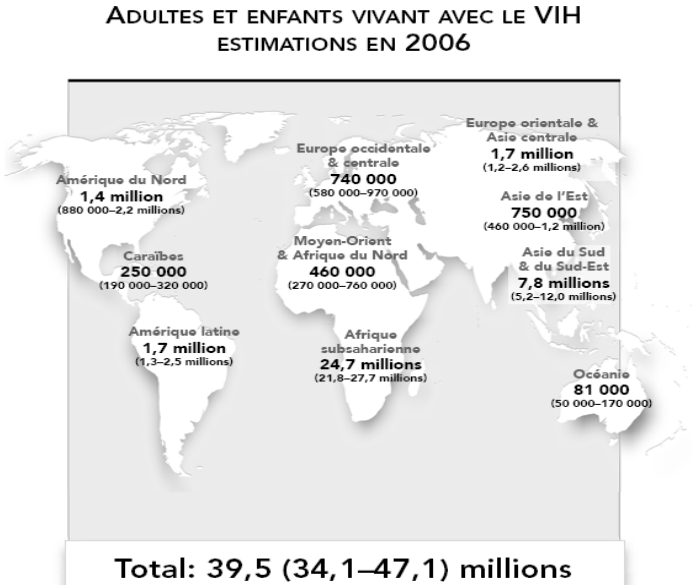
ANTIVIRAUX ACTIFS SUR LE VIRUS HIV ET PHARMACOTHERAPIE DU SIDA

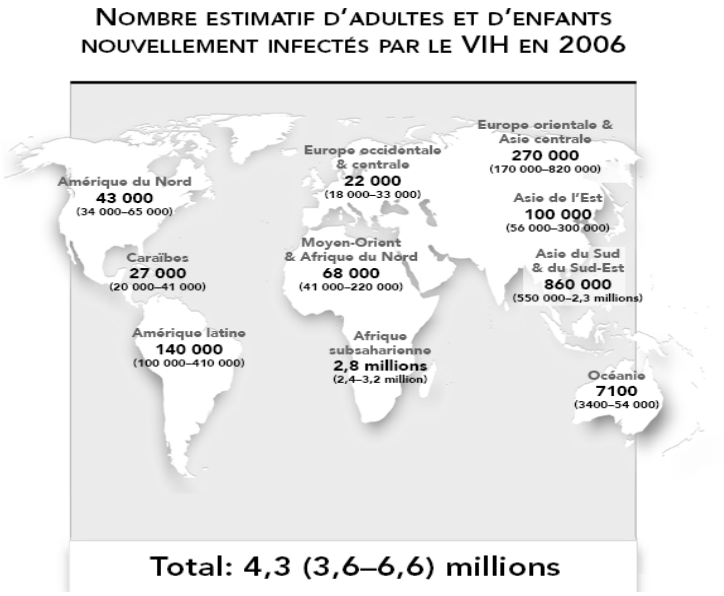
Enseignant : F. Van Bambeke

FARM2233 – année 2011-2012

Le SIDA: données épidémiologiques



Le SIDA: données épidémiologiques



Le SIDA: mortalité en Afrique (2001)

Rank		% of total
1	HIV/AIDS	**20.6**
2	Acute lower respiratory infections	**10.3**
3	Malaria	**9.1**
4	Diarrhoeal diseases	**7.3**
5	Perinatal conditions	**5.9**
6	Measles	**4.9**
7	Tuberculosis	**3.4**
8	Cerebrovascular disease	**3.2**
9	Ischaemic heart disease	**3.0**
10	Maternal conditions	**2.4**

The World Health Report 2000, WHO

Le SIDA: données épidémiologiques

BELGIUM

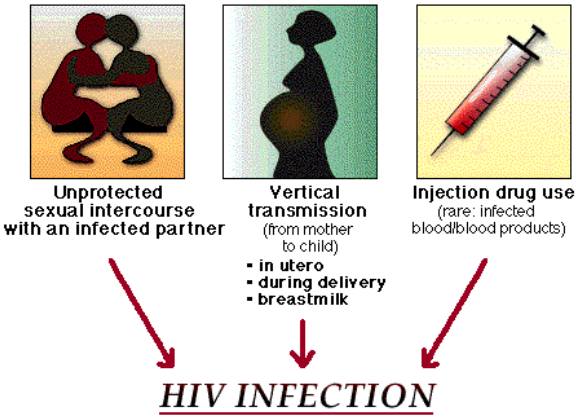
I. DEMOGRAPHIC, SOCIAL AND ECONOMIC INDICATORS

Estimated Population	10 419 000
Population Growth Rate	0.2%
Life expectancy at birth	
Women 81 Men	75
Human Development Index	9
Human Poverty Index	
Rank	13[1]
Value	12.4[2]
Percentage of people with less than US$ 2 a day	–
Per Capita Gross National Income, ppp, Intl dollar rate	31 360
Per Capita Government Expenditure on Health at Intl dollar rate	1902

II. HIV AND AIDS ESTIMATES

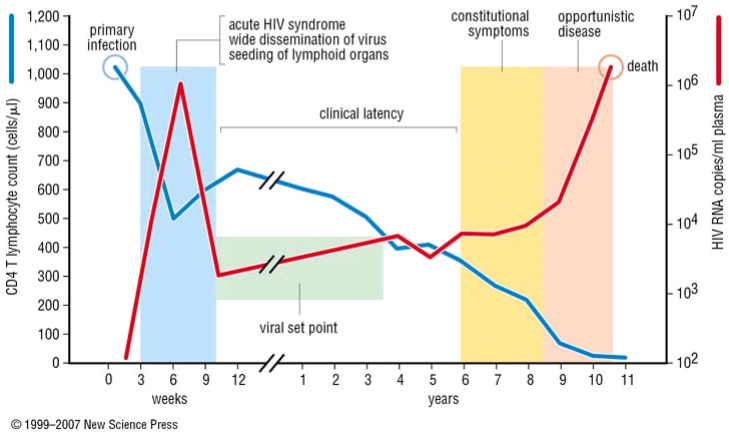
Number of people living with HIV	14 000 [8100 – 22 000]
Adults aged 15 to 49 HIV prevalence rate	0.3 [0.2 – 0.5%]
Adults aged 15 and over living with HIV	14 000 [8100 – 22 000]
Women aged 15 and over living with HIV	5400 [2800 – 9500]
Deaths due to AIDS	<100 [<200]

Le SIDA: voies de transmission

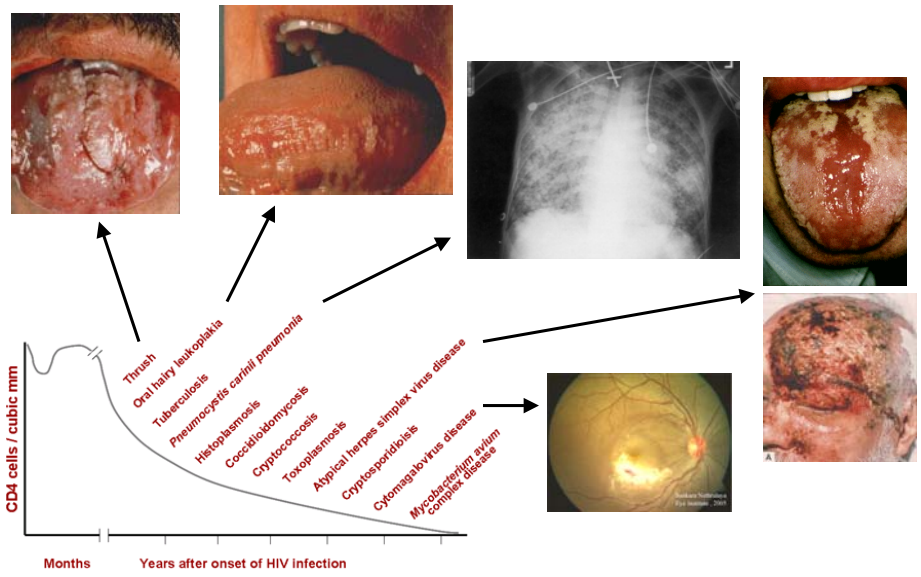


L'infection à HIV: histoire naturelle

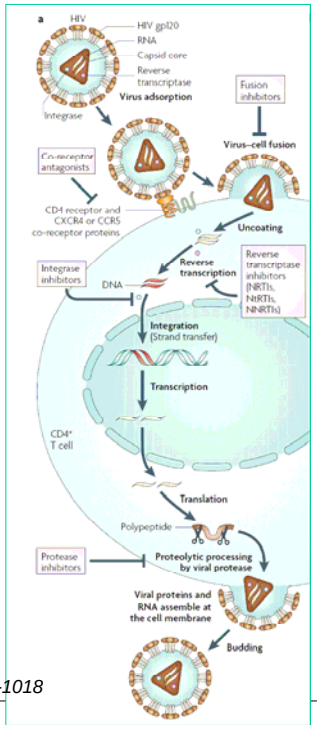
From **Immunity: The Immune Response in Infectious and Inflammatory Disease**
by DeFranco, Locksley and Robertson



