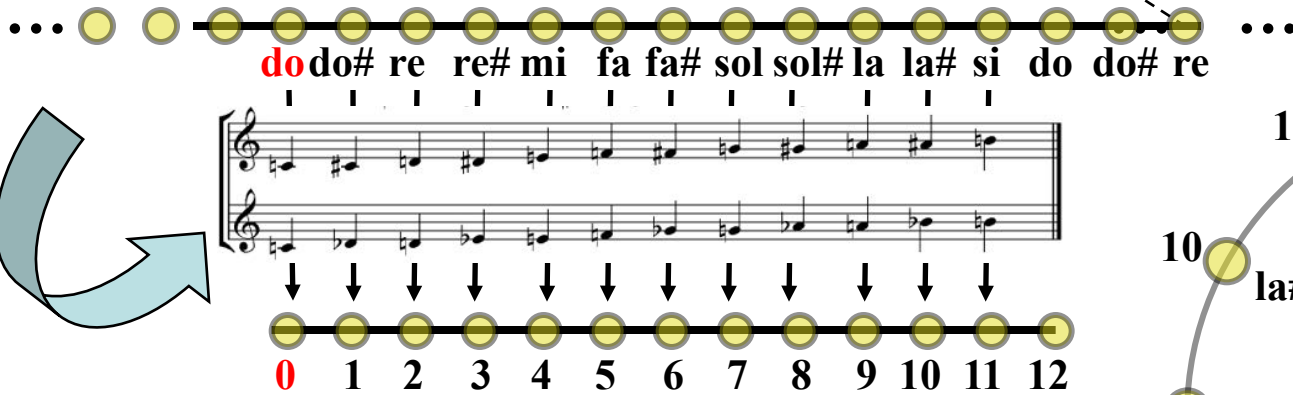
→ Quels sont les autres intervalles qui engendrent le total chromatique ?

La réduction à l'octave et le cadran d'horloge



?

2



→ Quels sont les autres intervalles qui engendrent le total chromatique ?

La réduction à l'octave et le cadran d'horloge

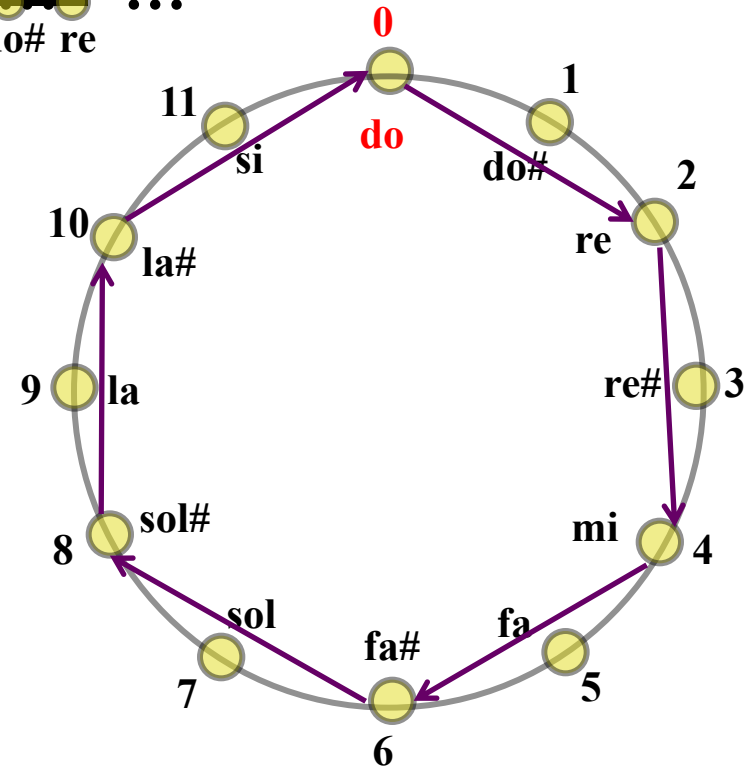
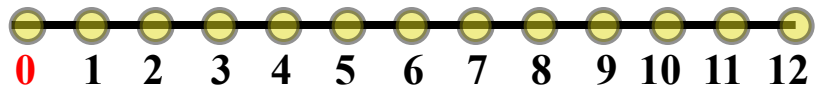


?

2

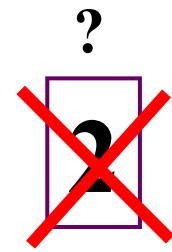


do do# re re# mi fa fa# sol sol# la la# si do do# re

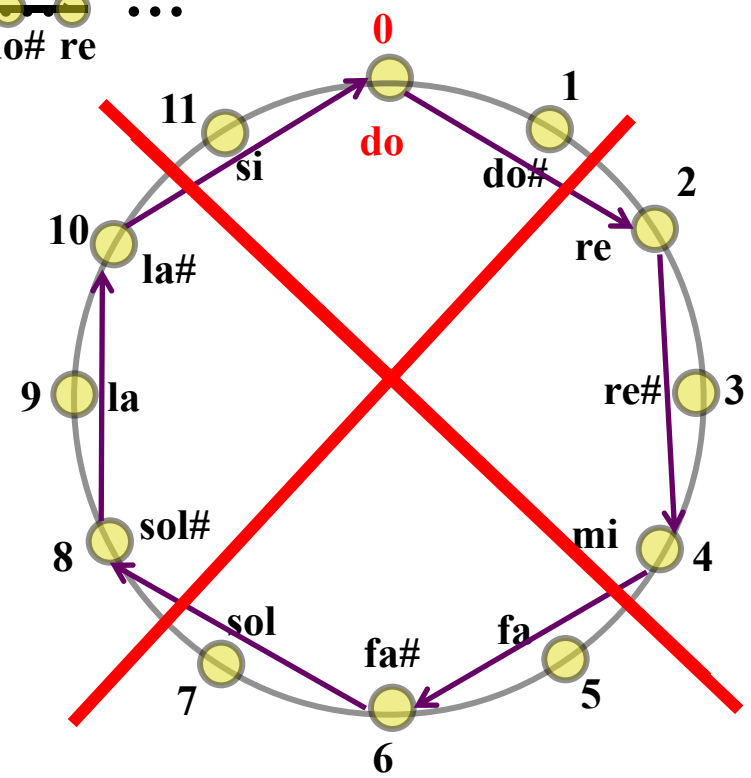


➔ Quels sont les autres intervalles qui engendrent le total chromatique ?

La réduction à l'octave et le cadran d'horloge



0 1 2 3 4 5 6 7 8 9 10 11 12

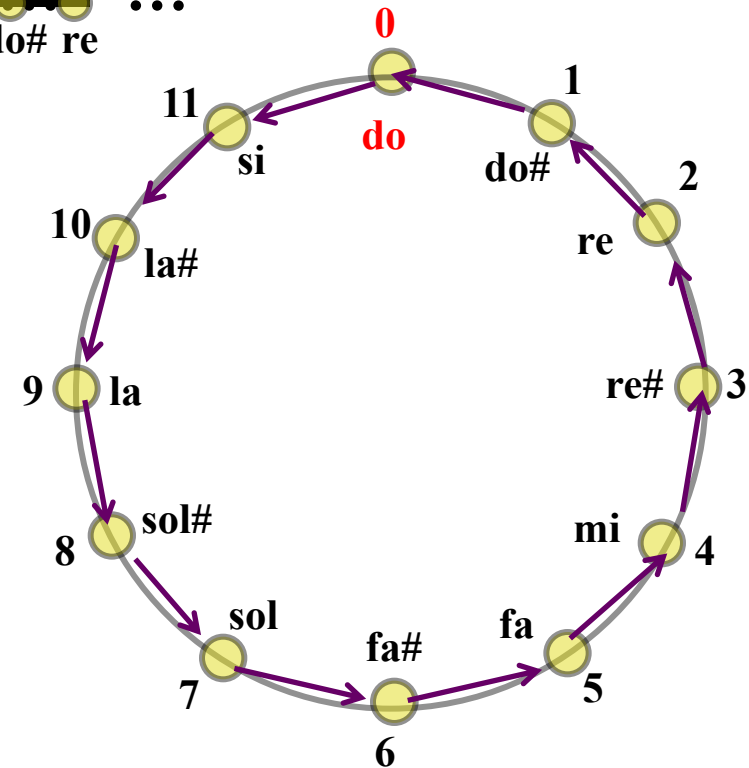
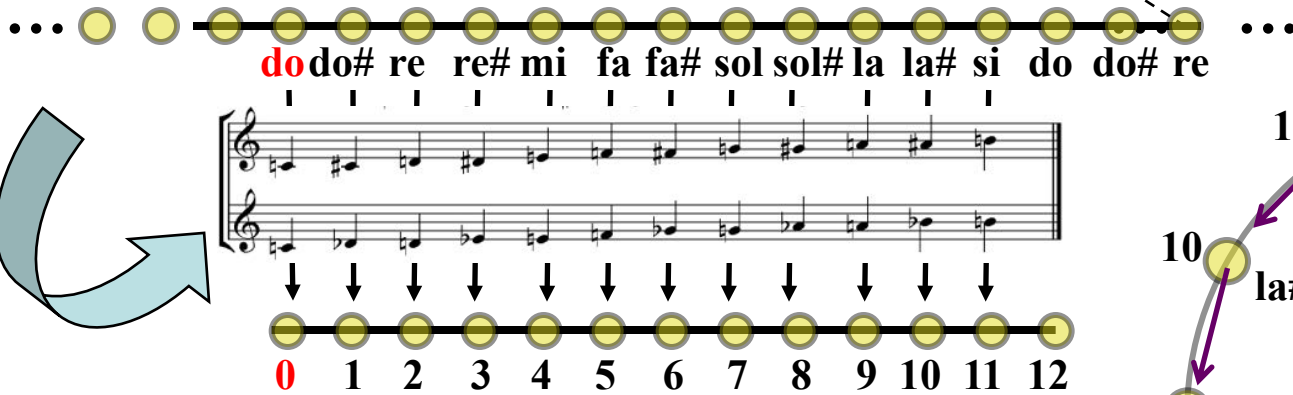


→ Quels sont les autres intervalles qui engendrent le total chromatique ?

La réduction à l'octave et le cadran d'horloge

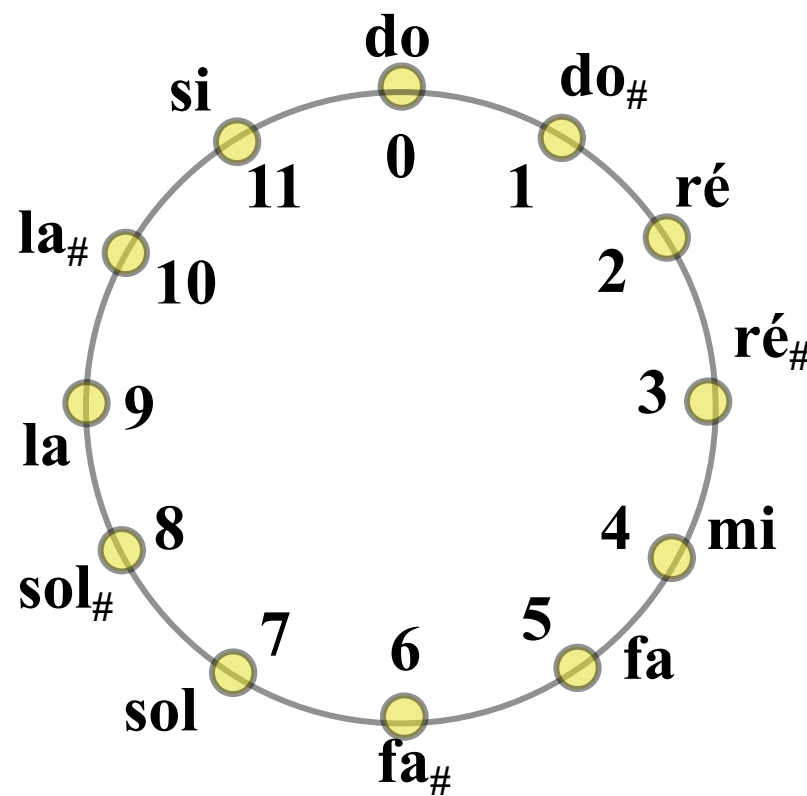
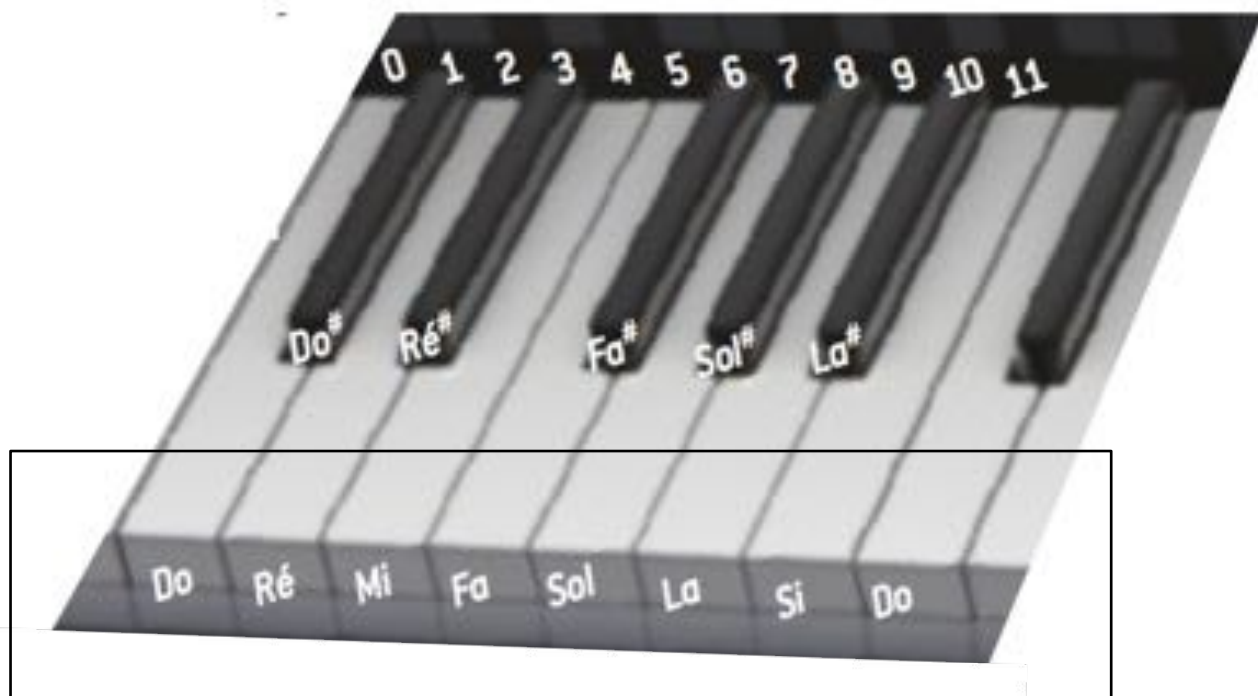


11

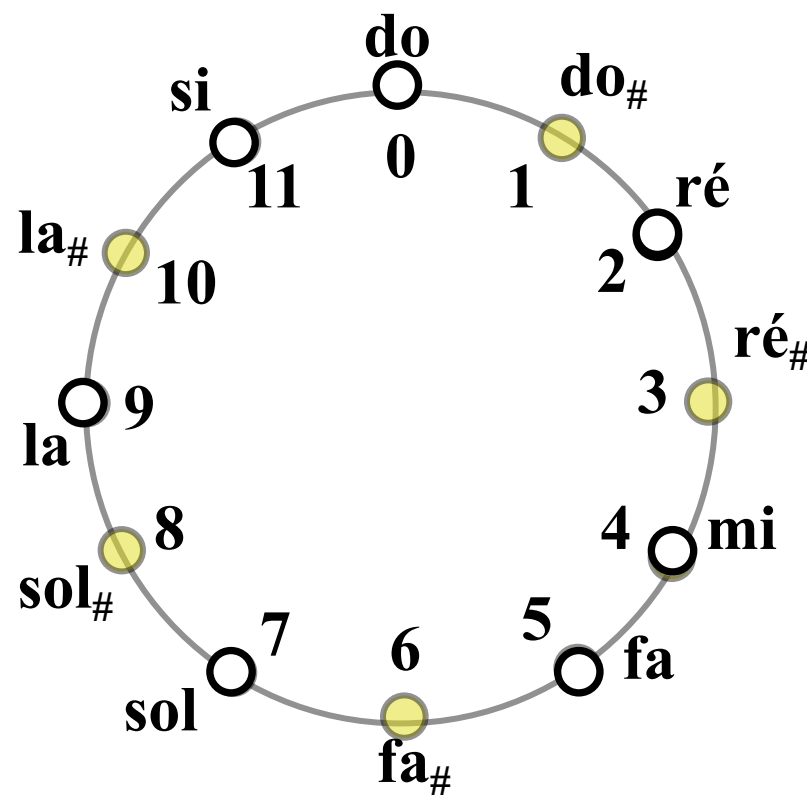
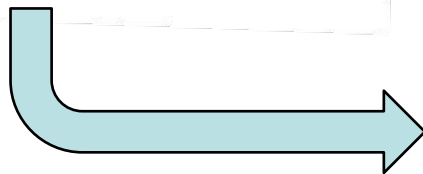
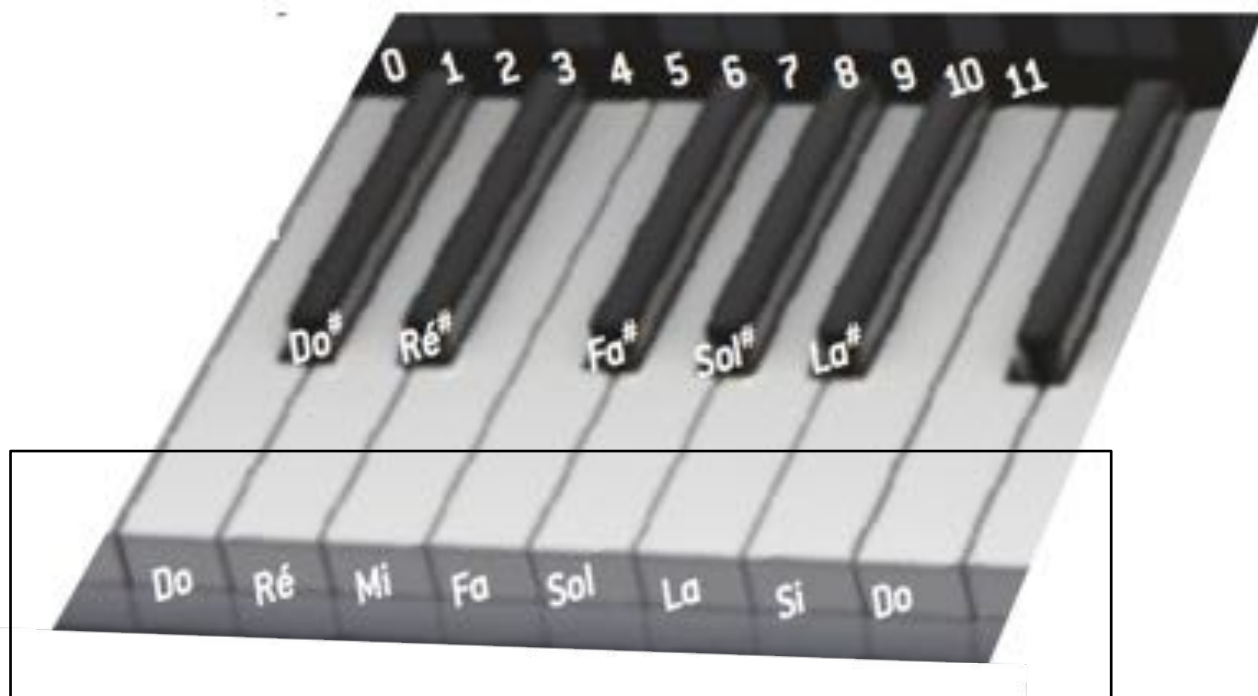


→ Quels sont les autres intervalles qui engendrent le total chromatique ?