L'infection à HIV: infections opportunistes



Cible des médicaments actifs sur le HIV



3

4

5

1

2

De Clercq, Nature Rev. Drug Discov.(2007) 6:1001-1018

Historique des médicaments actuels

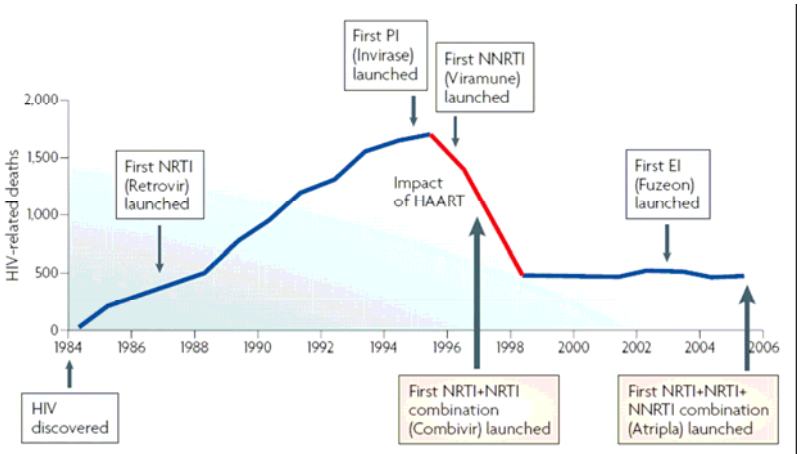
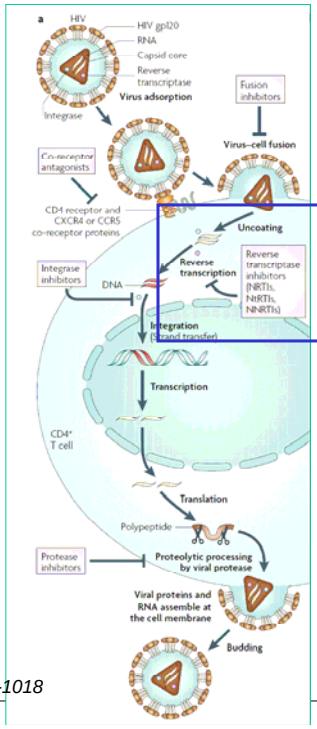


Figure 1 | **Timeline of the development of the HIV market (1984–2006) and UK HIV-related deaths (1894–2005)**[3]. EI, entry inhibitors; HAART, highly active antiretroviral therapy; NNRTI, non-nucleoside reverse transcriptase inhibitor; NRTI, nucleoside reverse transcriptase inhibitor; PI, protease inhibitor.

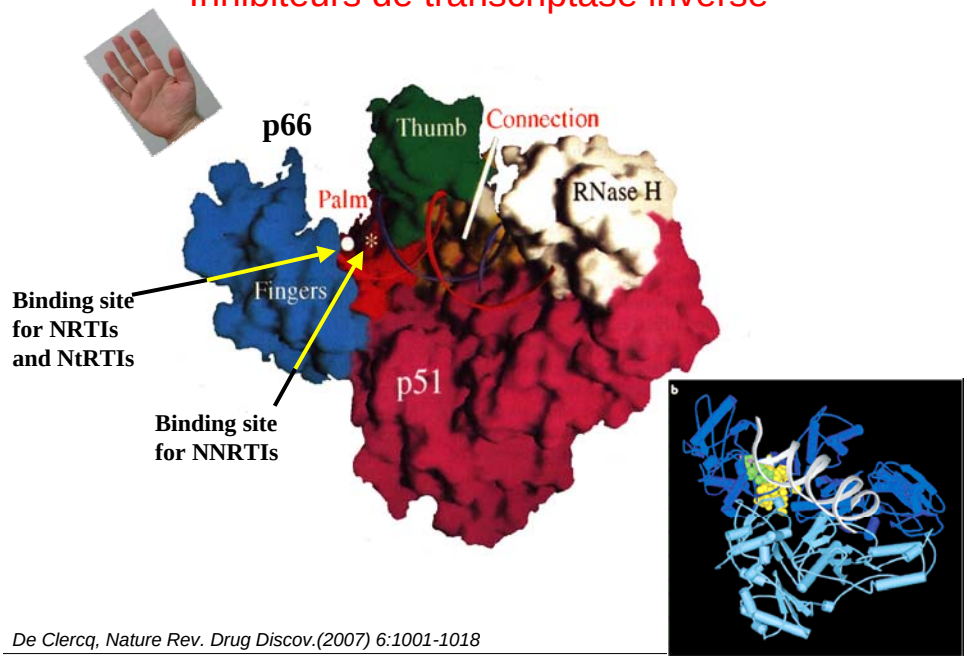
Oversteegen et al, Nature Rev. Drug Discov.(2007) 6:951-952

Cible des médicaments actifs sur le HIV



De Clercq, Nature Rev. Drug Discov.(2007) 6:1001-1018

Inhibiteurs de transcriptase inverse



De Clercq, Nature Rev. Drug Discov.(2007) 6:1001-1018

Inhibiteurs de transcriptase inverse

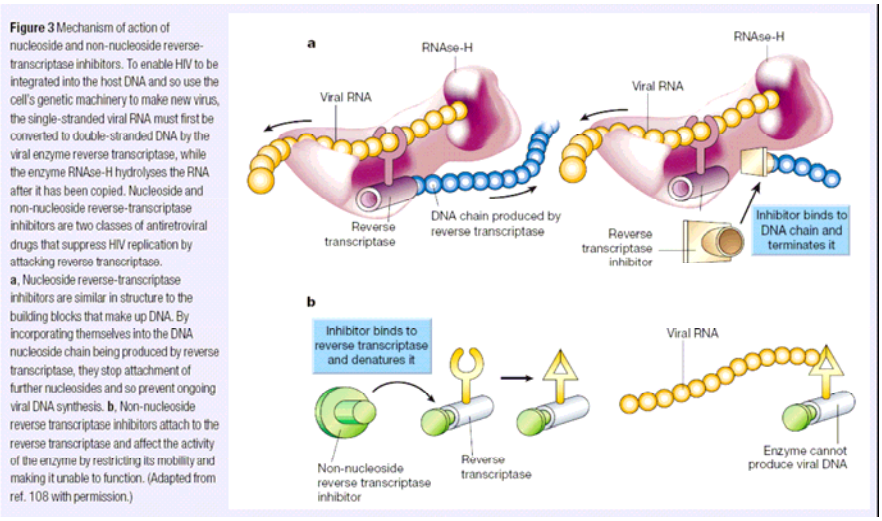
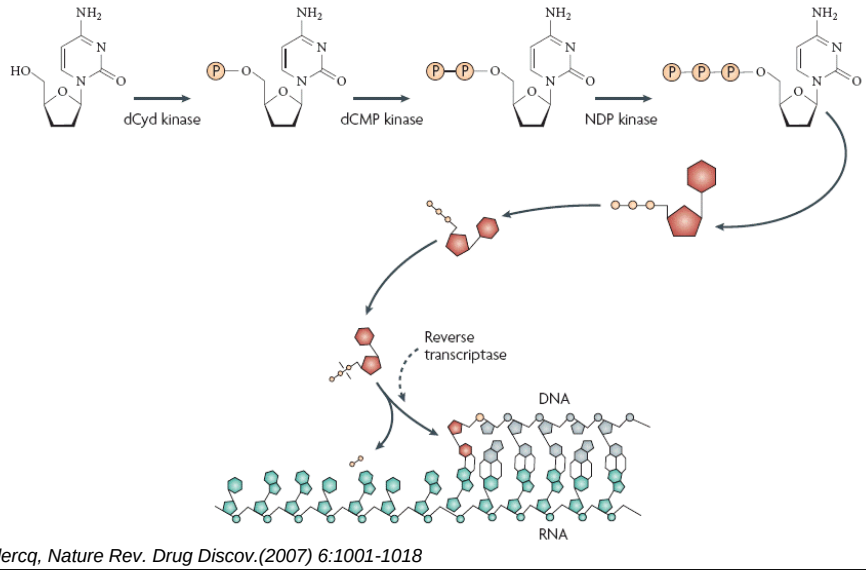


Figure 3 Mechanism of action of nucleoside and non-nucleoside reverse-transcriptase inhibitors. To enable HIV to be integrated into the host DNA and so use the cell's genetic machinery to make new virus, the single-stranded viral RNA must first be converted to double-stranded DNA by the viral enzyme reverse transcriptase, while the enzyme RNAse-H hydrolyses the RNA after it has been copied. Nucleoside and non-nucleoside reverse-transcriptase inhibitors are two classes of antiretroviral drugs that suppress HIV replication by attacking reverse transcriptase. **a**, Nucleoside reverse-transcriptase inhibitors are similar in structure to the building blocks that make up DNA. By incorporating themselves into the DNA nucleoside chain being produced by reverse transcriptase, they stop attachment of further nucleosides and so prevent ongoing viral DNA synthesis. **b**, Non-nucleoside reverse transcriptase inhibitors attach to the reverse transcriptase and affect the activity of the enzyme by restricting its mobility and making it unable to function. (Adapted from ref. 108 with permission.)

Richman, Nature (2001) 410:995-1001

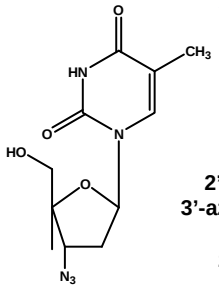
Mode d'action des inhibiteurs de transcriptase inverse analogues nucléosidiques/nucléotidiques



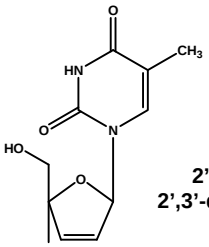
De Clercq, Nature Rev. Drug Discov.(2007) 6:1001-1018

analogues nucléosidiques

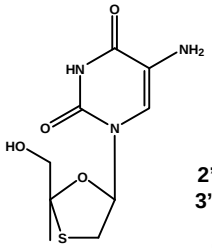
Analogues des bases pyrimidiques



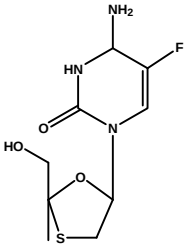
2',3'-Dideoxy-
3'-azidothymidine
(AZT)
zidovudine



2',3'-Didehydro-
2',3'-dideoxythymidine
(D4T)
stavudine



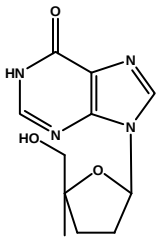
2',3'-Dideoxy-
3'-thiacytidine
(3TC)
lamivudine



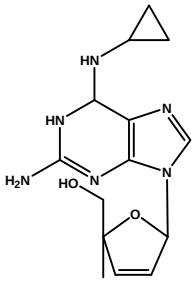
(FTC)
emtricitabine

analogues nucléosidiques

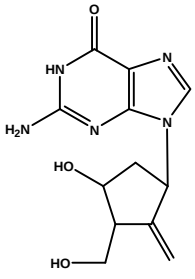
Analogues des bases puriques



2',3'-Dideoxy-inosine
(DDI)
didanosine

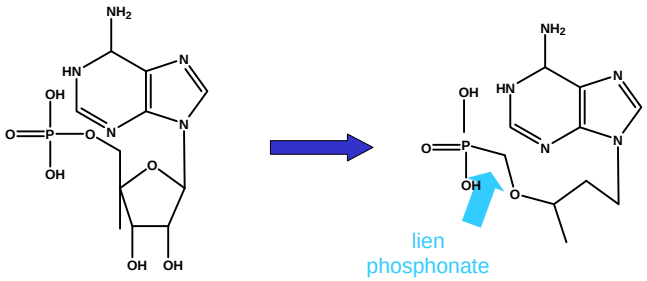


2',3'-Dideoxy-inosine
(ABC)
abacavir



entecavir

analogues nucléotidiques: tenofovir



adenosine-mono-P tenofovir

Pharmacocinétique

- bonne biodisponibilité orale

didanosine : résorption réduite par l'acidité gastrique ou la prise de nourriture.

- distribution dans les liquides de l'organisme, y compris le LCR
- $T_{½}$ plasmatique courte mais fréquence d'administration dictée par $T_{½}$ cellulaire des formes triphosphorylées

Agent	Biodis-ponibilité orale (%)	$t_{1/2}$ sérique (h)	$t_{1/2}$ des formes triphosphate (h)	Voies d'élimimination	Principal dosage (adulte)
Zidovudine	63	1.1	3-4	glucurono-conjugaison et elimination rénale	300 mg / 12 h
Didanosine	40 (à jeûn)	1.5	8-24	métabolisme cellulaire	400 mg / 24 h
Stavudine	86	1.1	3	excrétion rénale	40 mg / 12 h
Lamivudine	86	2.5	11-14	excrétion rénale	300 mg / 24 h
Abacavir	83	1.5	3.3	glucurono-conjugaison et carboxylation	300 mg / 24 h
Tenofovir	39 (avec un repas)	12-14	>12 *	excrétion rénale	300 mg / 24 h
Emtricitabine	93	10	>24		200 mg /24 h

Combinaisons et compliance

Table 1 | **Overview of currently launched fixed-dose combination products for the treatment of HIV***

Drug	Class	Pill volume	Total pills per day	Dosing schedule	Combination product	Total pills per day	Dosing schedule	2006 sales‡
Tenofovir	NRTI	300 mg		Once daily	Truvada		Once daily	1,125
Emtricitabine	NRTI	200 mg		Once daily	Atripla		Once daily	174
Efavirenz	NNRTI	600 mg		Once daily		–	–	–
Abacavir	NRTI	300 mg		Once daily	Epzicom		Once daily	396
Lamivudine	NRTI	300 mg		Once daily	Trizivir		Twice daily	478
Zidovudine	NRTI	300 mg		Twice daily	Combivir		Twice daily	789

Oversteegen et al, Nature Rev. Drug Discov.(2007) 6:951-952

Effets secondaires

Communs à la classe

- hyperlactacidémie (menant parfois à une acidose sévère)
- hépatomégalie et stéatose
  (inhibition de la DNA-polymérase impliquée dans la réplication du DNA mitochondrial (surtout pour didanosine, stavudine, et zidovudine).

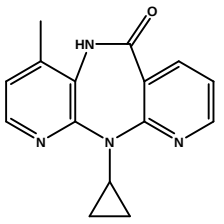
Particuliers à certaines molécules

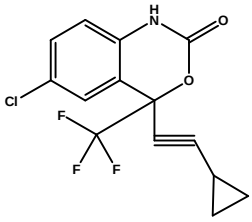
molécule	Effet secondaire
zidovudine	Anémie neutropénique
didanosine	pancréatite, neuropathie périphérique
stavudine	neuropathie périphérique
abacavir	réactions d'hypersensibilité
tenofovir	toxicité rénale à long terme
emtricitabine	hyperpigmentation des mains et pieds

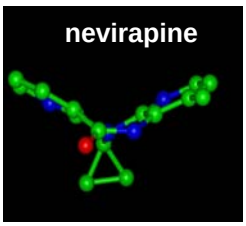
Interactions médicamenteuses

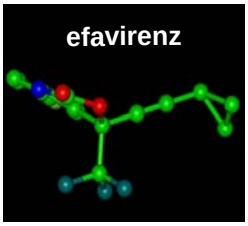
- excipient de la didanosine (sels de Mg^{2+} et d'Al^{3+}) :
  ↓ absorption de nb médicaments:
  (kétoconazole, dapsone, tétracyclines, fluoroquinolones)
- ganciclovir (et autres médicaments myélotoxiques)
  ↑ risque de myélosuppression de l'azidothymidine
- ranitidine: ↓ faible de l'absorption de la didanosine
- pentamidine : ↑ toxicité pancréatique (didanosine, stavudine et zalcitabine)
- probénécide, pyréméthamine/ sulfadiazine :
  ↓ glucuronoconjugaison ou élimination rénale de l'azidothymidine
  ↑ sa toxicité

analogues non nucléosidiques









Inhibiteurs allostériques non compétitifs;
pas de résistance croisée avec les NRTI !

Pharmacocinétique

névirapine

- bonne résorption orale
- élimination par métabolisation hépatique;
  inducteur de son propre métabolisme
  → $t_{½}$ = 45 h après une dose unique
  = 25 h après administration répétée
  → augmentation des posologies après 15 jours de traitement

efavirenz

- forte liaison aux protéines et demi-vie prolongée (40 h)
  → administration 1X/jour
- inducteur et inhibiteur des cytochromes P450 (3A4 et 2B6), n'entraînant pas de modificaton importante de son propre métabolisme.

Effets secondaires

névirapine

- réactions cutanées fréquentes, parfois mortelles (syndrome de Stevens Johnson; nécrolyse cutanée).

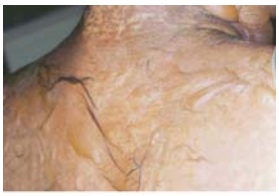


Figure 1. Typical Pattern of Toxic Epidermal Necrolysis.
Blisters and wrinkled areas result from full-thickness necrosis of the epidermis.