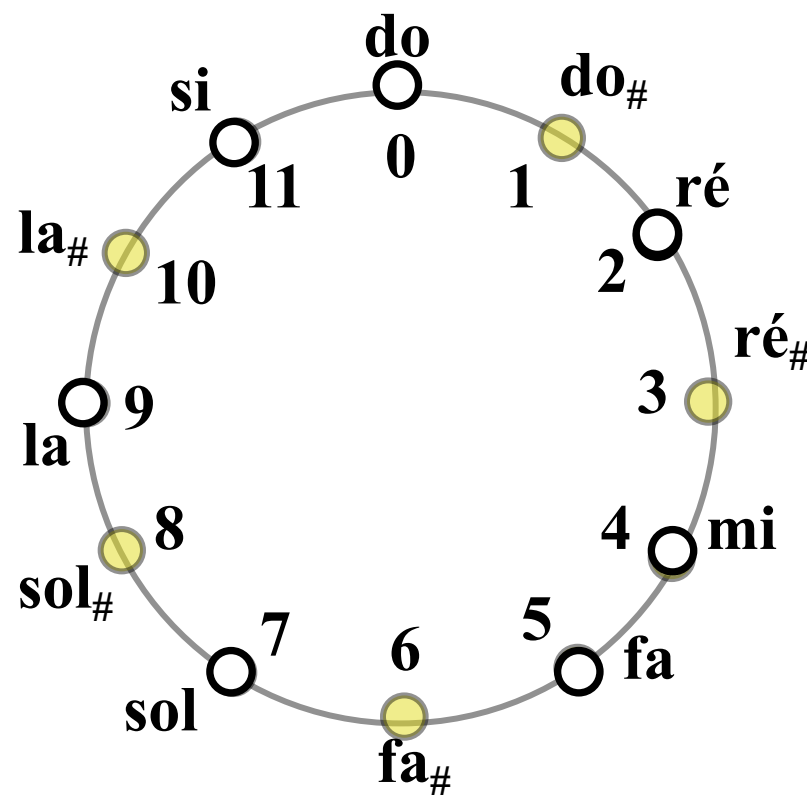
Du piano à l'horloge musicale : les touches blanches



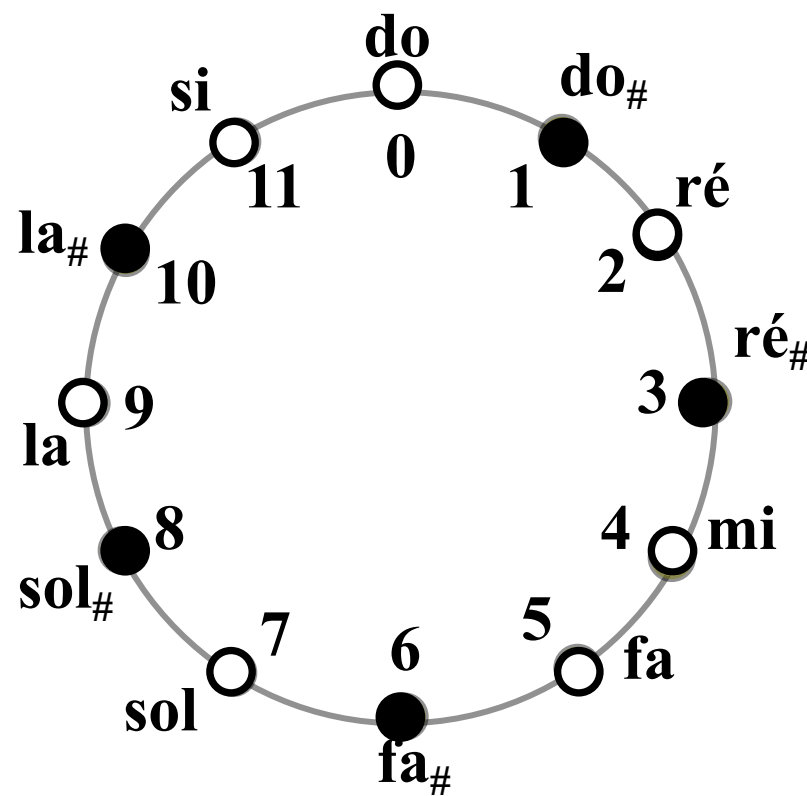
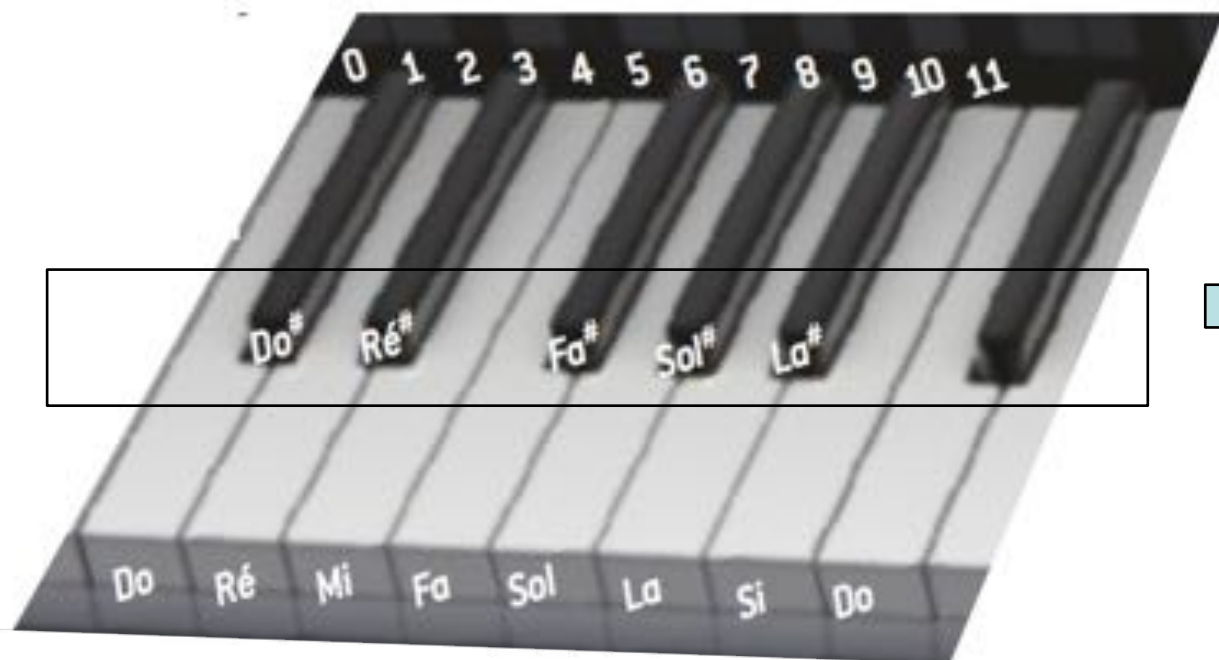
Du piano à l'horloge musicale : les touches blanches



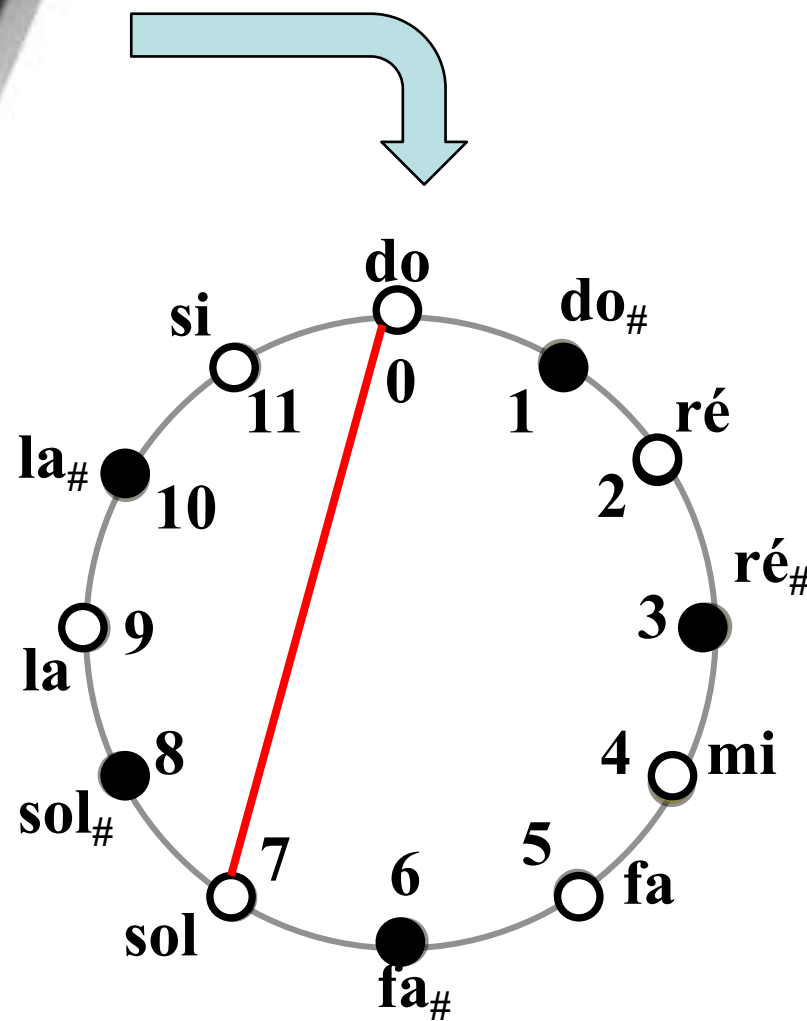
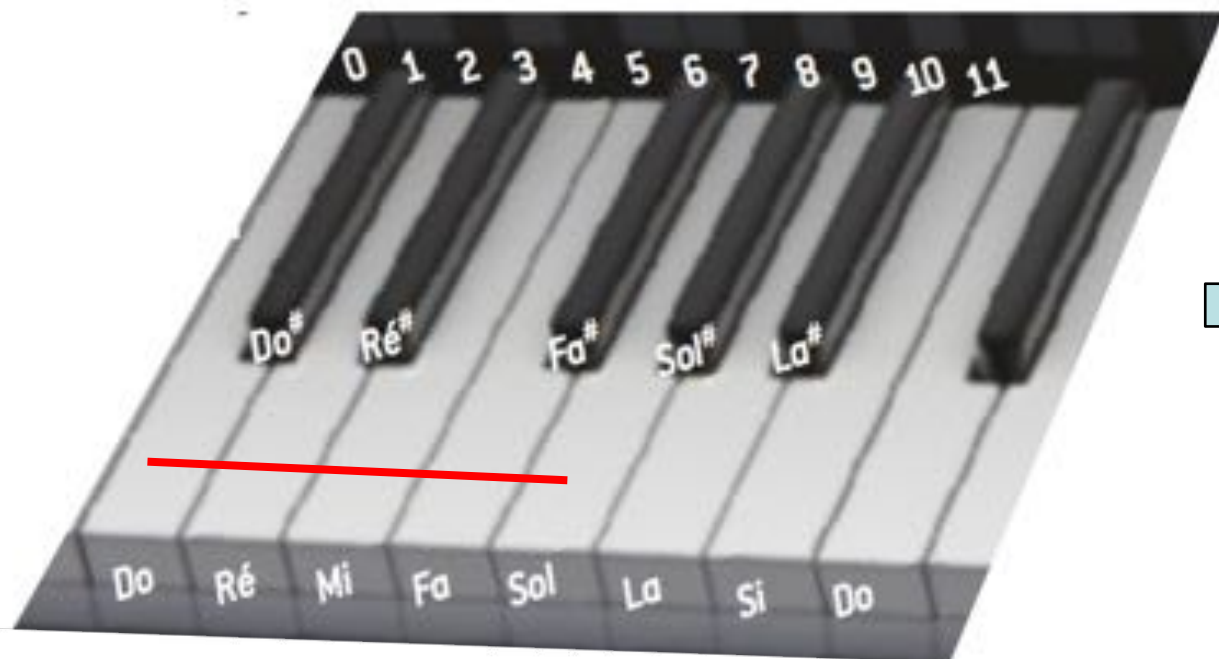
Du piano à l'horloge musicale : et les touches noires ?



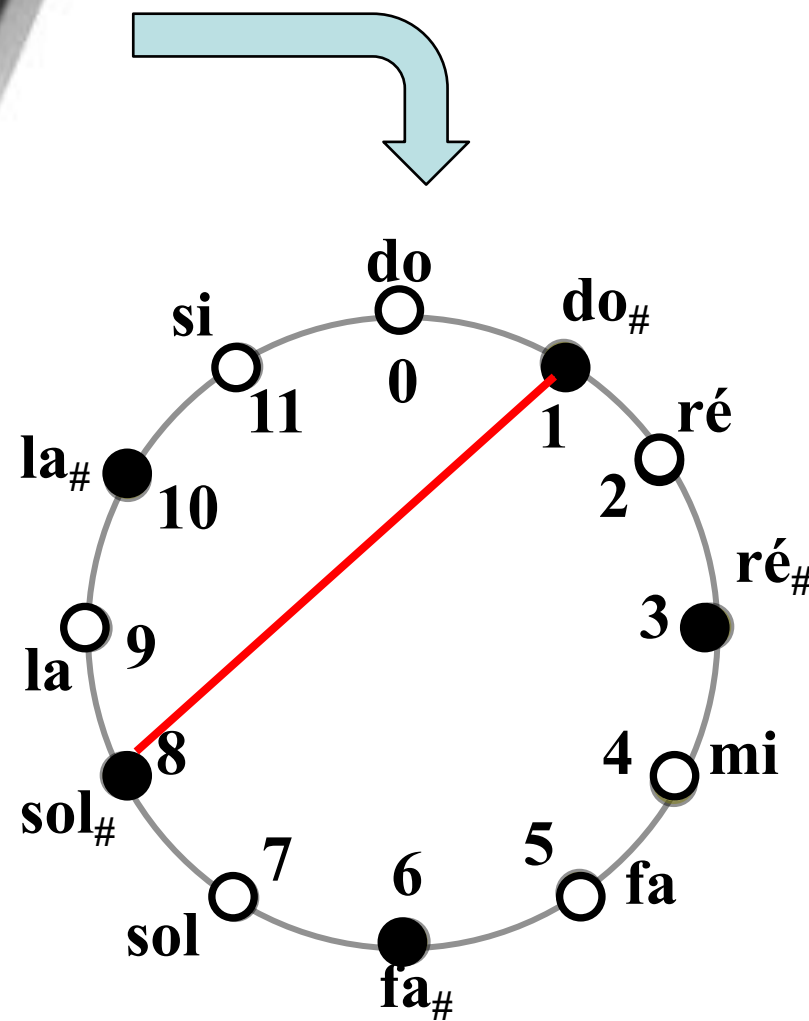
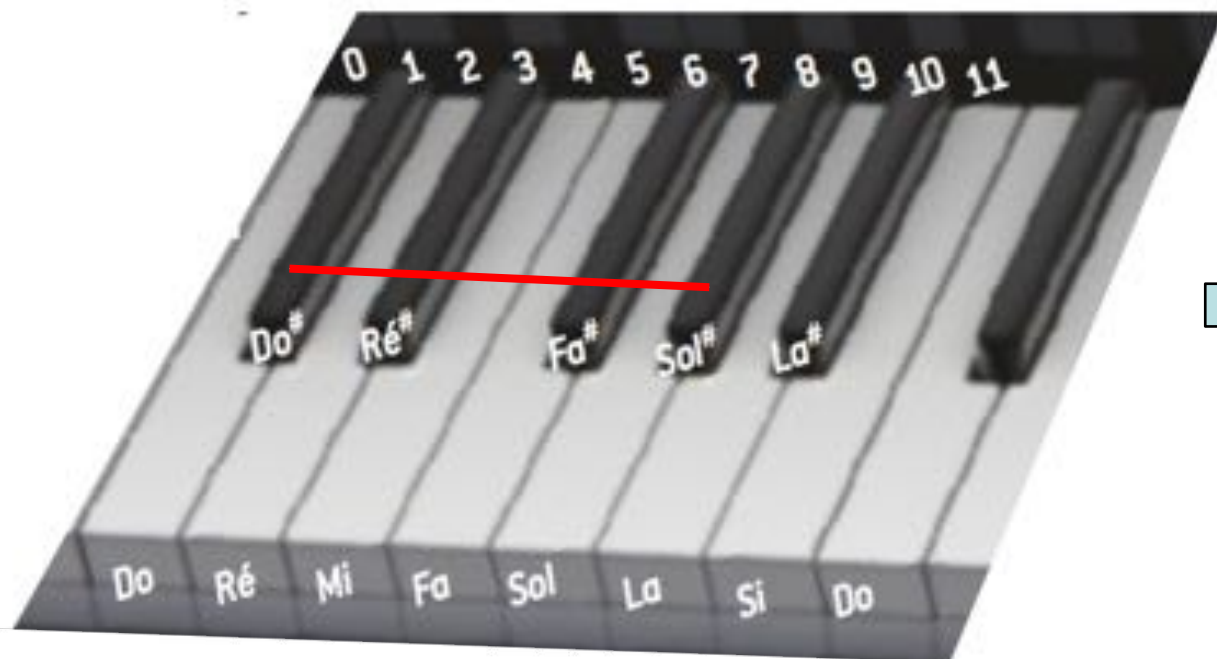
Du piano à l'horloge musicale : et les touches noires ?