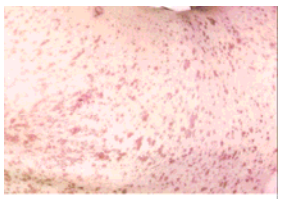


Figure 2. Typical Pattern of Stevens–Johnson Syndrome.
Blisters develop on widespread purpuric macules.

→ Interrompre le traitement dès l'apparition de signes précurseurs
(rash cutané, fièvre, lésions orales, conjonctivite, douleurs musculaires ou articulaires, malaise généralisé).

- toxicité hépatique (possibilité d'hépatites fulminantes).
- agranulocytose chez les enfants
- nausées, fièvre, maux de tête.

Effets secondaires

Efavirenz

- effets sur le système nerveux :
  étourdissements, vertiges, somnolence, maux de tête, dépression

→ administration le soir

- rashs (ne demandent que rarement l'arrêt du traitement).

Interactions médicamenteuses

Inducteurs/inhibiteurs des CYP

Névirapine:

↓ taux sérique de rifabutine, rifampicine
kétoconazole
anticoagulants oraux

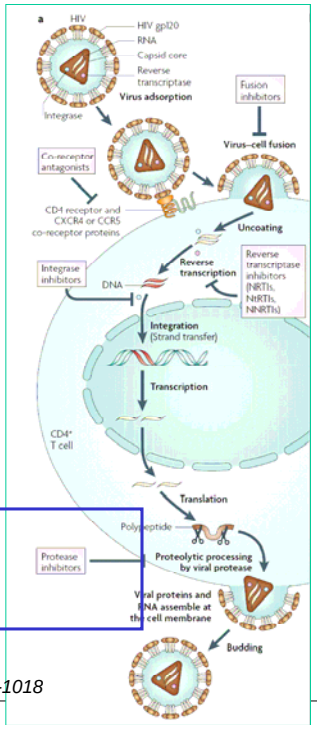
Efavirenz:

↓ taux sérique de inhibiteurs de la protéase du virus HIV
méthadone
rifabutine, clarithromycine.

↑ taux sérique de ritonavir

Patients susceptibles de développer des infections opportunistes !

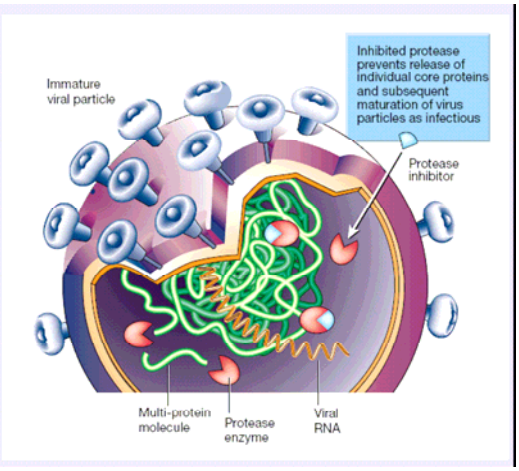
Cible des médicaments actifs sur le HIV



De Clercq, Nature Rev. Drug Discov.(2007) 6:1001-1018

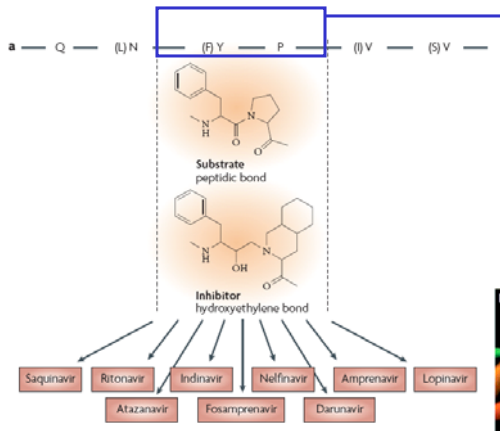
Protéase et inhibiteurs

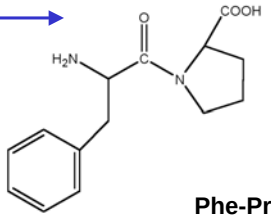
Figure 4 Mechanism of action of protease inhibitors. After transcription in the nucleus, viral mRNA enters the cytoplasm and uses the host's cellular machinery to manufacture virus proteins. The viral components then gather at the cell membrane and immature viruses bud off the cell. Core proteins are produced as part of long polypeptides, which must be cut into smaller fragments by the enzyme protease in order to form mature, functional proteins. Protease inhibitors bind to the site where protein cutting occurs, and so prevent the enzyme from releasing the individual core proteins. In this way the new viral particles are unable to mature or become infectious. (Adapted from ref. 108 with permission.)



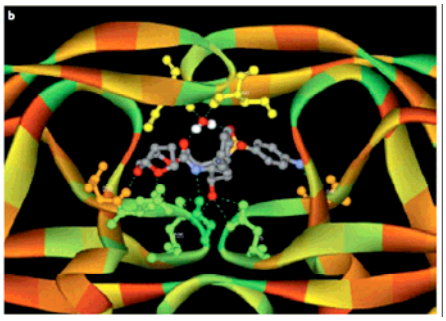
Richman, Nature (2001) 410:995-1001

Inhibiteurs de protéase HIV



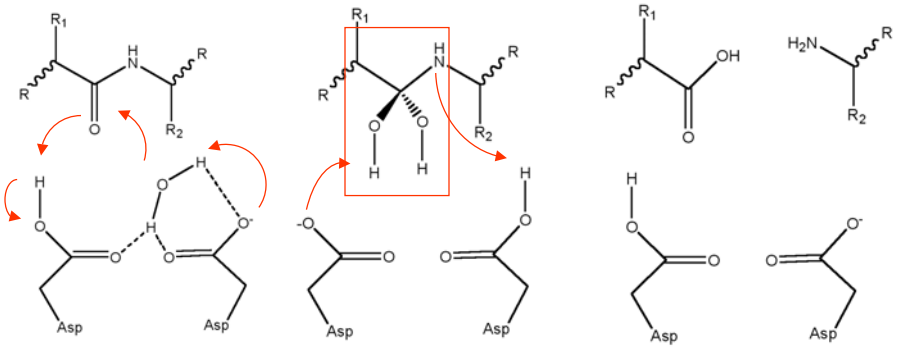


Phe-Pro

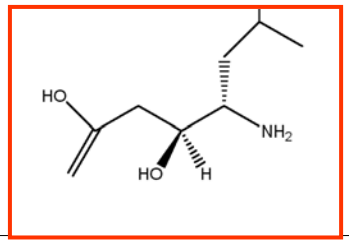


De Clercq, Nature Rev. Drug Discov.(2007) 6:1001-1018

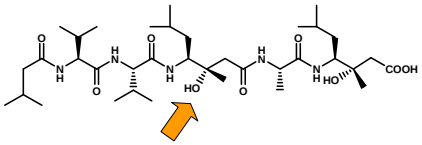
La protéase HIV, une Aspartate- protease



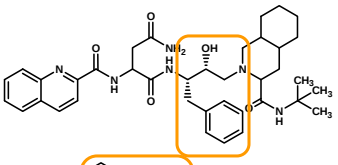
Inhibiteur-type:
pepstatine...



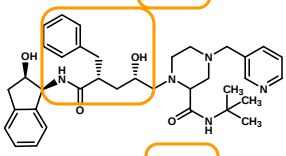
Inhibiteurs de protéase HIV



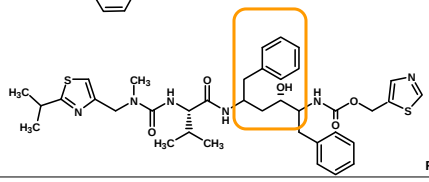
PEPSTATINE A



SAQUINAVIR

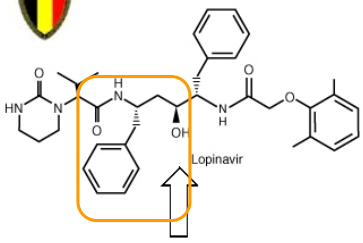


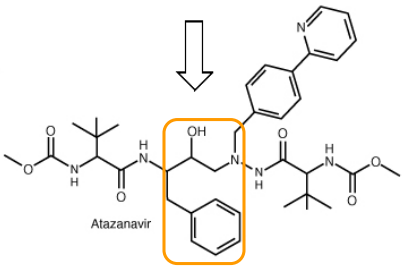
INDINAVIR

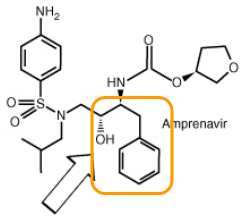


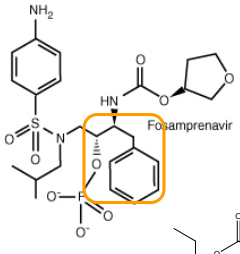
RITONAVIR

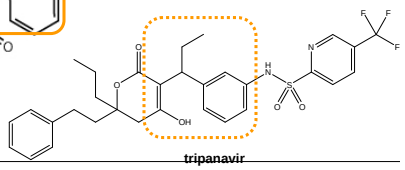
Inhibiteurs de protéase HIV







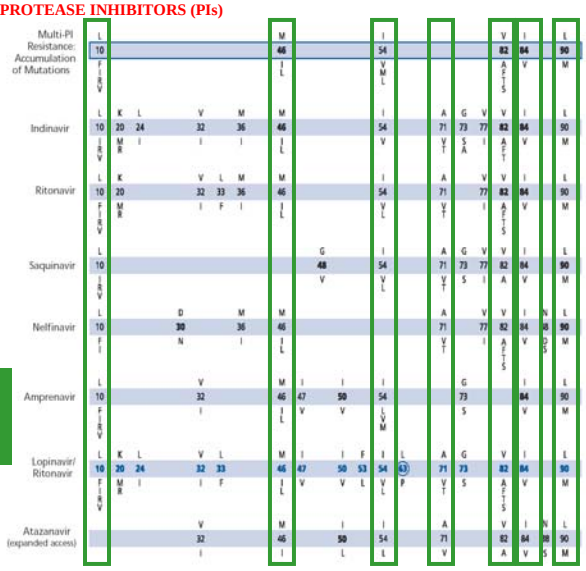




tripanavir

Résistance par mutation

MUTATIONS IN THE HIV PROTEASE GENE ASSOCIATED WITH REDUCED SUSCEPTIBILITY TO PROTEASE INHIBITORS (PIs)



Certaines mutations confèrent des résistances croisées !

http:/www.iasusa.org/resistance_mutations/index.html

Pharmacocinétique

- faible biodisponibilité
  (poids moléculaire élevé, mauvaise solubilité et instabilité)

- $T_{½}$ courte (quelques heures)

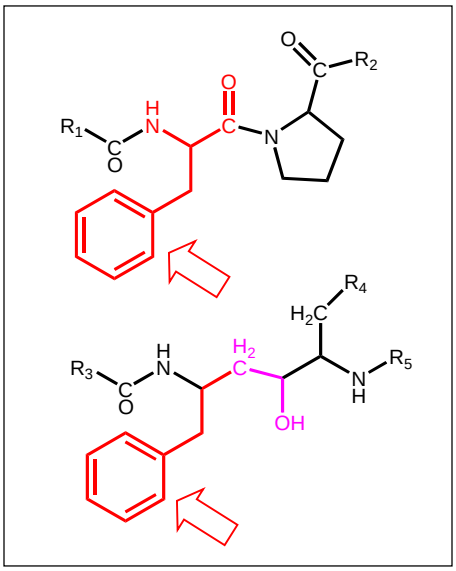
→ administrations 2 ou 3 X/jour

- métabolisation par les cytochrome P-450 hépatiques (principalement 3A4).

→ inhibiteurs ou activateurs du métabolisme de nb médicaments.

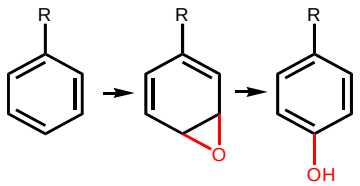
Inhibiteurs de protéase HIV et cytochromes

- la protéase doit scinder un lien Phe-Pro
- Les inhibiteurs miment donc tous une Phe…

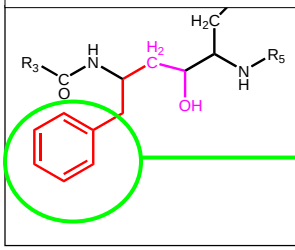


Inhibiteurs de protéase HIV et cytochromes

- La plupart des médicaments (et autres substances) à noyau aromatique sont métabolisées en dérivés hydroxylés, ce qui est essentiel pour leur élimination



- phénytoïne (antépileptique)
- phénobarvital (sédatif)
- propranolol (antihypertenseur)
- phénylbutazone (anti-inflammatoire)
- éthinyloestradiol (hormone)
- dicoumarol (anticoagulant)
- …..



- Par leur noyau aromatique (essentiel pour l'activité !!), les inhibiteurs de protéase entrent en **compétition** avec ces médicaments (et bien d'autres)
- il vont **ralentir leur élimination**, et, dès lors
- créer un risque d'**intoxication par excès** …

Pharmacocinétique

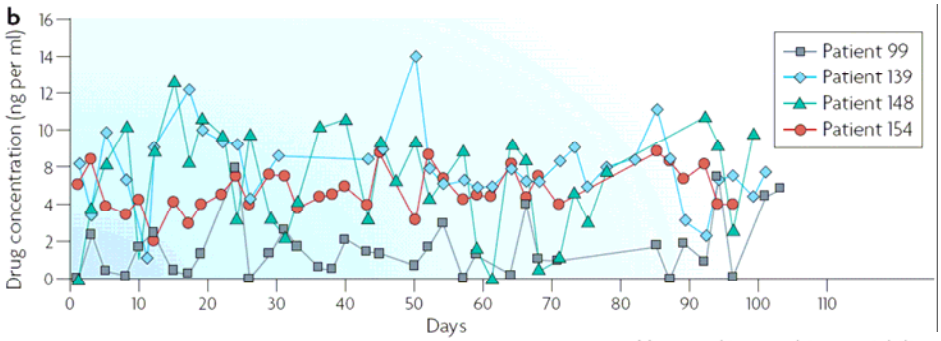
• faible biodisponibilité
(poids moléculaire élevé, mauvaise solubilité et instabilité)

• $T_{½}$ courte (quelques heures)
→ administrations 2 ou 3 X/Jour

• métabolisation par les cytochrome P-450 hépatiques (principalement 3A4).
→ inhibiteurs ou activateurs du métabolisme de nb médicaments.

Très important pour le ritonavir; utilisé à faible dose comme inhibiteur du métabolisme des autres inhibiteurs de protéase.
→ 200 mg lopinavir + 50 mg ritonavir (KALETRA®).
[tripranavir + ritonavir]

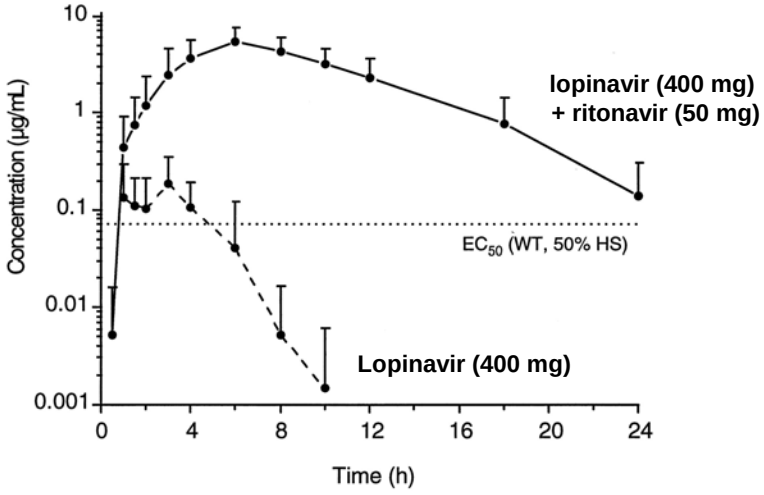
Lopinavir: variabilité pharmacocinétique



Measured intra-subject variability in concentrations of lopinavir dosed 400 mg every 12 hours. Participants had undetectable plasma HIV RNA on treatment for at least 3 months, and were seen in the clinic 3 times a week for up to 4 months. Blood for lopinavir concentration analysis was collected at approximately the same time of day at each visit

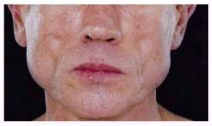
Flexner, Nature Rev. Drug Discov.(2007) 6:959-66

Lopinavir: influence du ritonavir sur le profil PK

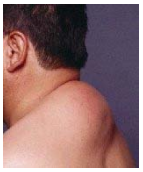


Sham et al, AAC (1998) 42:3218-24.

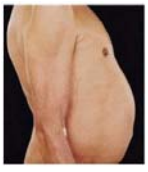
Effets secondaires



"syndrome de lipodystrophie"



- bajoues et dépôts graisseux sur la face
- dépôts de graisse au niveau du cou ["bosse de bison"] et du tronc
- accumulation de graisse derrière les muscles abdominaux
- lipomes disséminés
- hyperplasie graisseuse des seins



- hyperglycémie, hyperinsulinémie
- augmentation des taux lipides sériques

risque de diabète non insulinodépendant
et de maladie cardiovasculaire.