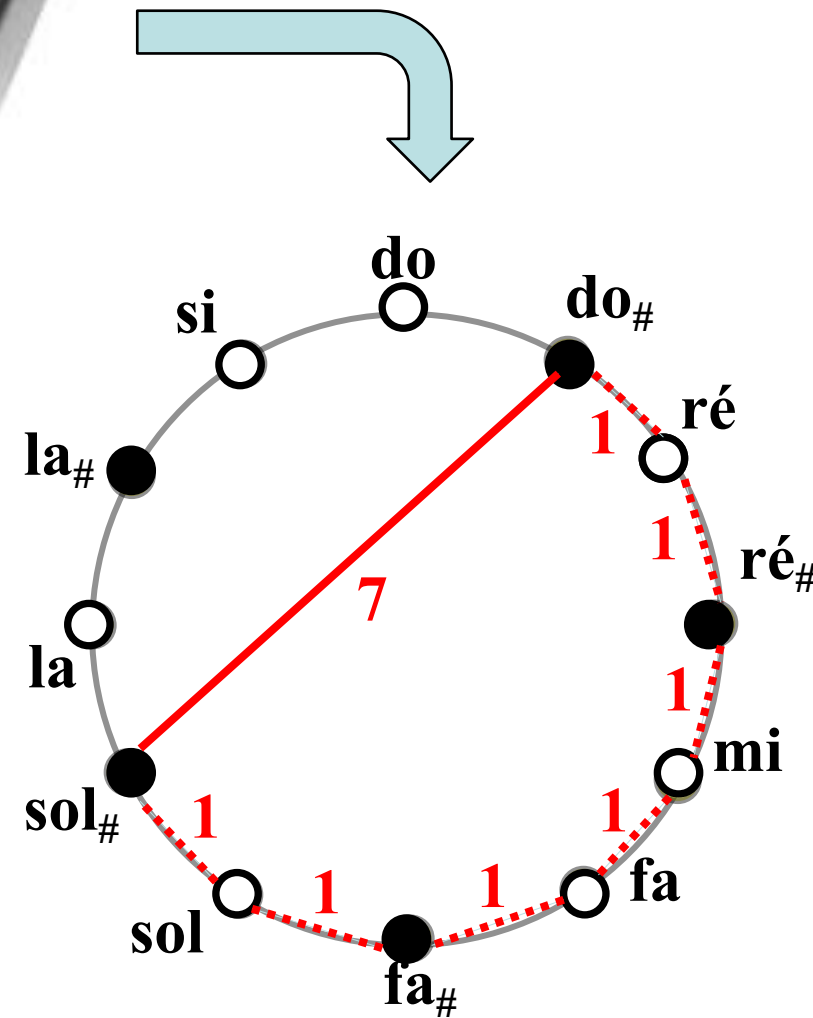
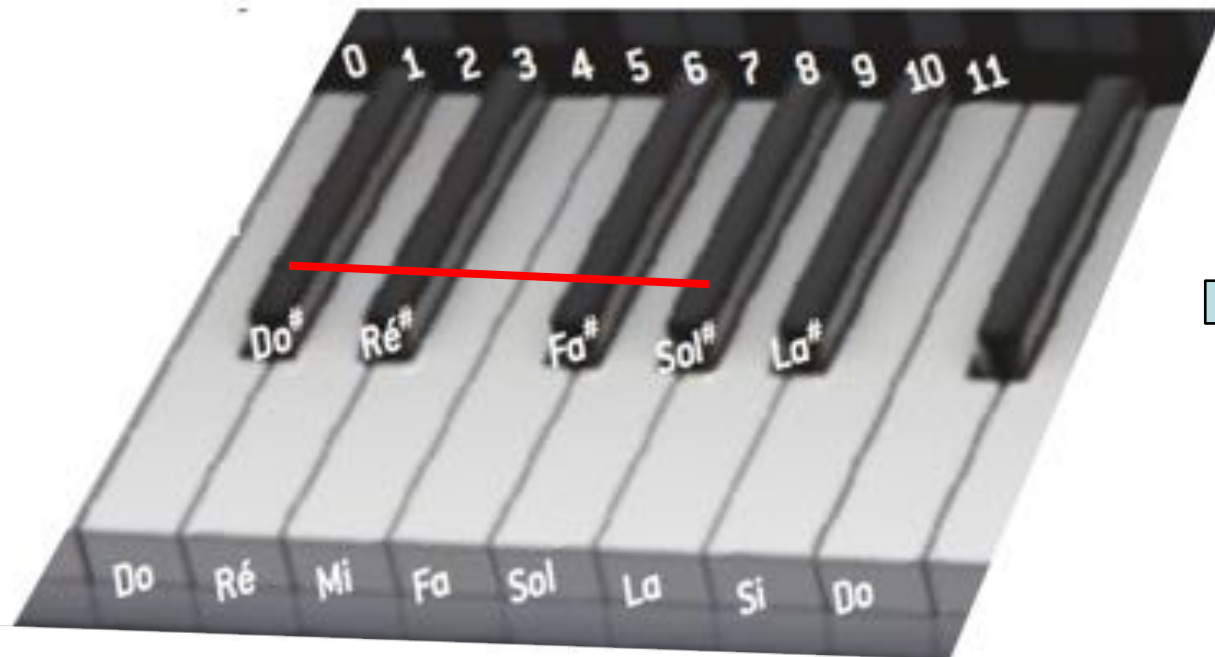
Les intervalles : la QUINTE = 5 touches (blanches)



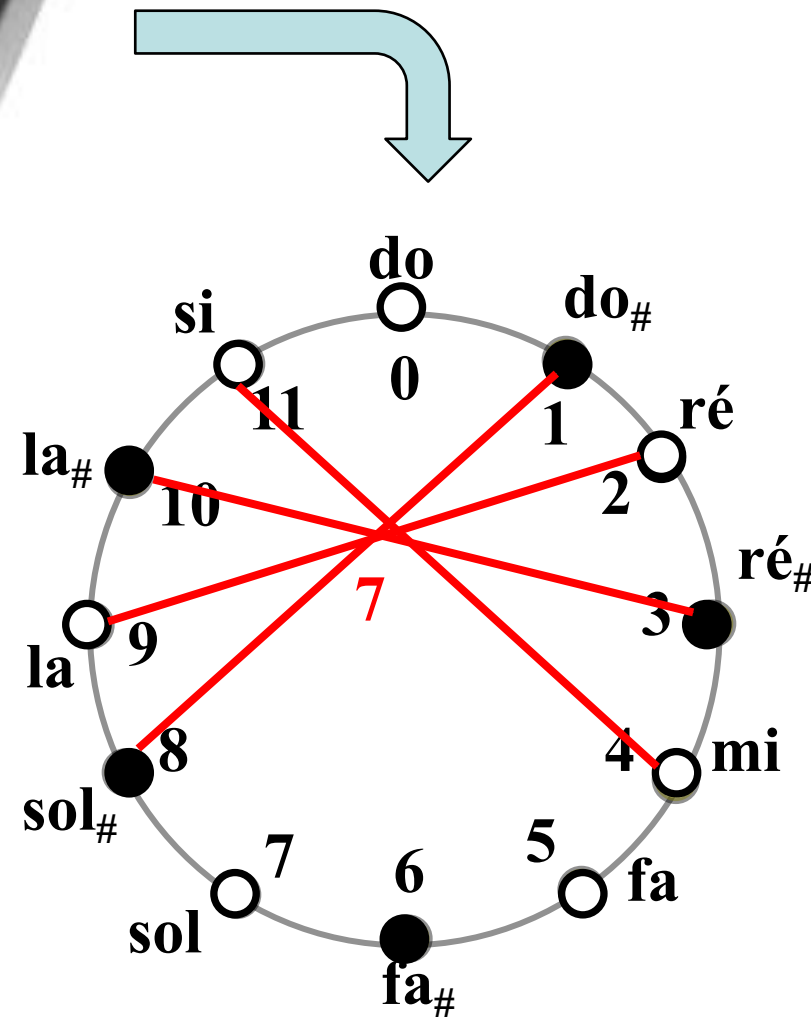
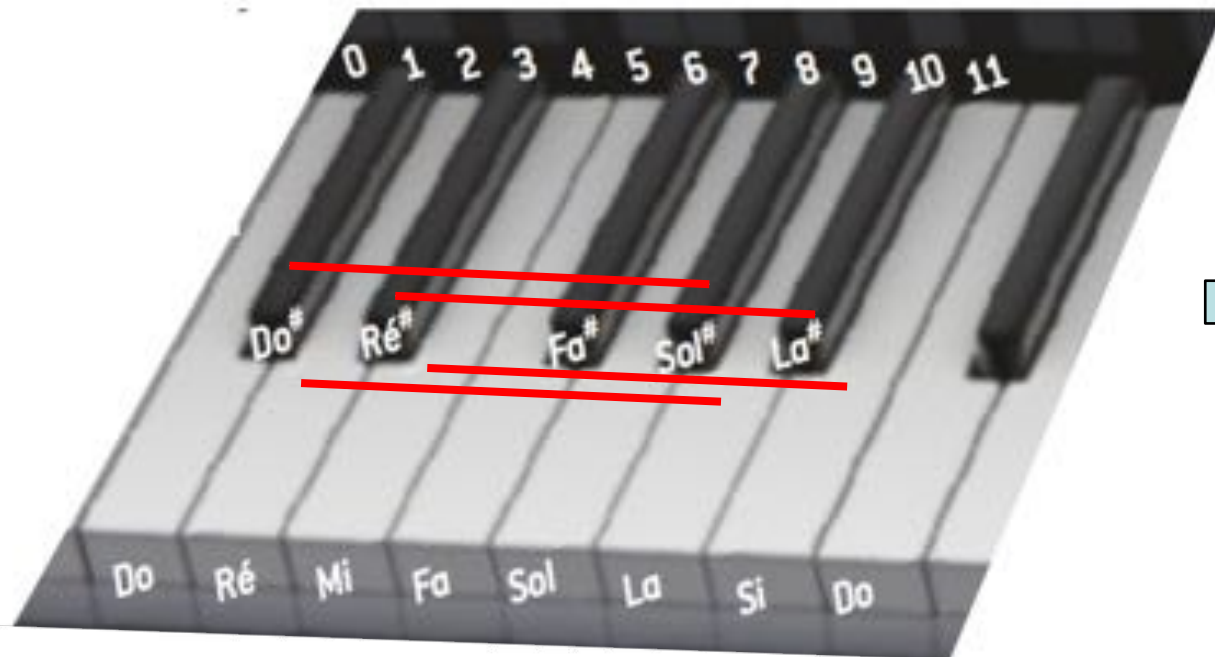
Et les touches noires ?



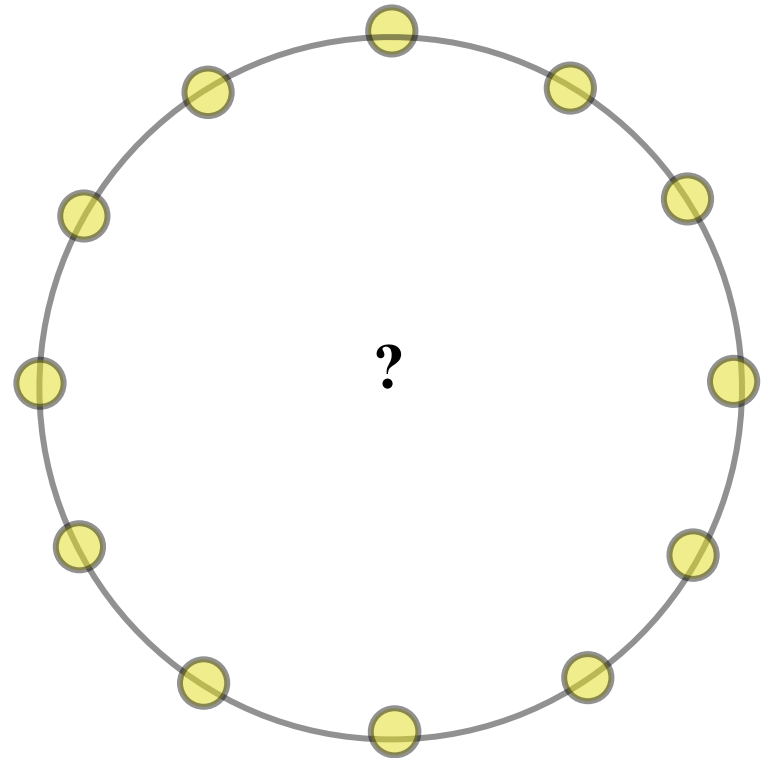
L'intervalle de QUINTE = 7 demi-tons



L'intervalle de QUINTE = 7 demi-tons

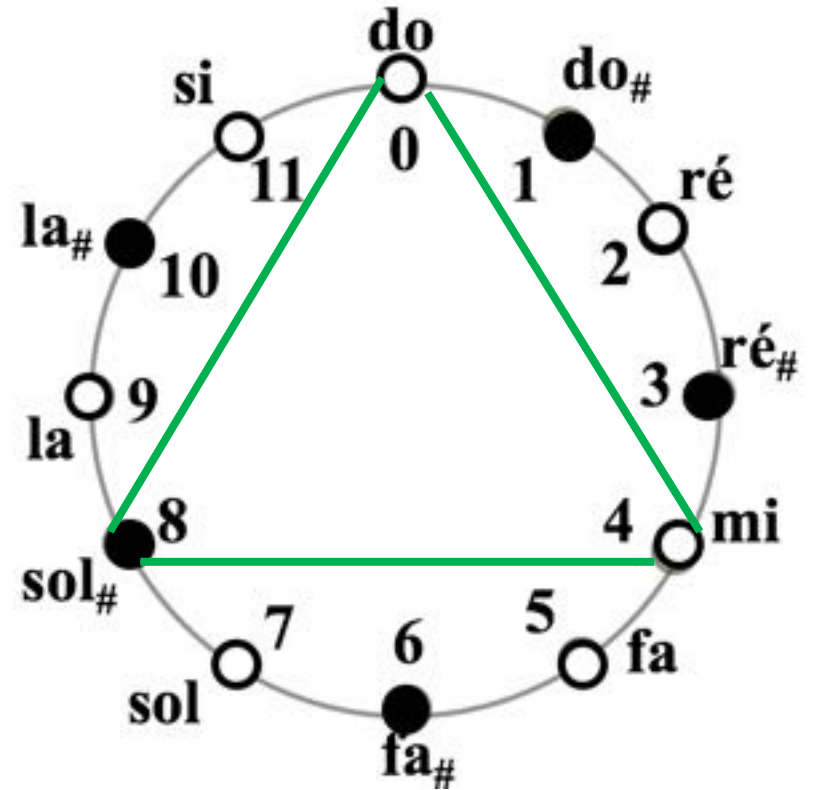
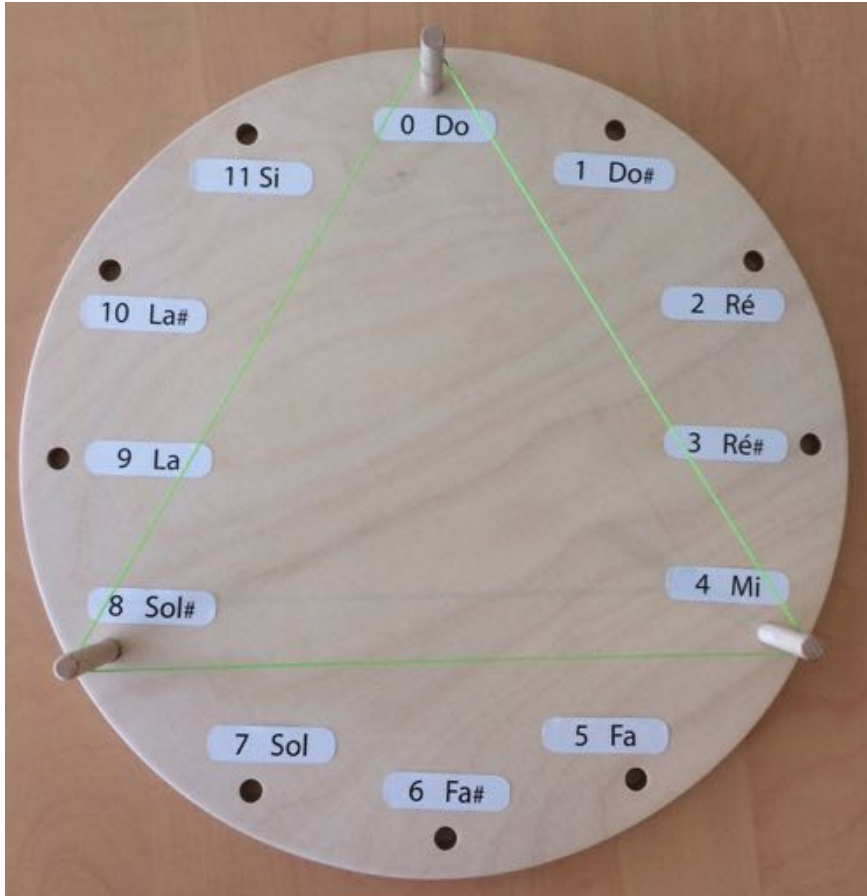


A vous de jouer...