Effets secondaires

Selon la molécule (orientation du choix!)

saquinavir	intolérance gastro-intestinale, diarrhée maux de tête ↗ taux sériques de triglycérides et de cholestérol
ritonavir:	intolérance digestive et diarrhée très importantes paresthésies ↗ transaminases hépatiques disgueusie
indinavir:	intolérance gastro-intestinale, diarrhée hyperbilirubinémie non conjuguée asymptomatique néphrolithiases (peuvent être prévenues par hydratation) ↗ transaminases maux de tête, insomnie
nelfinavir	diarrhée et flatulence fréquentes altération de la formule sanguine ↗ transaminases

Effets secondaires

Selon la molécule (orientation du choix!)

amprenavir	maux de tête nausée et diarrhée fréquente rash
lopinavir	diarrhée et nausées ↗ importante des taux sériques de triglycérides et de cholestérol
tripanavir	diarrhées et nausées céphalées hépatotoxicité saignements éruptions cutanées
azatanavir	diarrhée et nausées hyperbilirubinémie non conjuguée asymptomatique

Interactions médicamenteuses

- inhibition des cytochromes : ritonavir > indinavir et nelfinavir > saquinavir
  →nb risques d'interactions à surveiller !

- modification des taux d'IP par d'autres médicaments

  clarithromycine ↗ taux sérique du ritonavir et de l'indinavir
  fluconazole ↗ taux sérique du ritonavir
  kétoconazole ↗ ↗ taux sérique de saquinavir, d'indinavir et de nelfinavir
  quinidine ↗ taux sérique de l'indinavir
  rifampicine ↘ ↘ le taux sérique de saquinavir (et nelfinavir et ritonavir)
  névirapine ↘ concentration-pic du saquinavir

- boissons acides ↘ taux sérique de l'indinavir et du nelfinavir

- substrats de P-glycoprotéine et inhibiteurs de MRP2 :
  modulation de la pharmacocinétique et interaction avec d'autres médicaments

Interactions médicamenteuses

Interactions médicamenteuses importantes ou très dangereuses (! = contre indication) des inhibiteurs de protéase anti HIV (à l'exclusion des interactions entre anti-HIV).

Médicaments (classe)	Indavir	Ritonavir	Saquinavir	Nelfinavir	Amprenavir[1]	Lopinavir (assoc. au ritonavir)	Azatanavir	tripanavir (assoc. au ritonavir)
Antibiotiques		caltithromycine rifabutine			clarithromycine metronidazole (!) rifabutine	clarithromycine rifabutine	rifampicine (!)	rifampicine rifabutine clarithromycine
Analgésiques		opiacés méperidine (!) propoxyphène (!) piroxicam (!)						opiacés et methadone/ méperidine
Dérivés de l'ergot		tous (!)		tous (!)	tous (!)	tous (!)	tous (!)	
Antiarythmiques		tous (!)	quinidine	amiodarone quinidine		Amiodarone, bepridil, lidocaine (systémique), et quinidine.		
Cardiotoniques		digoxine						
Anticoagulants		coumariniques				coumariniques		
Anticonvulsivants	carbamazépine phénytoine phénobarbital	tous	carbamezépine phénytoine phénobarbital	carbamazépine phénytoine phénobarbital		Carbamazepine, phenobarbital, phenytoine		
Antidépresseur		tous buspirone (!)						millepertuis desipramine
Antihistaminiques	terfénadine (!) astimizole (!) autres molécules (!)	terfénadine (!) astimizole (!) autres molécules (!)	terfénadine (!) astimizole (!) autres molécules (!)	terfénadine (!) astimizole (!) autres molécules (!)				
Antifongiques	kétoconazole	kétoconazole itraconazole			kétoconazole	Ketoconazole, itraconazole.		voriconazole (imprédictible)
Anticancéreux		étoposide alcaloïdes vinca tamoxifine					irinotecan	
Autres agents cardiovascul.		la plupart bepridil (!)	antagon. Ca^{++}	antagon. Ca^{++}		antagon. Ca^{++}		

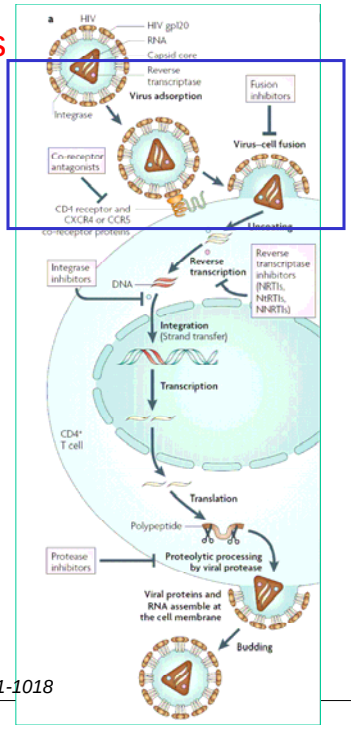
Interactions médicamenteuses

Table 135-2. Drug interactions between antiretrovirals and oral contraceptives. Recommended adjustments are listed. Data from CDC.[21]

DRUG INTERACTIONS BETWEEN ANTIRETROVIRALS AND ORAL CONTRACEPTIVES				
			Recommendation	
Agent	Effect on oral contraceptive	No dose adjustment	No data	Use alternative agent or second method
Indinavir	Norethindrone℞ levels ↑26% ethinylestradiol levels ↑24%	X		
Ritonavir℞	Ethinylestradiol levels ↓40%			X
Saquinavir℞			X	
Nelfinavir	Norethindrone℞ levels ↓18% ethinylestradiol levels ↓47%			X
Amprenavir℞	Potential for interaction		X	X
Lopinavir	Ethinylestradiol levels ↓42%			X
Nevirapine℞	Ethinylestradiol levels ↓20%			X
Delavirdine			X	
Efavirenz℞	Ethinylestradiol levels ↑37% no data on norethindrone℞ levels			X

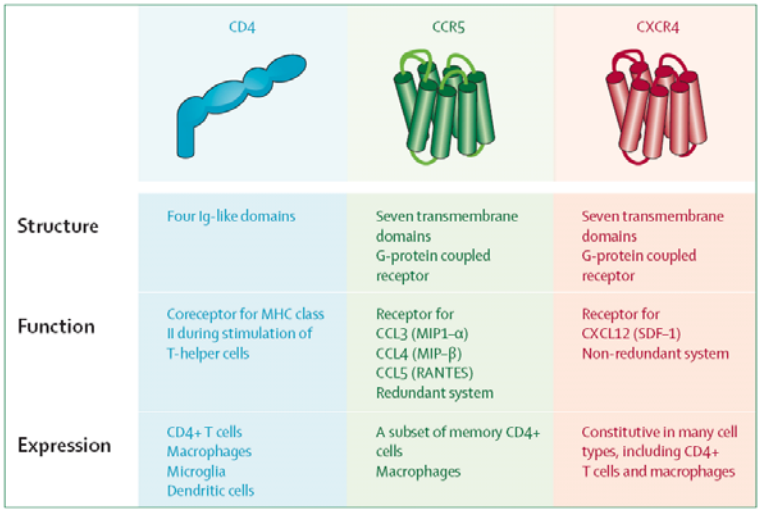
Cible des médicaments actifs sur le HIV

Inhibiteurs d'entrée



De Clercq, Nature Rev. Drug Discov.(2007) 6:1001-1018

Récepteurs cellulaires au virus HIV



	CD4	CCR5	CXCR4
Structure	Four Ig-like domains	Seven transmembrane domains G-protein coupled receptor	Seven transmembrane domains G-protein coupled receptor
Function	Coreceptor for MHC class II during stimulation of T-helper cells	Receptor for CCL3 (MIP1-α) CCL4 (MIP-β) CCL5 (RANTES) Redundant system	Receptor for CXCL12 (SDF-1) Non-redundant system
Expression	CD4+ T cells Macrophages Microglia Dendritic cells	A subset of memory CD4+ cells Macrophages	Constitutive in many cell types, including CD4+ T cells and macrophages

Figure 2: Receptors for HIV-1 entry

Este & Telenti, Lancet (2007) 370:81-88

Fusion du virus avec la cellule hôte

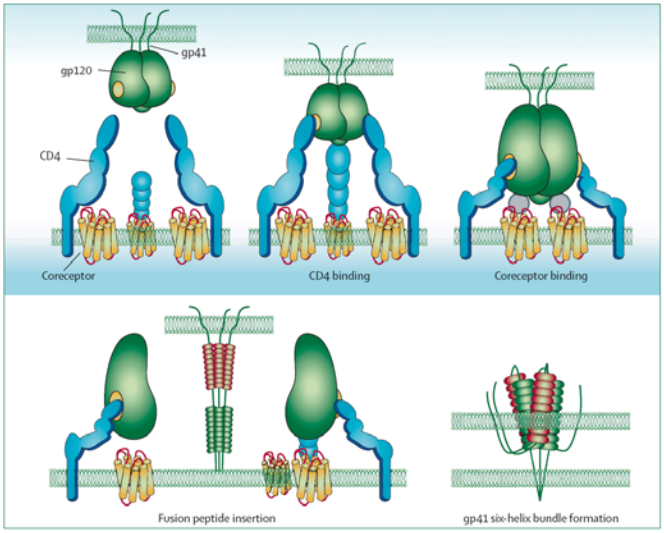


Figure 1: Mechanism of HIV entry
On CD4 binding (binding site for CD4 is shown in yellow), gp120 undergoes conformational changes. CD4-induced epitopes can then bind to chemokine receptors. Thereafter, gp41 is released into a fusogenic conformation and its N-terminal (green) and C-terminal (red) helices form a hairpin structure, leading to the approximation of viral and cellular membranes, which results in membrane fusion.

Este & Telenti, Lancet (2007) 370:81-88

Inhibiteurs de fusion

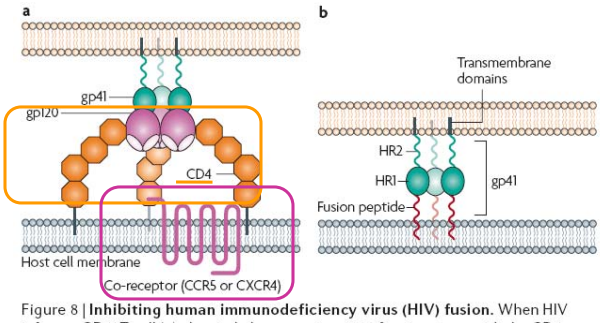
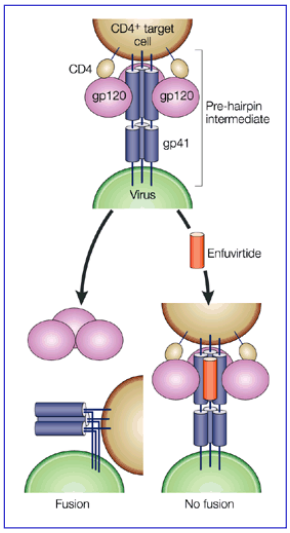


Figure 8 | **Inhibiting human immunodeficiency virus (HIV) fusion.** When HIV infects a CD4+ T cell (**a**), the viral glycoprotein gp120 first interacts with the CD4 receptor, then with the CCR5 or CXCR4 co-receptor, upon which the viral gp41 will bring the viral envelope in contact with the host cell membrane (**b**). The gp41 glycoprotein contains four major functional domains: starting from the N terminus towards the C terminus these are the fusion peptide, the heptad repeat 1 (HR1), the heptad repeat 2 (HR2) and the transmembrane domain that anchors gp41 into the viral lipid bilayer. Enfuvirtide is homologous to part of the HR2 region. When the N terminal fusion peptide of gp41 is inserted into the host cell membrane, the three HR2 domains of the gp41 trimer loop back in a triple hairpin and 'zip' themselves into three highly conserved hydrophobic grooves on the outer face of the HR1 trimeric bundle to form a six-helix bundle that pulls the outer membranes of the virus and the cell into close physical proximity, thus enabling the two membranes to fuse[13]. This process depends on an interaction of the heptad repeat HR2 with HR1. By being homologous to the HR2 domain, enfuvirtide blocks this interaction[90].



La Bonte et al (2003) & De Clercq (2007), Nature Rev. Drug Discov. 2: 345-346 & 6:1001-1018

Inhibiteurs de fusion

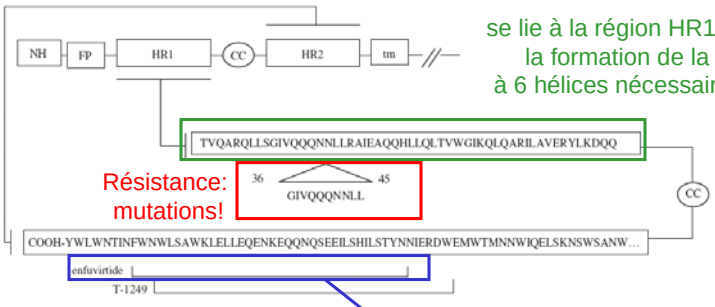
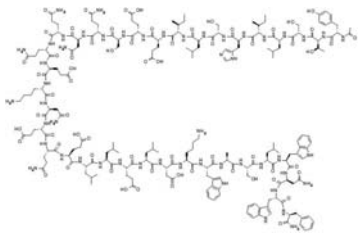


Figure 5. Schematic representation of the gp41 linear structure. Enfuvirtide and T-1249 sequences mimic HR2. FP, fusion peptide; CC, cysteine-cysteine; TM, transmembrane domain.

se lie à la région HR1 et empêche la formation de la structure à 6 hélices nécessaire à la fusion

Résistance: mutations!

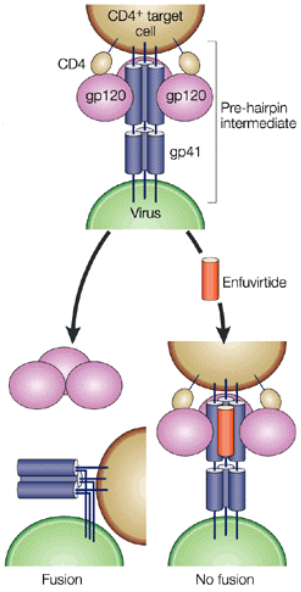
enfuvirtide = fragment de 36 AA de gp41 (HR2)



actif uniquement sur HIV-1

Briz et al, JAC (2006) 2006 57:619-27.

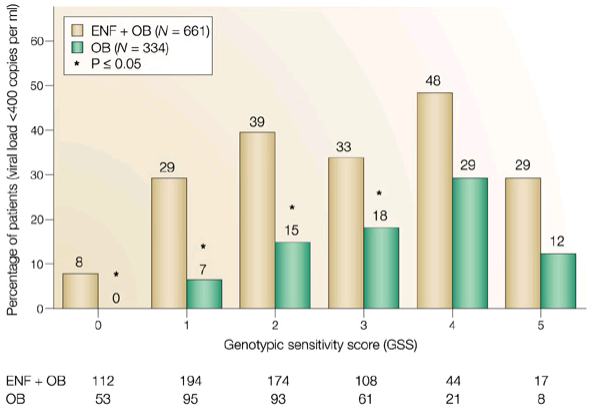
Inhibiteurs de fusion



The envelope glycoprotein of HIV-1 consists of two non-covalently associated subunits, gp120 and gp41. After attachment of HIV-1 to its target cells carrying the CD4 receptor, gp120 interacts with the CD4 receptor, which initiates a series of conformational changes in gp41 and gp120 that lead to the insertion of a region of gp41 into the membrane of the host cell, and the formation of a 'pre-hairpin intermediate' (top). Further changes in the conformation of gp41 bring the viral and cellular membranes into close enough proximity for membrane fusion (bottom left). Enfuvirtide binds to a region of gp41 that mediates this conformational change from pre-hairpin intermediate to the fusion-active structure, thereby preventing fusion and viral entry

Labonte et al, Nature Reviews Drug Discovery 2, 345-346

Inhibiteurs de fusion: efficacité clinique



Percent responders with HIV-1 RNA <400 copies per ml, week 48 (intent-to-treat, discontinuation or virological failure = failure).
GSS is the actual number of antiretrovirals that the baseline virus is sensitive to as indicated by standard primary mutations that each virus possesses.
ENF, enfuvirtide; OB, optimized treatment background.

Matthews et al, Nature Rev. Drug Discov.(2004) 3:1215-25

Enfuvirtide: propriétés pharmacologiques

Pharmacocinétique

• médicament peptidique:
 - administration par voie sous-cutanée
 - instable: préparation extemporanée

Risque de transmission par les aiguilles !

t ½ : 3-4 heures (hydrolyse); administration 2 X / jour

Effets secondaires:

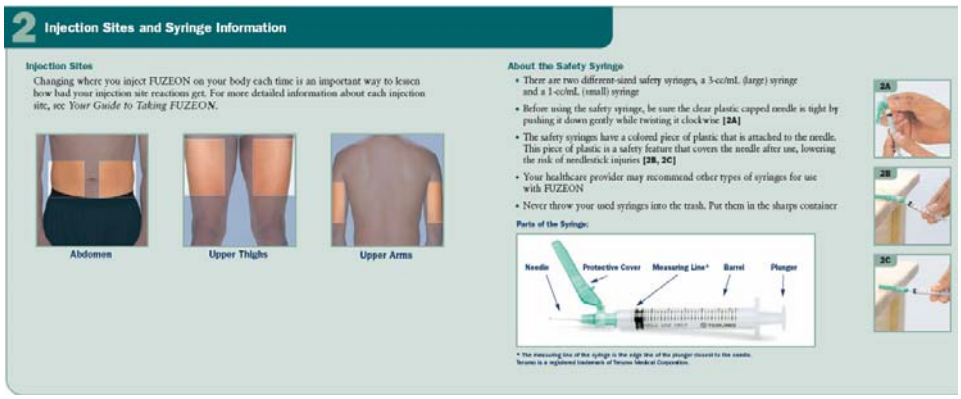
• réactions cutanées au site d'injection
• réactions d'hypersensibilité pouvant imposer l'arrêt du traitement
• augmentation du risque de pneumonie en début de traitement (raison peu claire)

Patient à risque d'infection opportuniste !