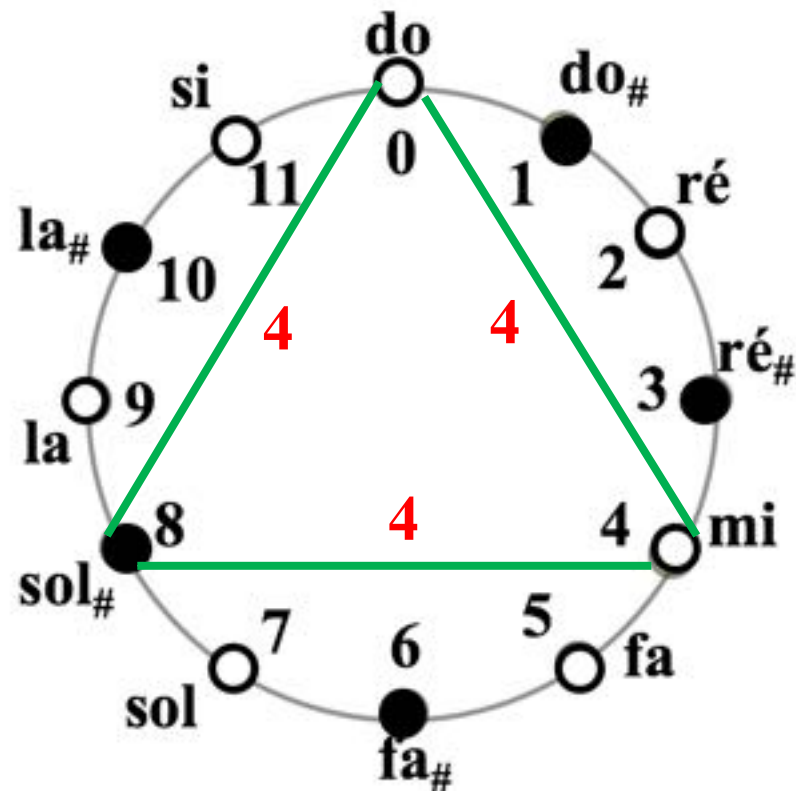
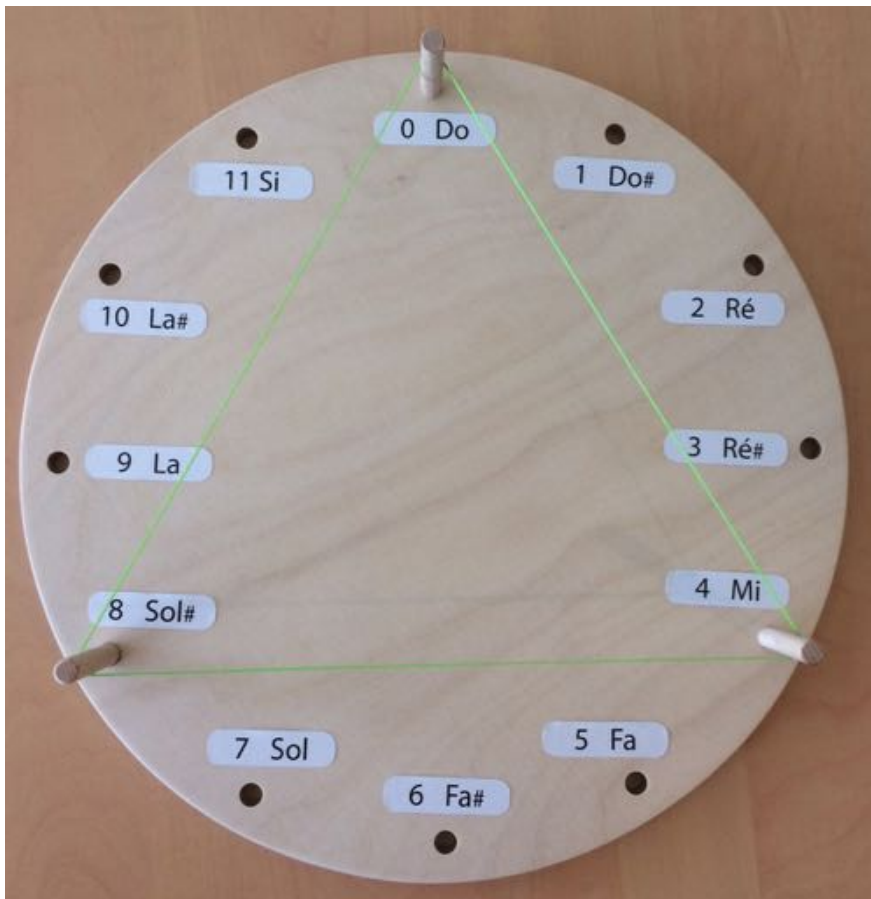


Quelle est la musique d'un triangle équilatéral ?

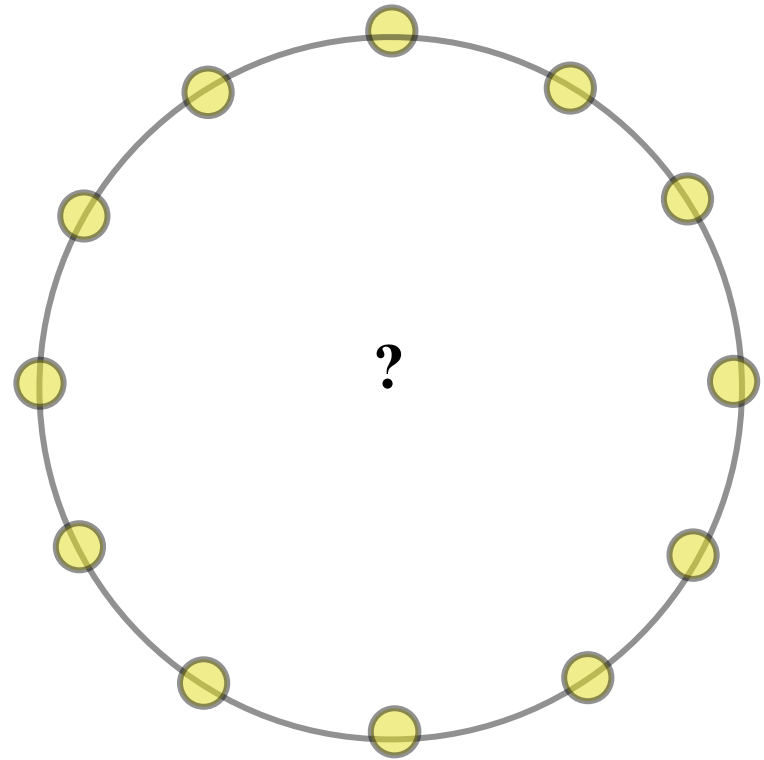
Le triangle équilatéral = l'accord augmenté



Le triangle équilatéral = l'accord augmenté ou (4, 4, 4)

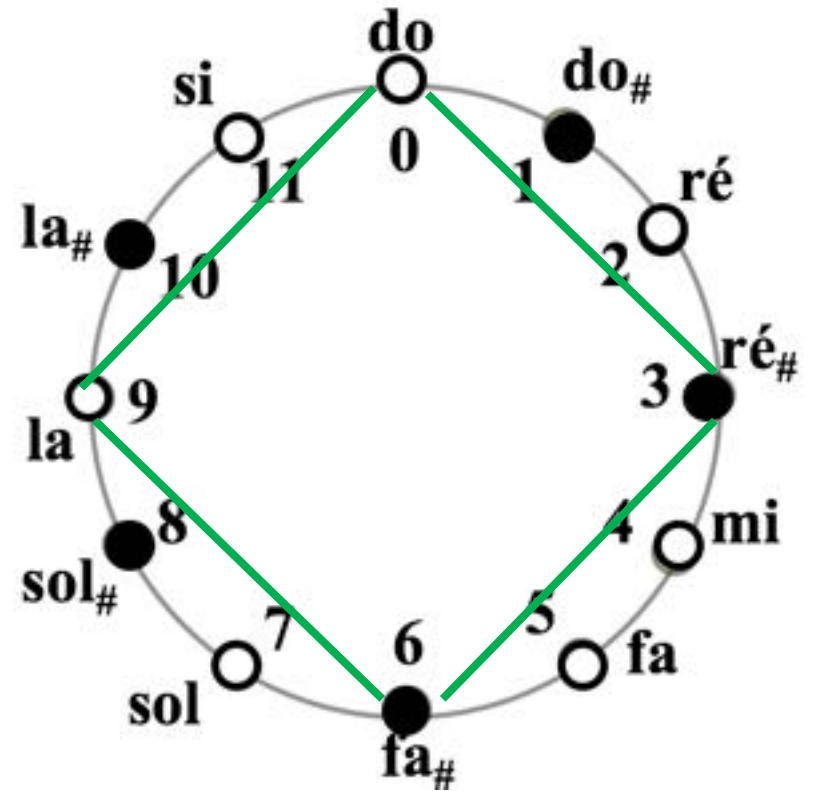
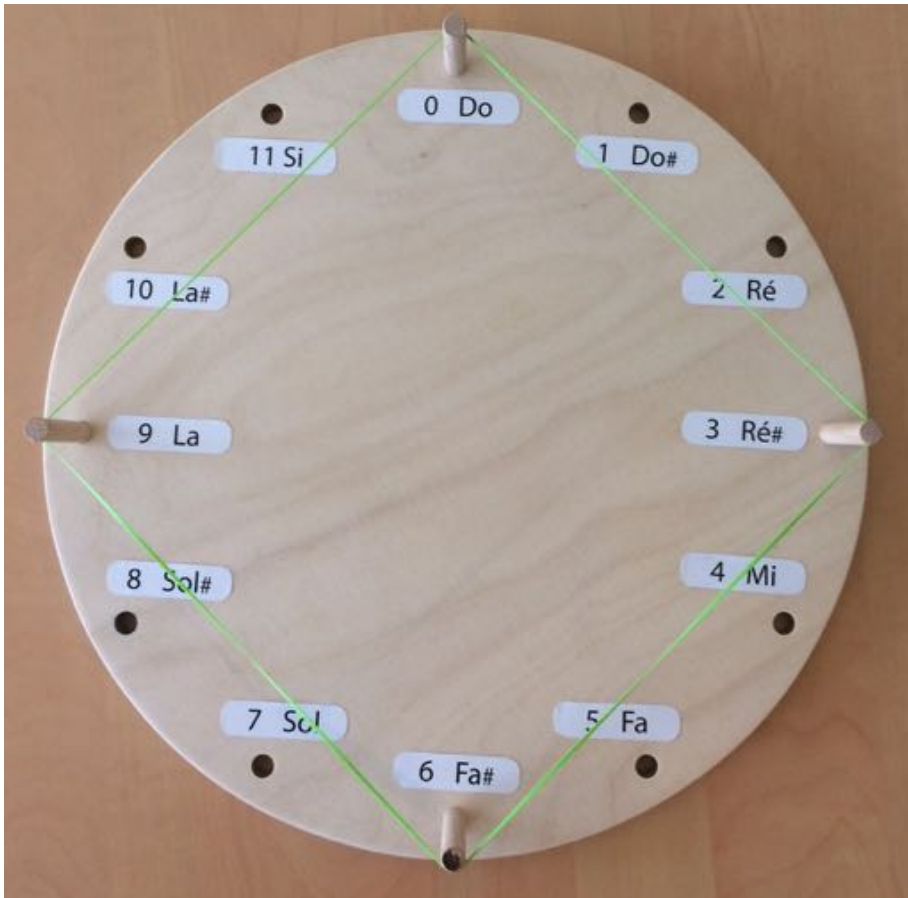


A vous de jouer...

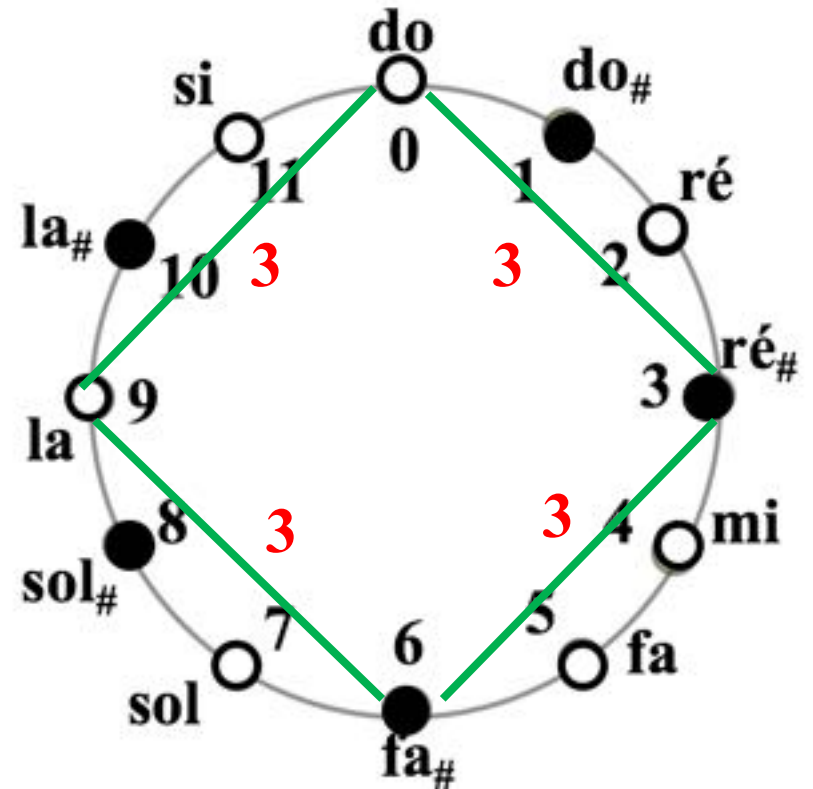
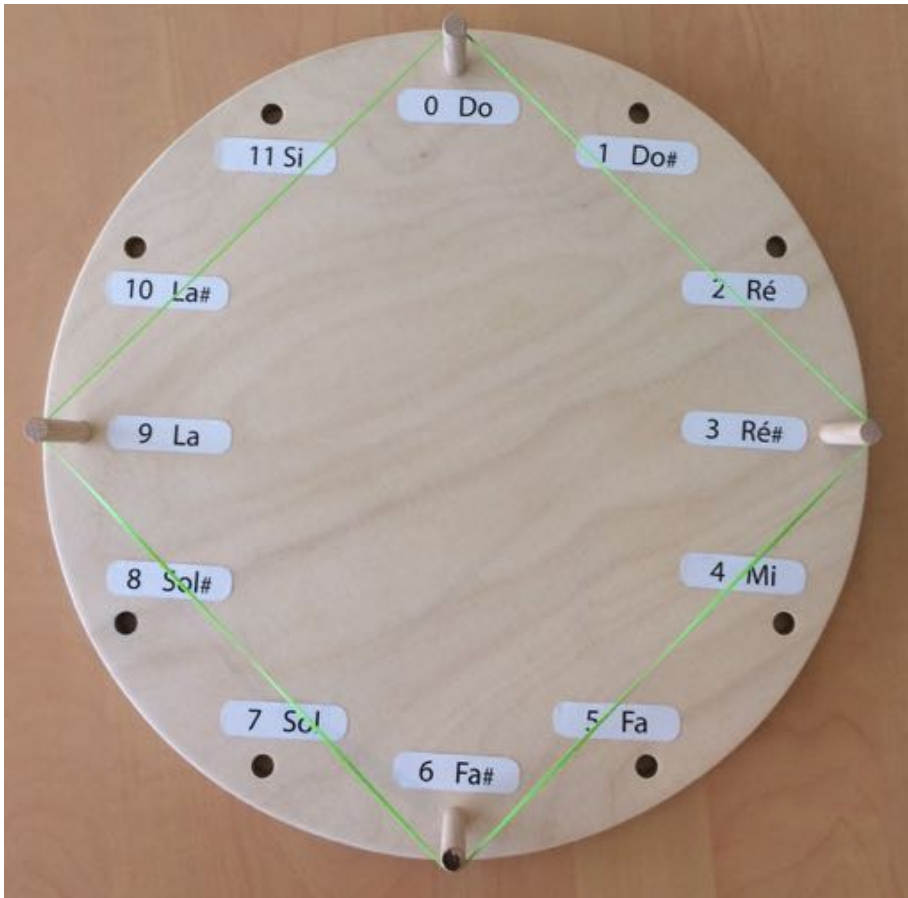


Quelle est la musique d'un carré ?

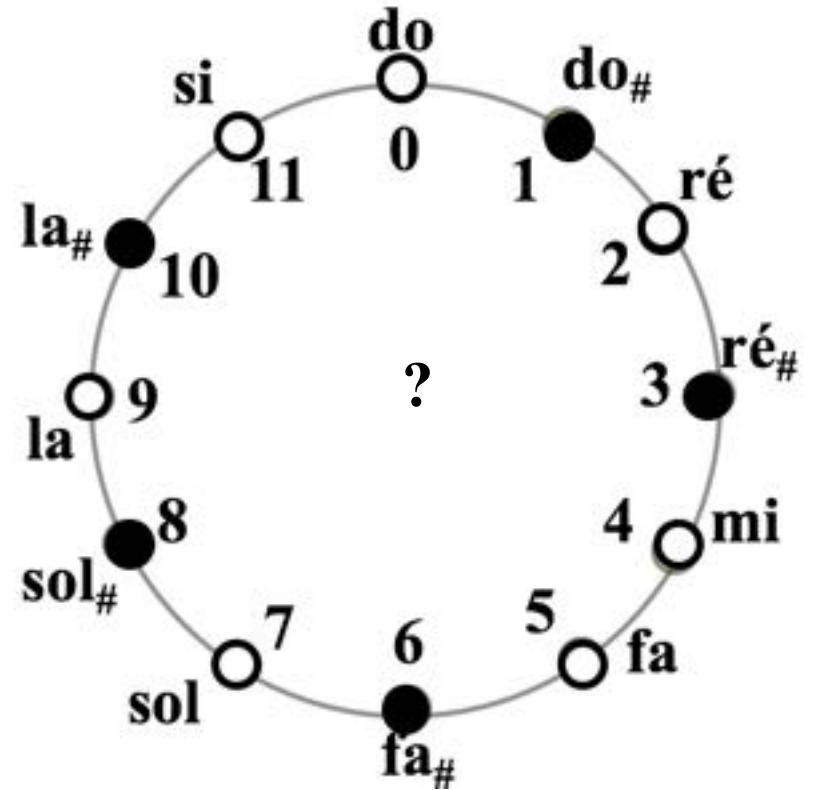
Le carré = l'accord diminué



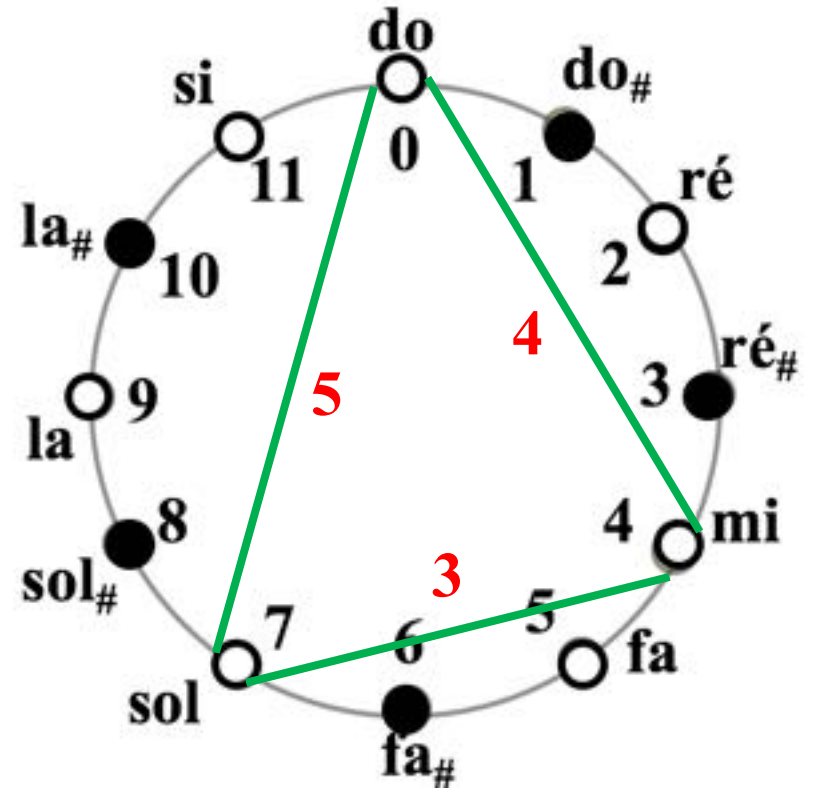
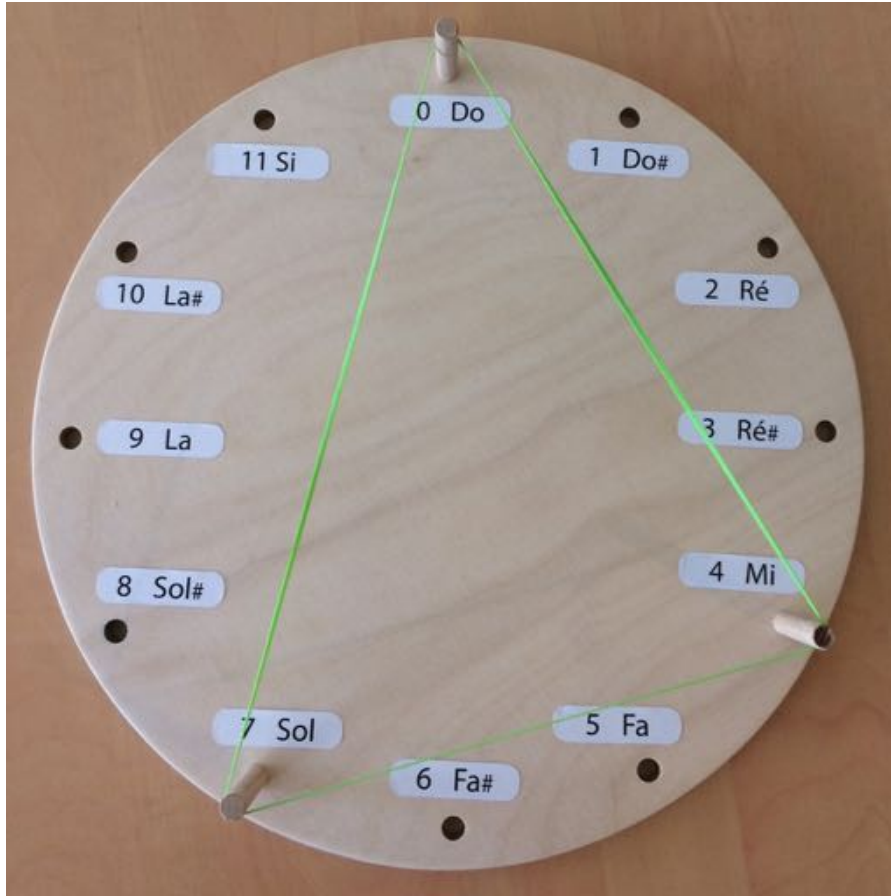
Le carré = l'accord diminué ou (3, 3, 3, 3)



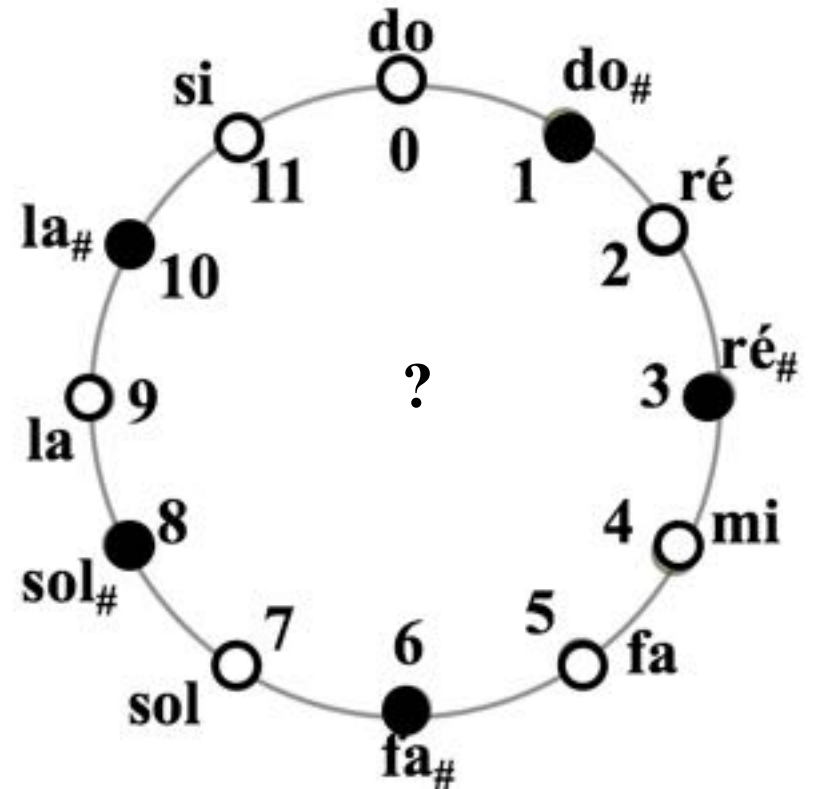
Dessine-moi l'accord majeur ou (4, 3, 5)



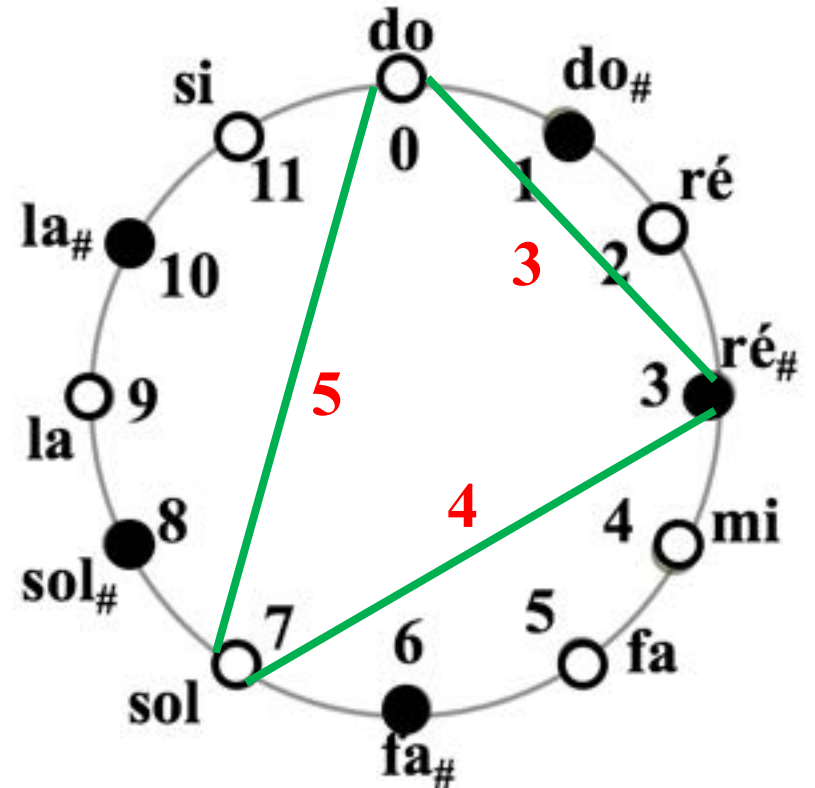
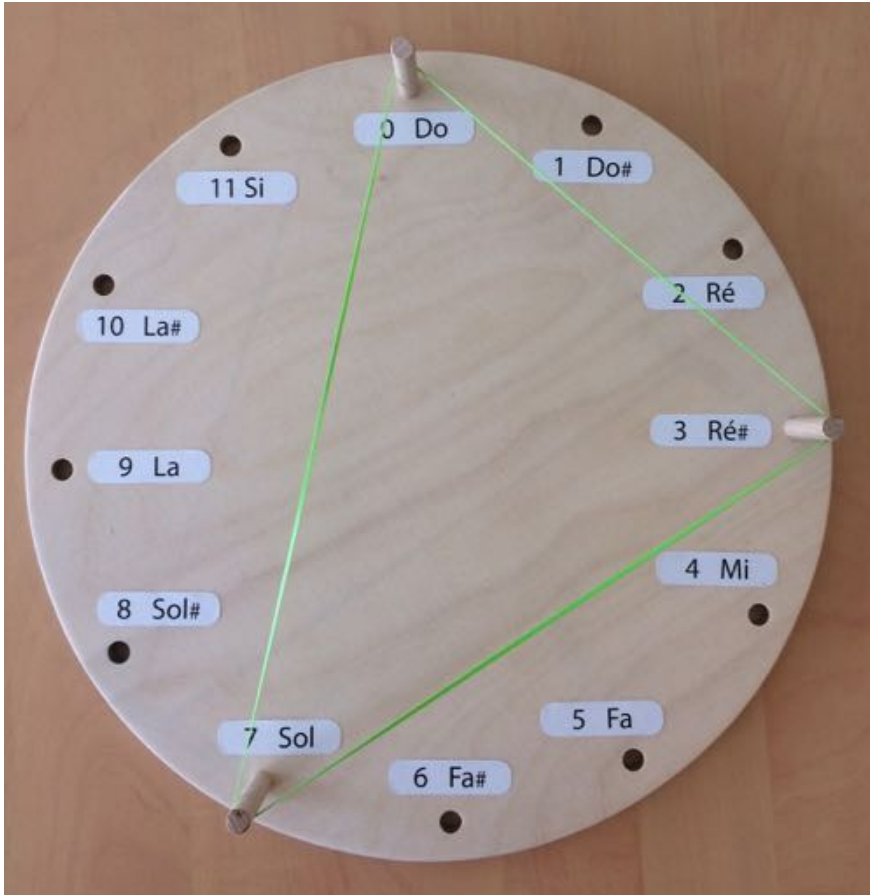
Dessine-moi l'accord majeur ou (4, 3, 5)



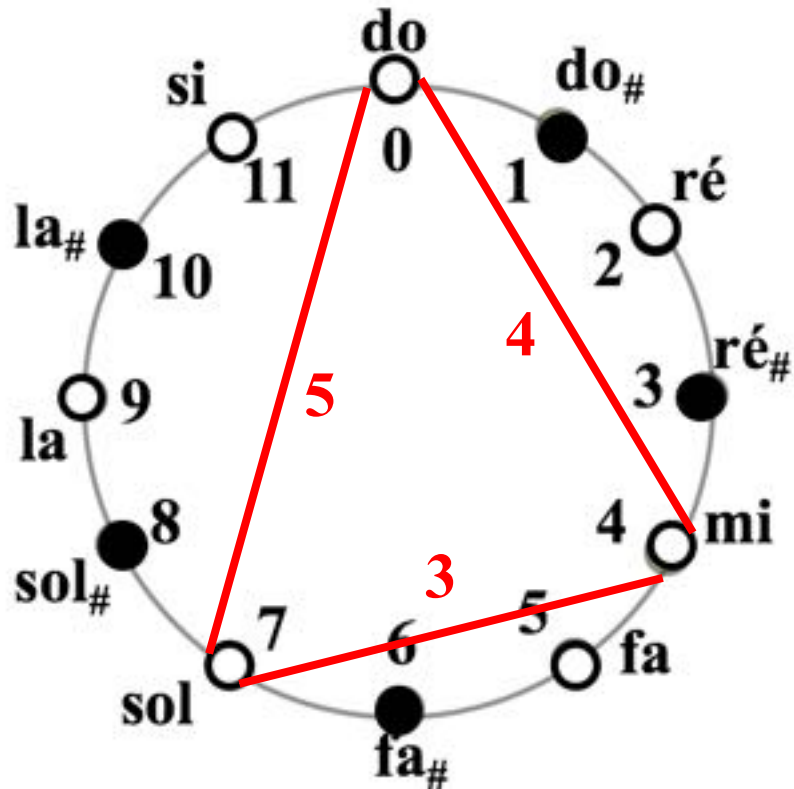
Dessine-moi l'accord mineur ou (3, 4, 5)



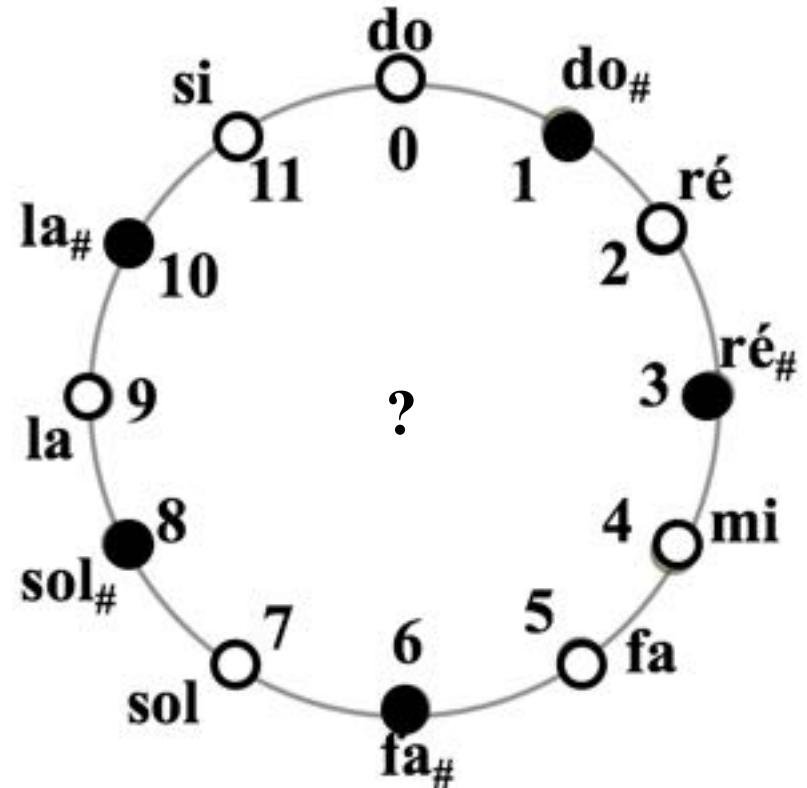
Dessine-moi l'accord mineur ou (3, 4, 5)



Dessine-moi deux accords majeurs

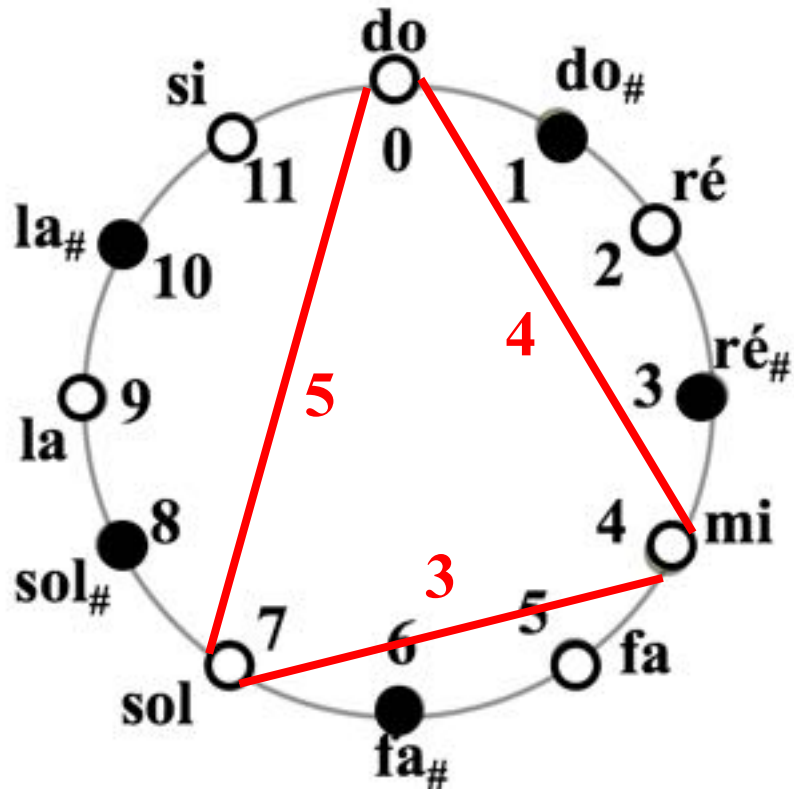


Do majeur

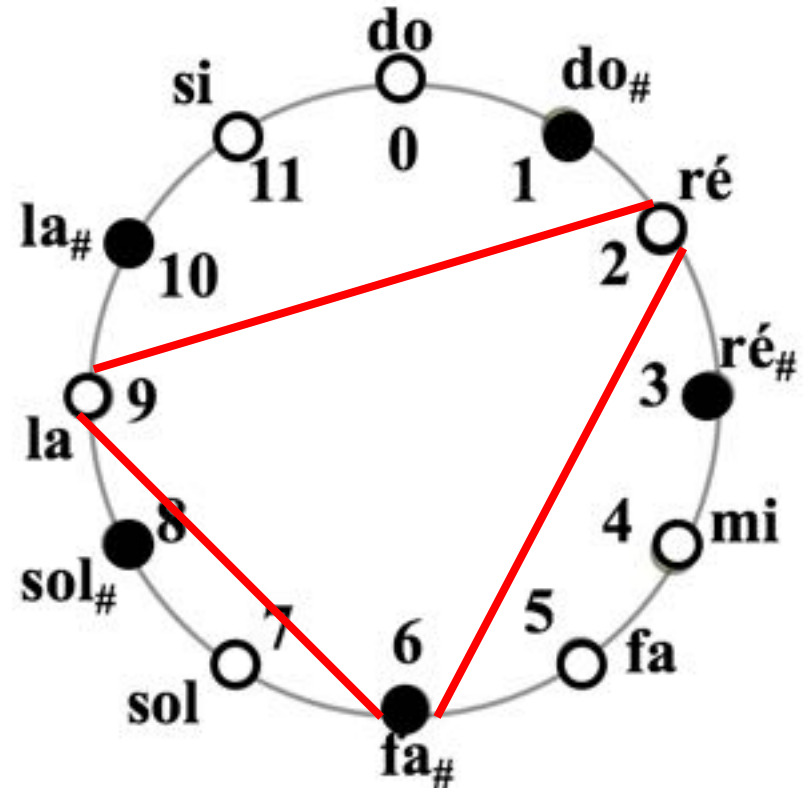


Ré majeur

Dessine-moi deux accords majeurs

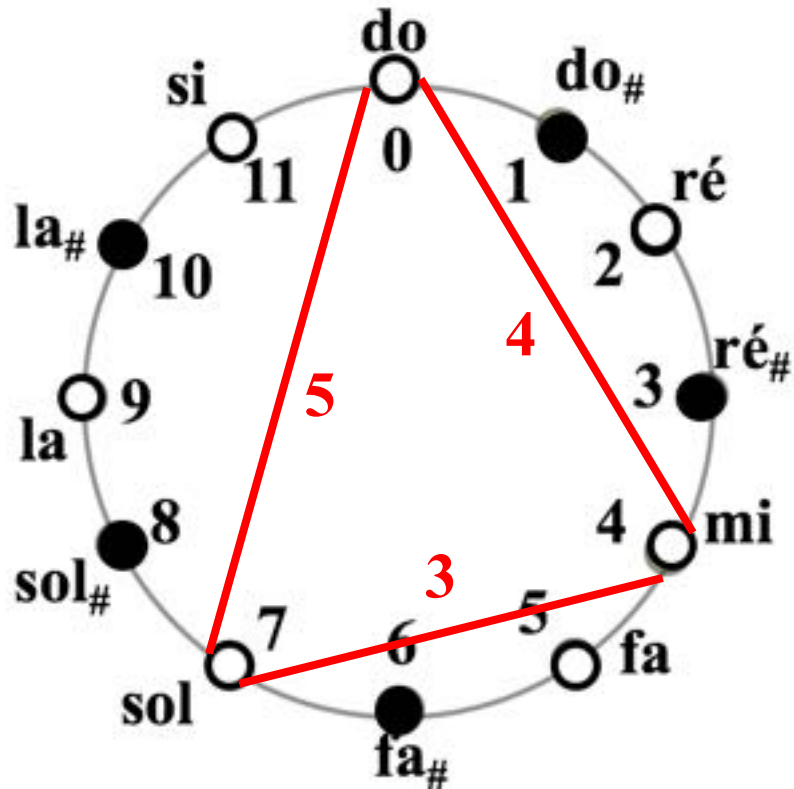


Do majeur

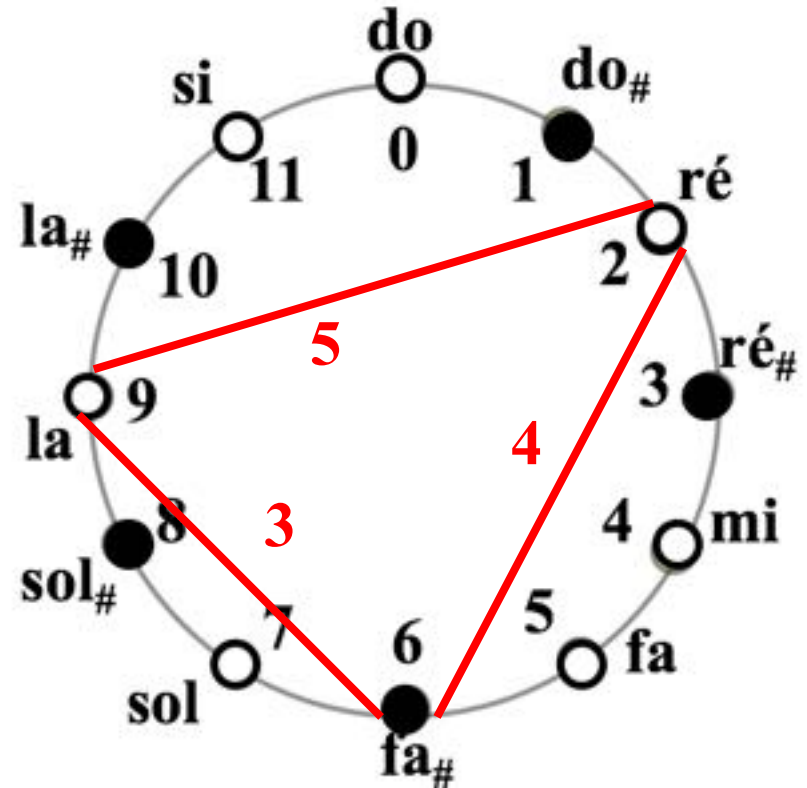


Ré majeur

Dessine-moi deux accords majeurs



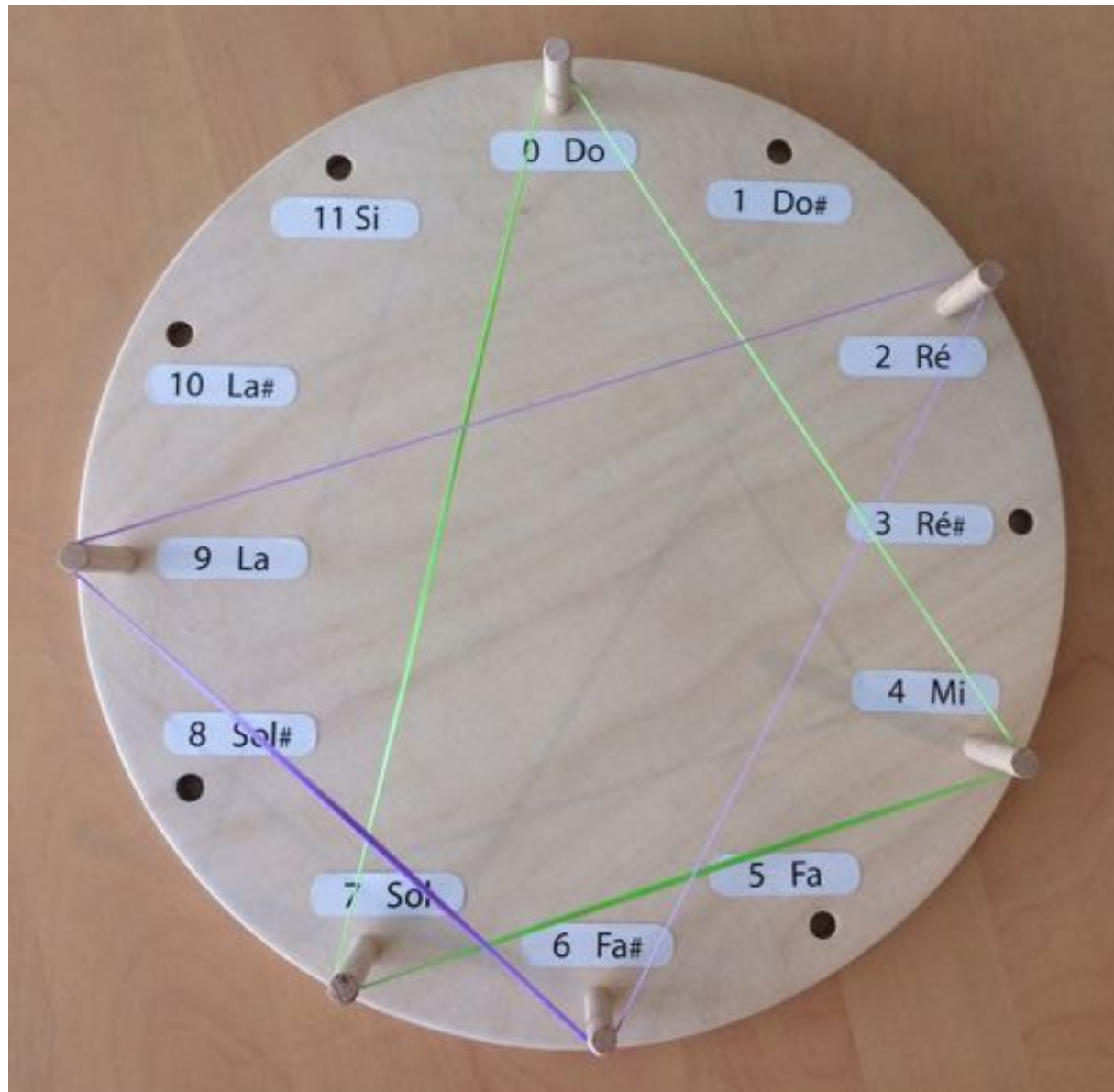
Do majeur



Ré majeur

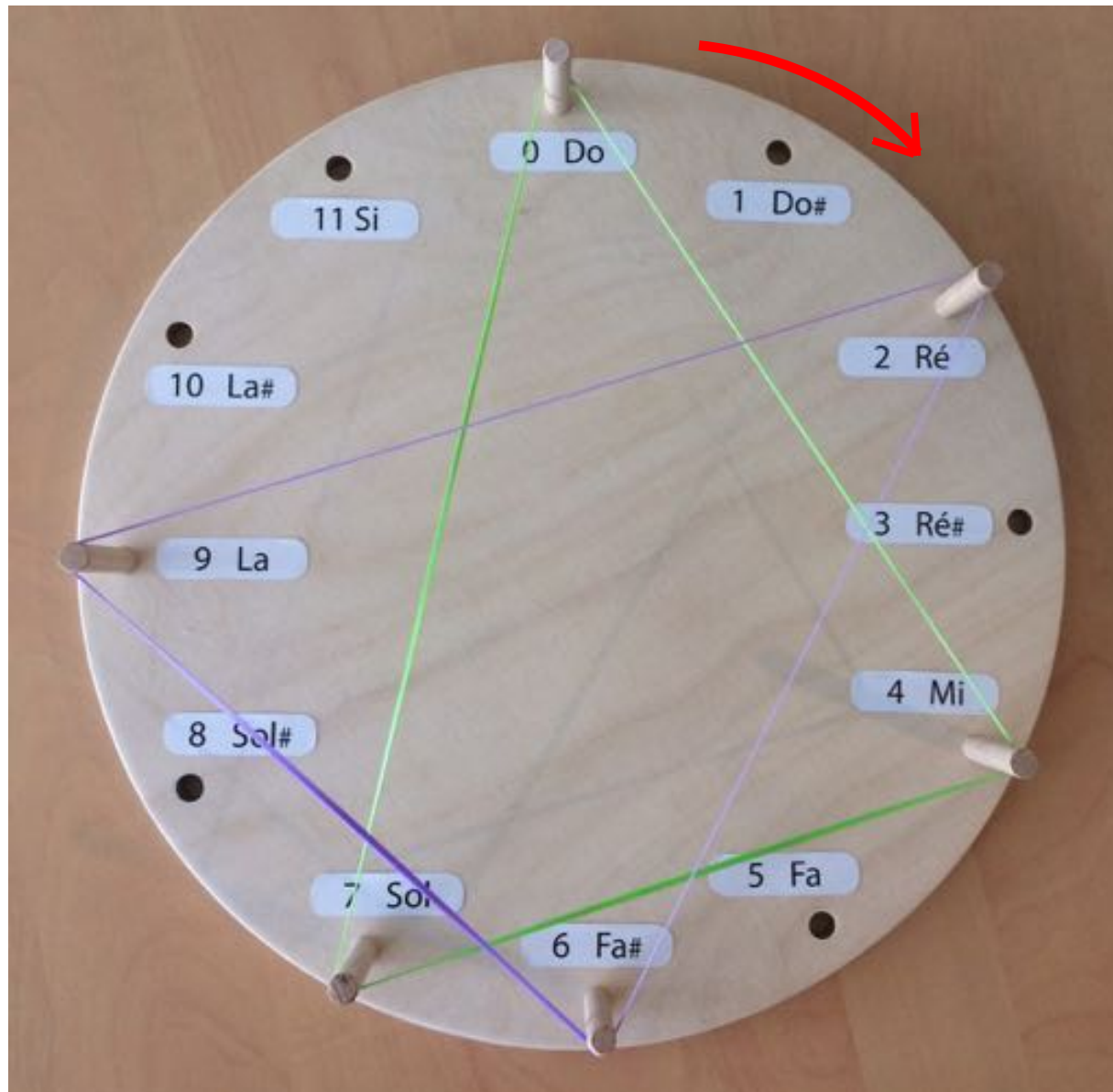
Quel est le rapport entre deux accords majeurs ?

On passe de l'un à l'autre via une ...



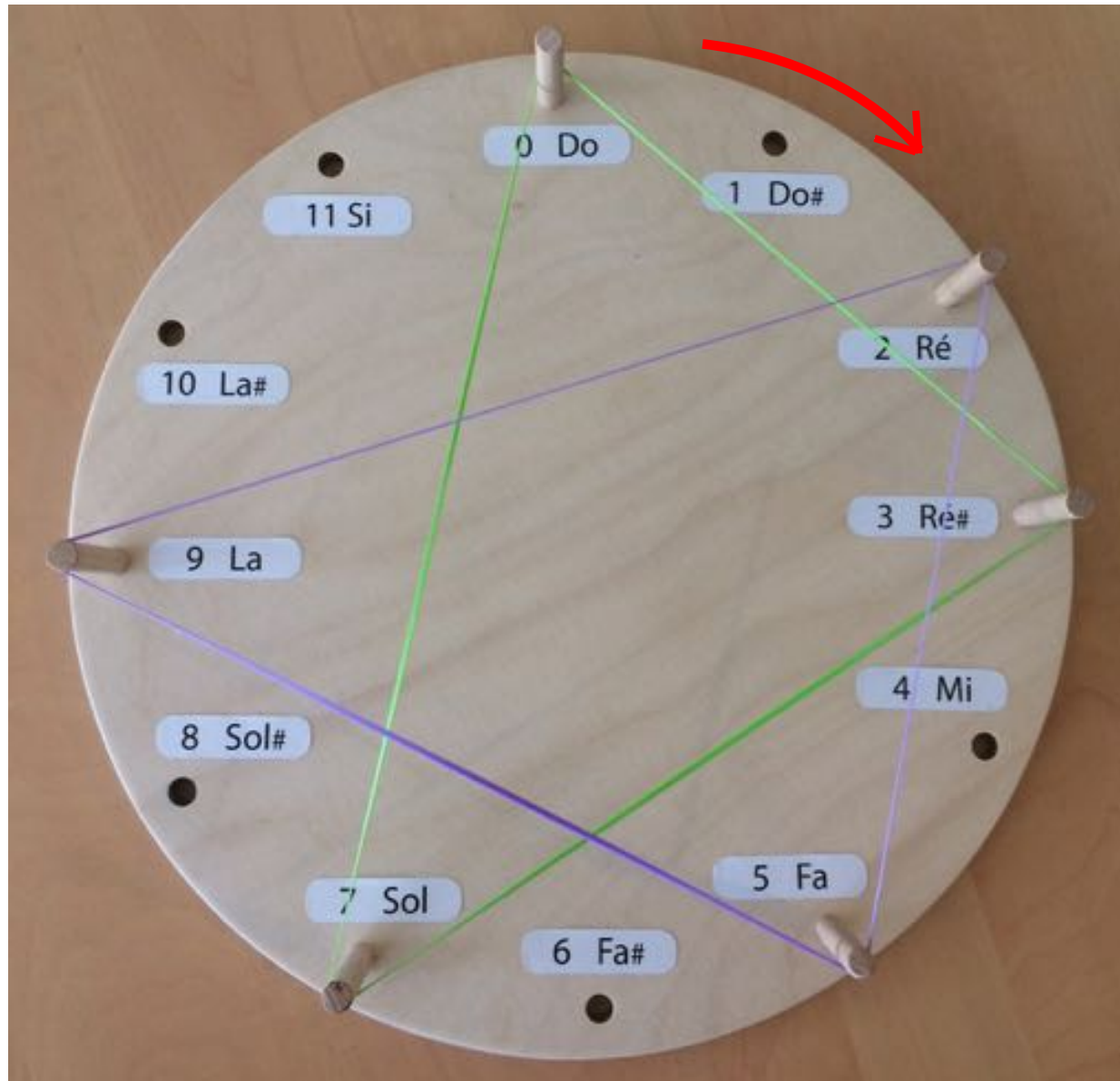
Quel est le rapport entre deux accords majeurs ?

On passe de l'un à l'autre via une **ROTATION**



Quel est le rapport entre deux accords mineurs ?

On passe de l'un à l'autre via une **ROTATION**





ACCORDS MAJEURS

ACCORDS MINEURS

MAGIC IN THE AIR

Feel the magic in the air. Allez, allez, allez
 Levez les mains en l'air. Allez, allez, allez (x2)
 (x4 avec toutes les voix)

Ré
 Comme d'habitude on est calés
La **Si-**
 Comme toujours ça va aller
Sol **Ré**
 On sème l'ambiance à gogo
La **Si-**
 Tous ensemble on fait le show
Sol **Ré**
 On t'invite à la magie Y'a pas de raccourci
La **Si-**
 Oublie tes soucis Viens faire la folie
Sol **Ré**
 On t'invite à la magie Y'a pas de raccourci
La **Si-**
 Oublie tes soucis Oh oh oh oh oh oh
Sol
 Feel the magic in the air ...

The diagram shows a grid of guitar chord diagrams. Major chords are labeled 'ACCORDS MAJEURS' and minor chords 'ACCORDS MINEURS'. Orange boxes highlight the Sol, Ré, and La chords, with arrows pointing to their musical notation. A green box highlights the Si- chord, with an arrow pointing to its musical notation.

Major Chords (ACCORDS MAJEURS):
 Do, Sol, Re, La, Mi, Si

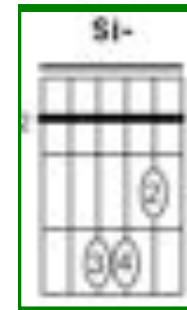
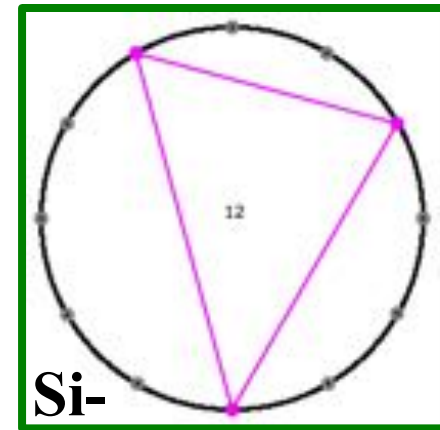
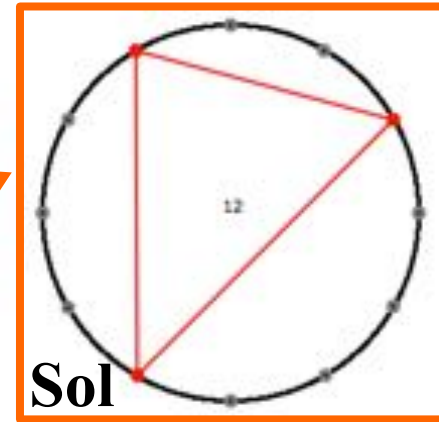
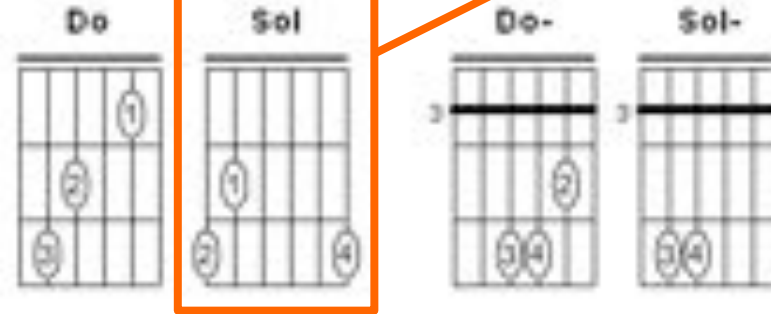
Minor Chords (ACCORDS MINEURS):
 Fa-, Do-, Sol-, Re-, La-, Mi-, Si-

Musical Notation:
 Sol (G4, B4, D5)
 Ré (D4, F#4, A4)
 La (A3, C#4, E4)
 Si- (B3, D4, F#4)



ACCORDS MAJEURS

ACCORDS MINEURS



MAGIC IN THE AIR

Sol Ré
 Feel the magic in the air, Allez, allez, allez
La **Si-**
 Levez les mains en l'air Allez, allez, allez
 (x2)

(x4 avec toutes les voix)

Ré
 Comme d'habitude on est calés
La **Si-**
 Comme toujours ça va aller
Sol **Ré**
 On sème l'ambiance à gogo
La **Si-**
 Tous ensemble on fait le show

Sol **Ré**
 On t'invite à la magie Y'a pas de raccourci
La **Si-**
 Oublie tes soucis Viens faire la folie

Sol **Ré**
 On t'invite à la magie Y'a pas de raccourci
La **Si-**
 Oublie tes soucis Oh oh oh oh oh oh

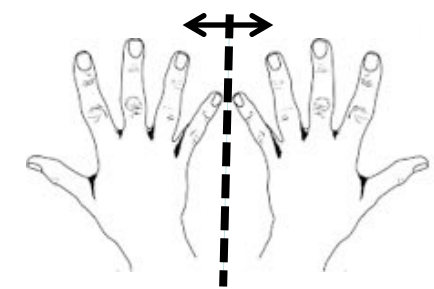
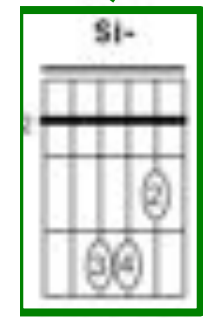
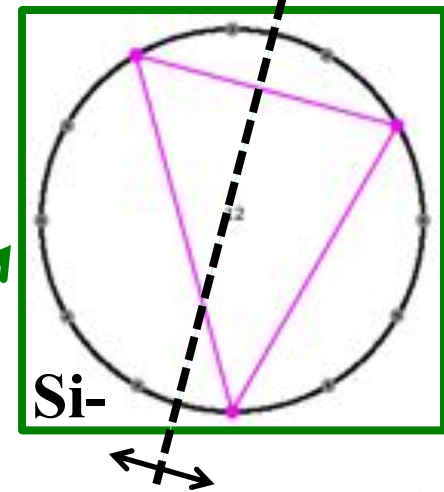
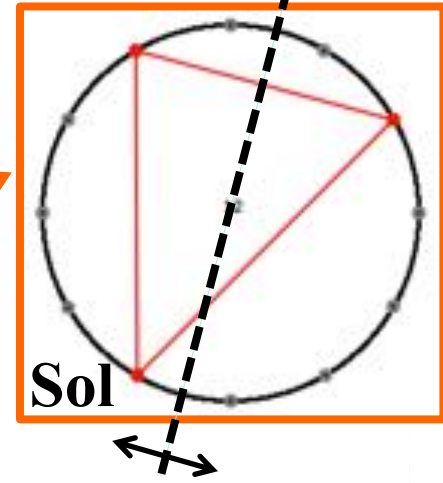
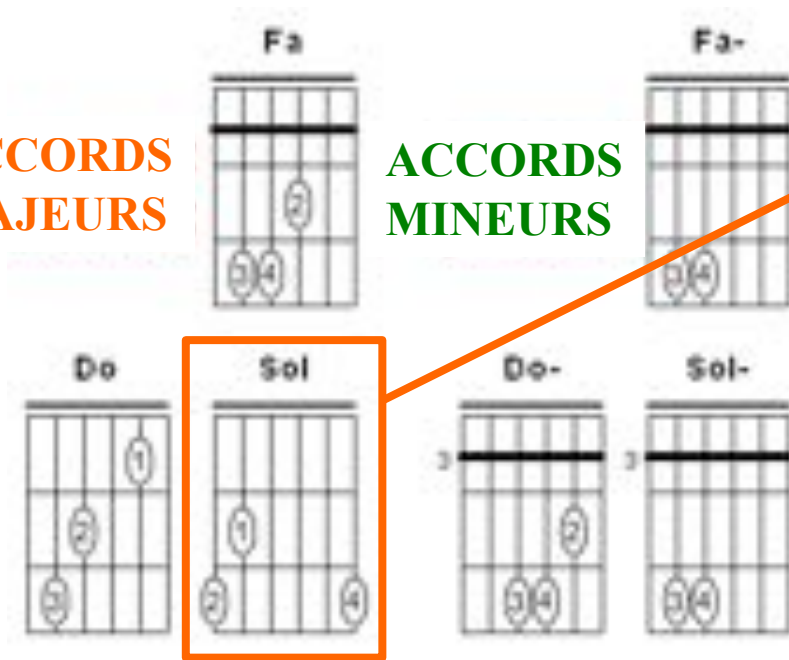
Sol
 Feel the magic in the air ...

**Comment
 passe-t-on
 d'un accord
 majeur à un
 accord
 mineur ?**



ACCORDS MAJEURS

ACCORDS MINEURS



On passe d'un accord majeur à un accord mineur à travers une symétrie !

MAGIC IN THE AIR

Sol **Ré**
 Feel the magic in the air, Allez, allez, allez
La **Si-**
 Levez les mains en l'air Allez, allez, allez
 (x2)

(x4 avec toutes les voix)

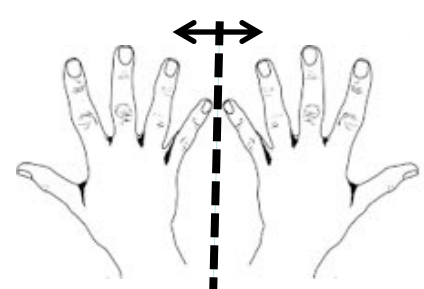
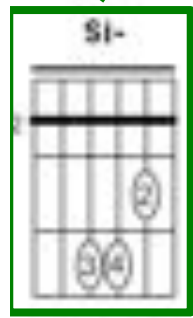
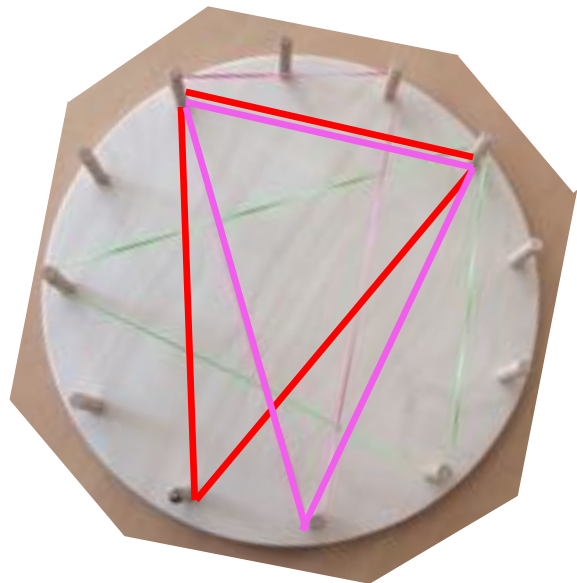
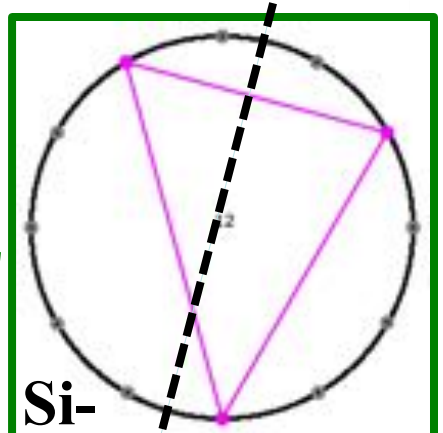
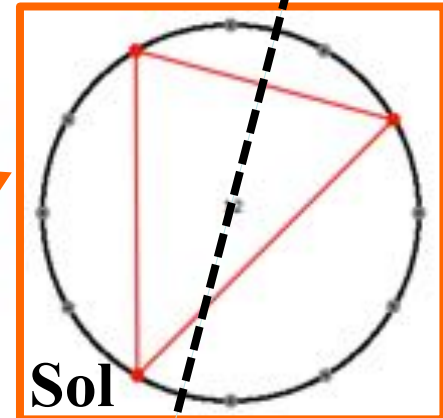
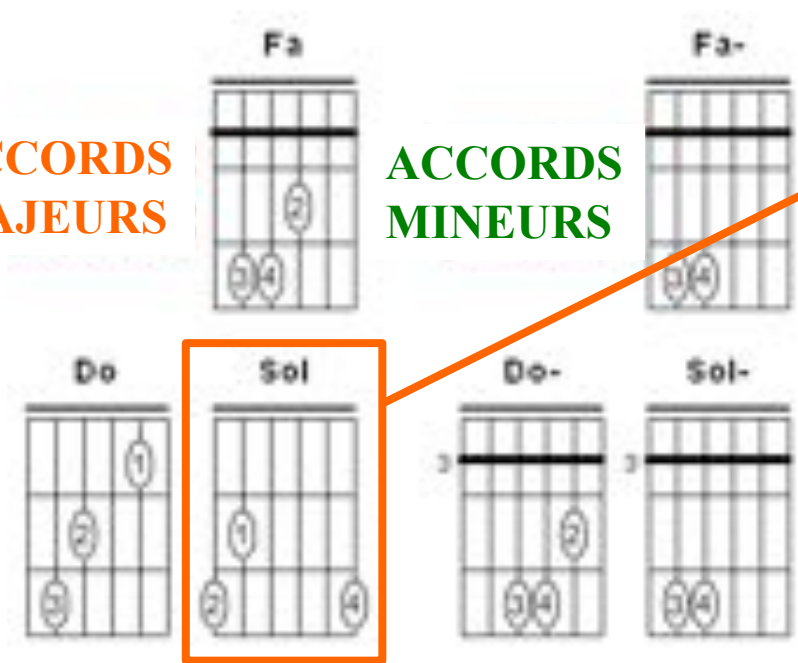
Ré
 Comme d'habitude on est calés
La **Si-**
 Comme toujours ça va aller
Sol **Ré**
 On sème l'ambiance à gogo
La **Si-**
 Tous ensemble on fait le show

Sol **Ré**
 On t'invite à la magie Y'a pas de raccourci
La **Si-**
 Oublie tes soucis Viens faire la folie
Sol **Ré**
 On t'invite à la magie Y'a pas de raccourci
La **Si-**
 Oublie tes soucis Oh oh oh oh oh oh
Sol
 Feel the magic in the air ...



ACCORDS MAJEURS

ACCORDS MINEURS



MAGIC IN THE AIR

Sol Ré

Feel the magic in the air, Allez, allez, allez

La Si-

Levez les mains en l'air Allez, allez, allez
(x2)

(x4 avec toutes les voix)

Ré
Comme d'habitude on est calés

La Si-
Comme toujours ça va aller

Sol Ré
On sème l'ambiance à gogo

La Si-
Tous ensemble on fait le show

Sol Ré
On t'invite à la magie Y'a pas de raccourci

La Si-
Oublie tes soucis Viens faire la folie

Sol Ré
On t'invite à la magie Y'a pas de raccourci

La Si-
Oublie tes soucis Oh oh oh oh oh oh

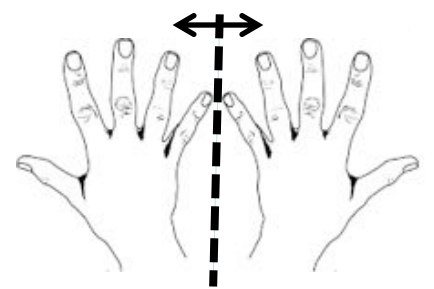
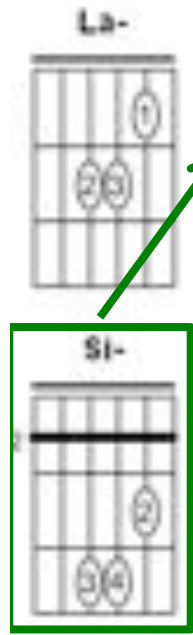
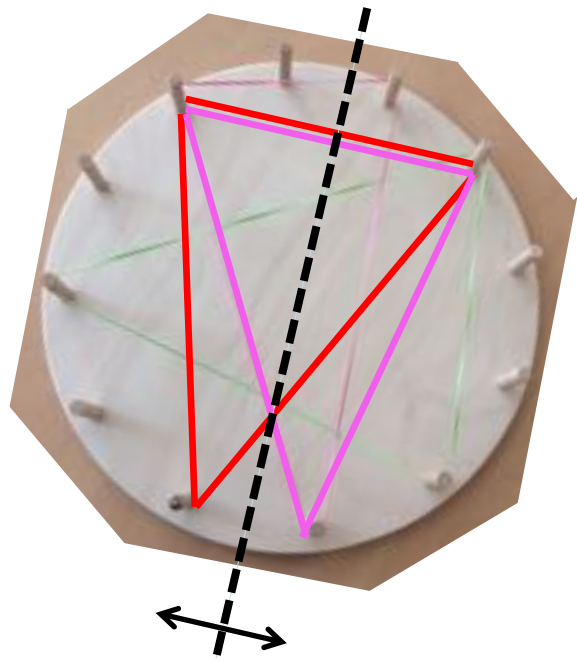
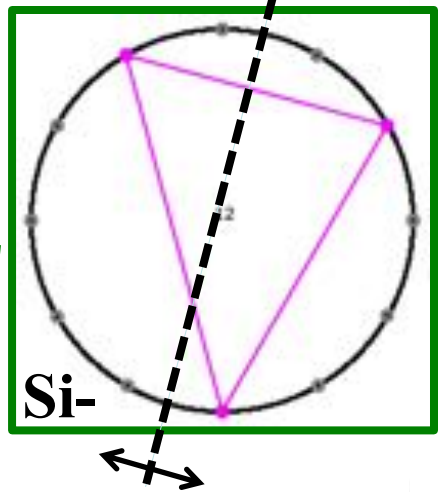
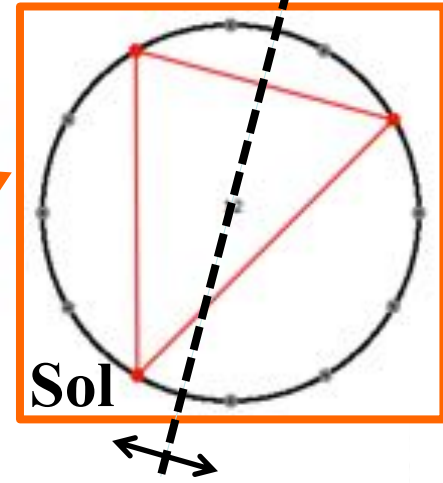
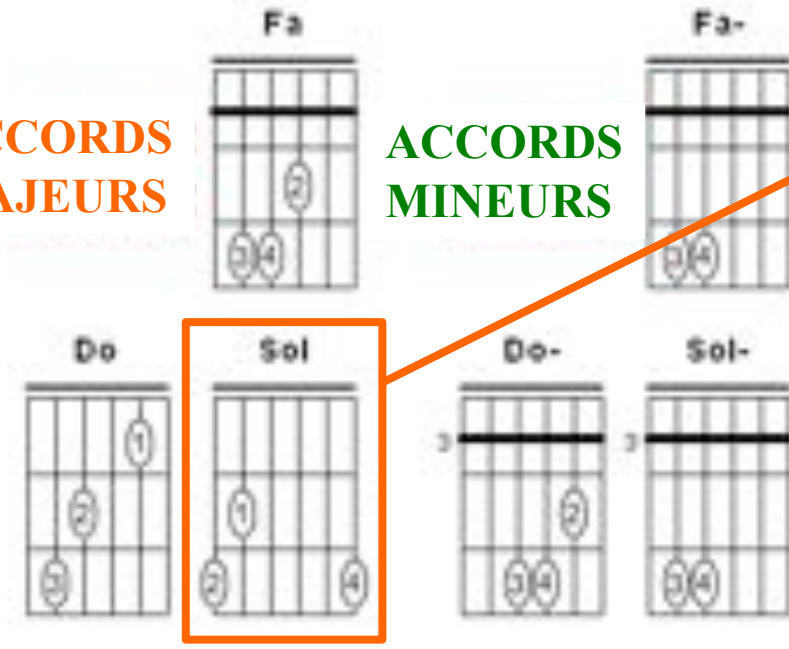
Sol

Feel the magic in the air ...



ACCORDS MAJEURS

ACCORDS MINEURS



MAGIC IN THE AIR

Sol **Ré**
 Feel the magic in the air, Allez, allez, allez
La **Si-**
 Levez les mains en l'air Allez, allez, allez
 (x2)

(x4 avec toutes les voix)

Ré
 Comme d'habitude on est calés
La **Si-**
 Comme toujours ça va aller
Sol **Ré**
 On sème l'ambiance à gogo
La **Si-**
 Tous ensemble on fait le show

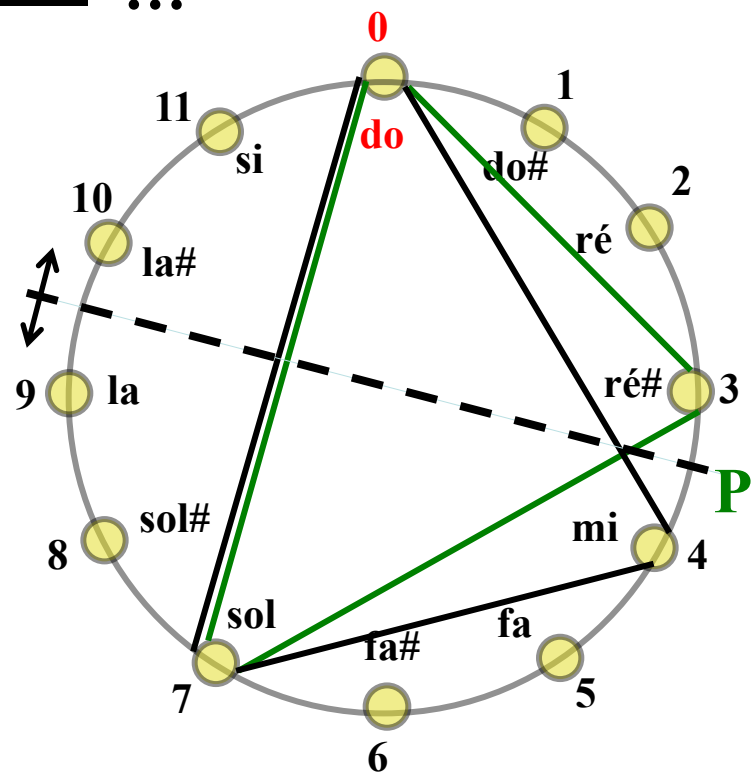
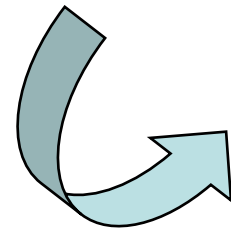
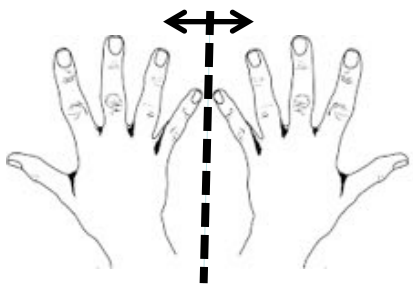
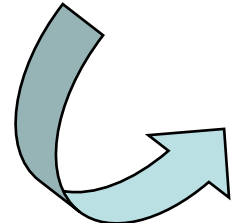
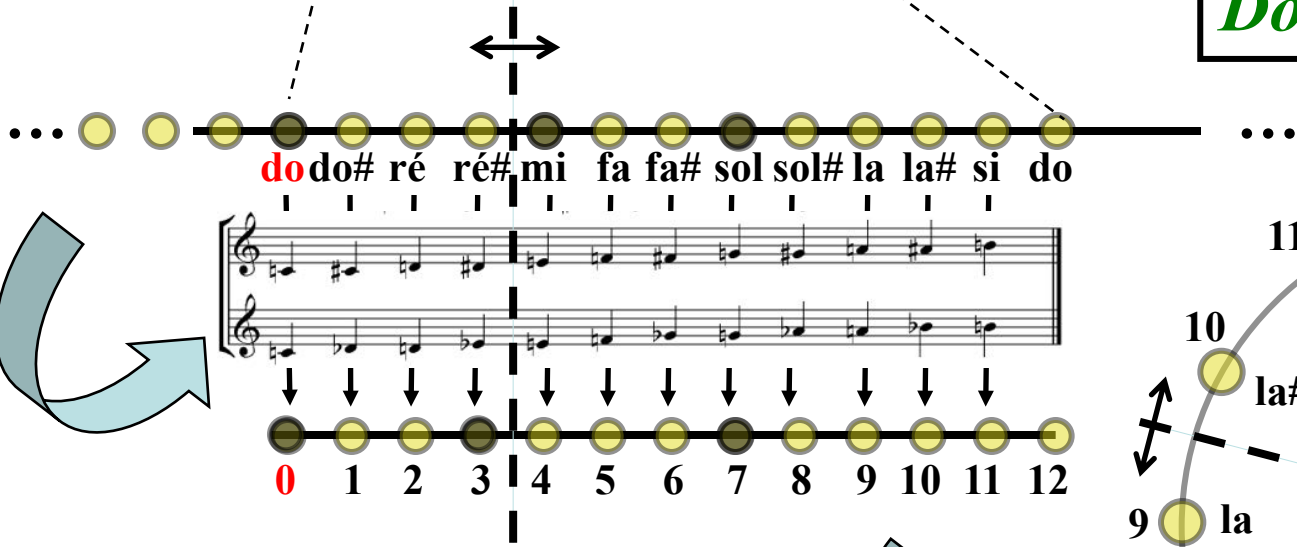
Sol **Ré**
 On t'invite à la magie Y'a pas de raccourci
La **Si-**
 Oublie tes soucis Viens faire la folie
Sol **Ré**
 On t'invite à la magie Y'a pas de raccourci
La **Si-**
 Oublie tes soucis Oh oh oh oh oh oh
Sol
 Feel the magic in the air ...

Les inversions sont des symétries axiales



P comme **parallèle**

Do maj = {0,4,7}
Do min = {0,3,7}



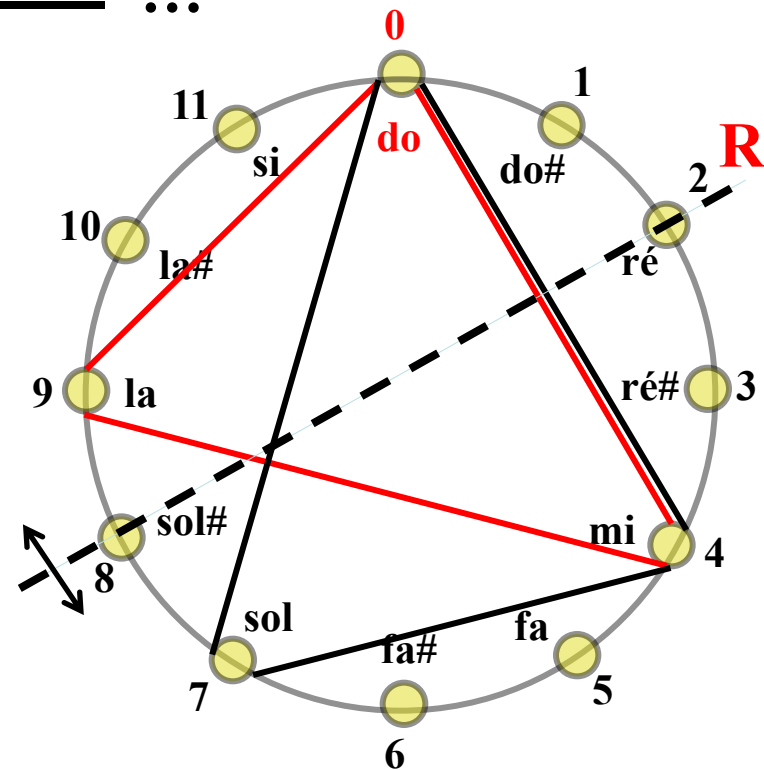
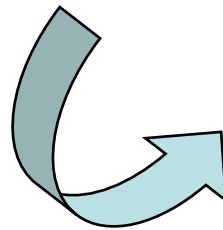
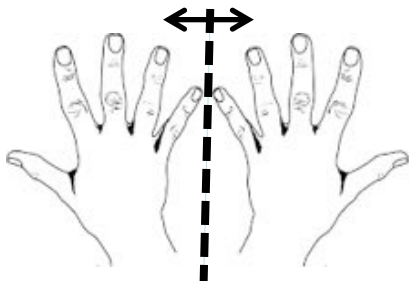
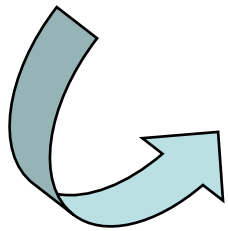
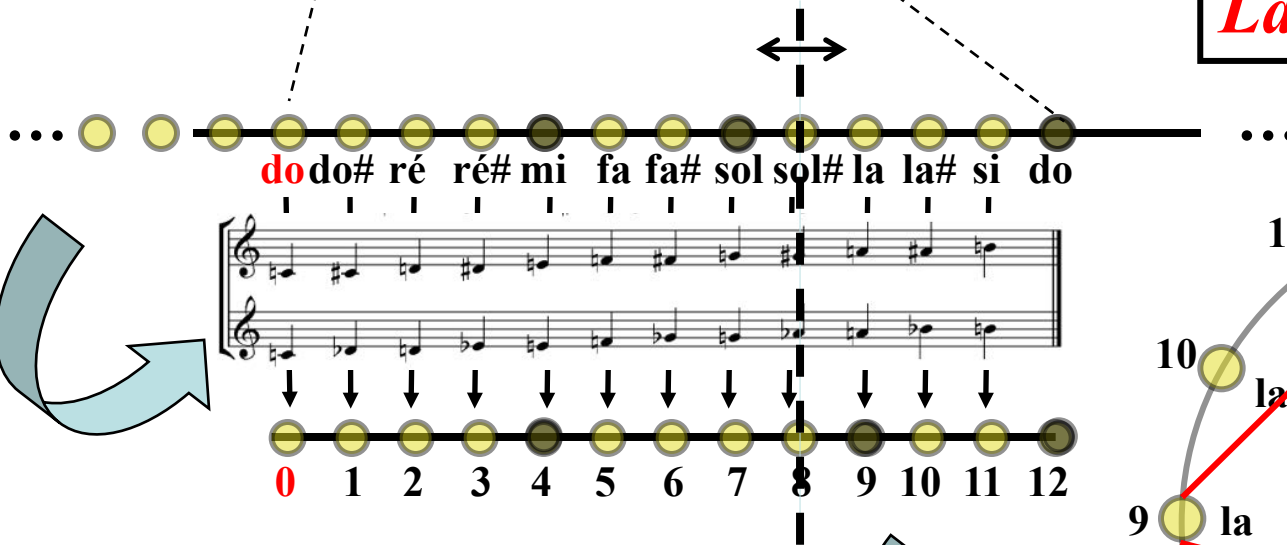
Les inversions sont des symétries axiales



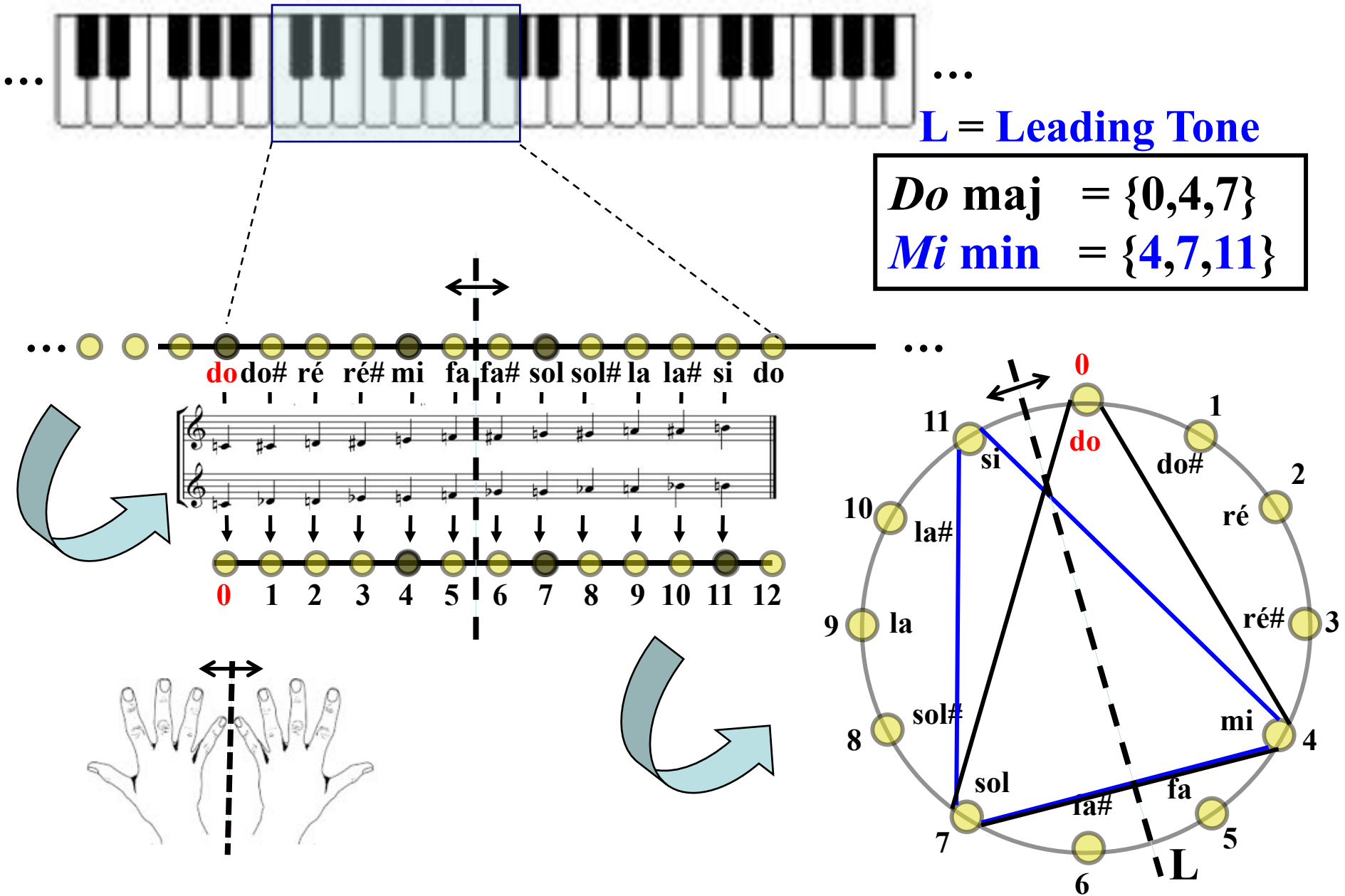
R comme **relatif**

Do maj = {0,4,7}

La min = {0,4,9}



Les inversions sont des symétries axiales



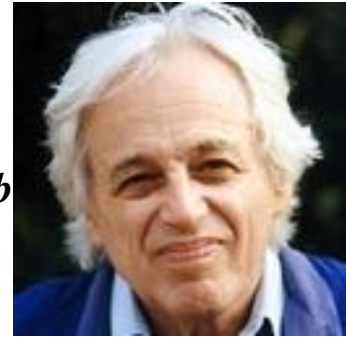
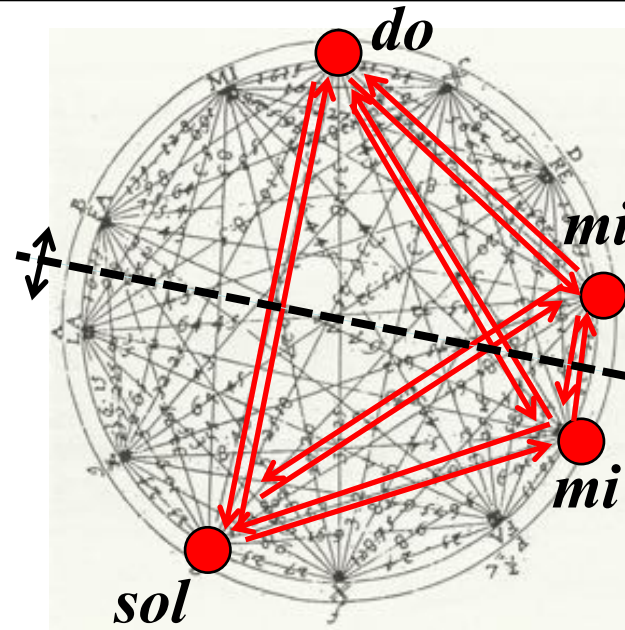
Approches permutatonnelles en musique savante

II 4. Marin Mersenne, *Harmonicorum Libri XII*, 1648

LIBER SEPTIMVS.
DE CANTIBVS, SEV CANTILENIS,
EARVMQ; NVMERO, PARTIBVS, ET SPECIEBVS.

Tabula Combinationis ab 1 ad 22.

I	1
II	2
III	6
IV	24
V	110
VI	710
VII	3040
VIII	40310
IX	361880
X	3618800
XI	39916800
XII	479001600
XIII	6127016800
XIV	87178191000
XV	1307674968000
XVI	20911789888000
XVII	315687418096000
XVIII	6401373705718000
XIX	121648100408810000
XX	24313010081766400000
XXI	50909418717094400000
XXII	1114000717777607480000



Six Bagatelles
(G. Ligeti, 1953)



Varietas, seu Combinatio quatuor notarum.

Musical score for "Varietas, seu Combinatio quatuor notarum" showing 22 numbered measures across four staves. A red arrow points from the table above to the score.

Une chanson permutationnelle

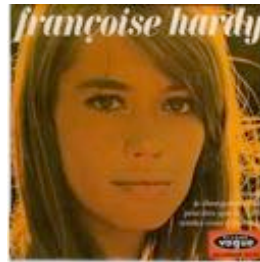
Se telefonando, 1966 (Maurizio Costanzo/Ennio Morricone) / Mina



(min. 0'53'')

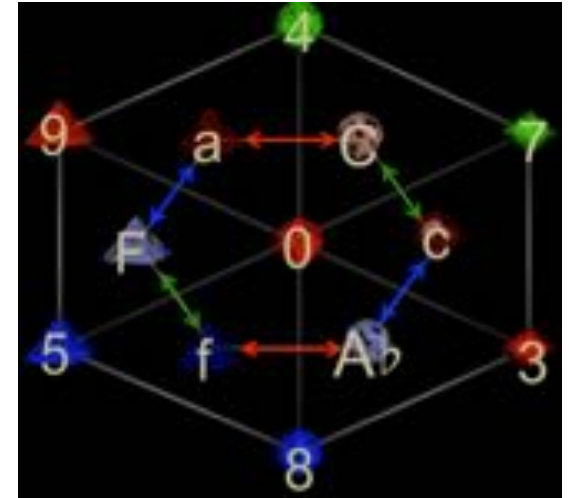


Ennio Morricone, Ma musique, ma vie.
Entretiens avec Alessandro De Rosa,
éditions Seguir, 2018. Traduit de
l'italien par Florence Rigollet.



Je changerais d'avis,
(Françoise Hardy)

L'espace harmonique



C	c	C#	c#	D	d
E _b	e _b	E	e	F	f
F#	f#	G	g	G#	g#
A	a	B _b	b _b	B	b

Chord enumeration