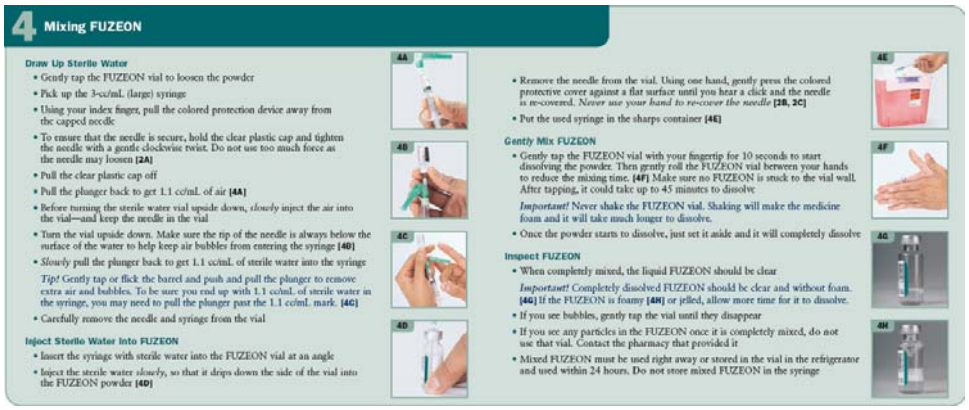
Usage clinique:

• en association avec d'autres antiviraux; patients phase avancée
 (souches multirésistantes)

Enfuvirtide: conseils d'auto-administration



Enfuvirtide: conseils d'auto-administration



4 Mixing FUZEON

Draw Up Sterile Water

- Gently tap the FUZEON vial to loosen the powder
- Pick up the 3-cc/mL (large) syringe
- Using your index finger, pull the colored protection device away from the capped needle
- To ensure that the needle is secure, hold the clear plastic cap and tighten the needle with a gentle clockwise twist. Do not use too much force as the needle may loosen **[2A]**
- Pull the clear plastic cap off
- Pull the plunger back to get 1.1 cc/mL of air **[4A]**
- Before turning the sterile water vial upside down, *slowly* inject the air into the vial—and keep the needle in the vial
- Turn the vial upside down. Make sure the tip of the needle is always below the surface of the water to help keep air bubbles from entering the syringe **[4B]**
- *Slowly* pull the plunger back to get 1.1 cc/mL of sterile water into the syringe

  Tip! Gently tap or flick the barrel and push and pull the plunger to remove extra air and bubbles. To be sure you end up with 1.1 cc/mL of sterile water in the syringe, you may need to pull the plunger past the 1.1 cc/mL mark. **[4C]**
- Carefully remove the needle and syringe from the vial

Inject Sterile Water Into FUZEON

- Insert the syringe with sterile water into the FUZEON vial at an angle
- Inject the sterile water *slowly*, so that it drips down the side of the vial into the FUZEON powder **[4D]**

4A 4B 4C 4D

- Remove the needle from the vial. Using one hand, gently press the colored protective cover against a flat surface until you hear a click and the needle is re-covered. *Never use your hand to re-cover the needle* **[2B, 2C]**
- Put the used syringe in the sharps container **[4E]**

Gently Mix FUZEON

- Gently tap the FUZEON vial with your fingertip for 10 seconds to start dissolving the powder. Then gently roll the FUZEON vial between your hands to reduce the mixing time. **[4F]** Make sure no FUZEON is stuck to the vial wall. After tapping, it could take up to 45 minutes to dissolve

  Important! Never shake the FUZEON vial. Shaking will make the medicine foam and it will take much longer to dissolve.
- Once the powder starts to dissolve, just set it aside and it will completely dissolve

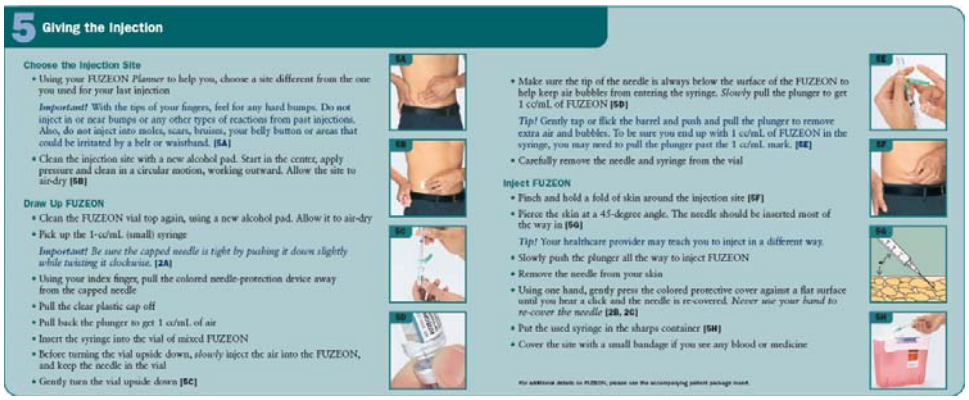
Inspect FUZEON

- When completely mixed, the liquid FUZEON should be clear

  Important! Completely dissolved FUZEON should be clear and without foam. **[4G]** If the FUZEON is foamy **[4H]** or jelled, allow more time for it to dissolve.
- If you see bubbles, gently tap the vial until they disappear
- If you see any particles in the FUZEON once it is completely mixed, do not use that vial. Contact the pharmacy that provided it
- Mixed FUZEON must be used right away or stored in the vial in the refrigerator and used within 24 hours. Do not store mixed FUZEON in the syringe

4E 4F 4G 4H

Enfuvirtide: conseils d'auto-administration



5 Giving the Injection

Choose the Injection Site

- Using your FUZEON *Planner* to help you, choose a site different from the one you used for your last injection

  Important! With the tips of your fingers, feel for any hard bumps. Do not inject in or near bumps or any other types of reactions from past injections. Also, do not inject into moles, scars, bruises, your belly button or areas that could be irritated by a belt or waistband. **[5A]**
- Clean the injection site with a new alcohol pad. Start in the center, apply pressure and clean in a circular motion, working outward. Allow the site to air-dry **[5B]**

Draw Up FUZEON

- Clean the FUZEON vial top again, using a new alcohol pad. Allow it to air-dry
- Pick up the 1-cc/mL (small) syringe

  Important! Be sure the capped needle is tight by pushing it down slightly while twisting it clockwise. **[2A]**
- Using your index finger, pull the colored needle-protection device away from the capped needle
- Pull the clear plastic cap off
- Pull back the plunger to get 1 cc/mL of air
- Insert the syringe into the vial of mixed FUZEON
- Before turning the vial upside down, *slowly* inject the air into the FUZEON, and keep the needle in the vial
- Gently turn the vial upside down **[5C]**

5A 5B 5C 5D

- Make sure the tip of the needle is always below the surface of the FUZEON to help keep air bubbles from entering the syringe. *Slowly* pull the plunger to get 1 cc/mL of FUZEON **[5D]**

  Tip! Gently tap or flick the barrel and push and pull the plunger to remove extra air and bubbles. To be sure you end up with 1 cc/mL of FUZEON in the syringe, you may need to pull the plunger past the 1 cc/mL mark. **[5E]**
- Carefully remove the needle and syringe from the vial

Inject FUZEON

- Pinch and hold a fold of skin around the injection site **[5F]**
- Pierce the skin at a 45-degree angle. The needle should be inserted most of the way in **[5G]**

  Tip! Your healthcare provider may teach you to inject in a different way.
- Slowly push the plunger all the way to inject FUZEON
- Remove the needle from your skin
- Using one hand, gently press the colored protective cover against a flat surface until you hear a click and the needle is re-covered. *Never use your hand to re-cover the needle* **[2B, 2C]**
- Put the used syringe in the sharps container **[5H]**
- Cover the site with a small bandage if you see any blood or medicine

5E 5F 5G 5H

Inhibiteurs des co-récepteurs CCR5

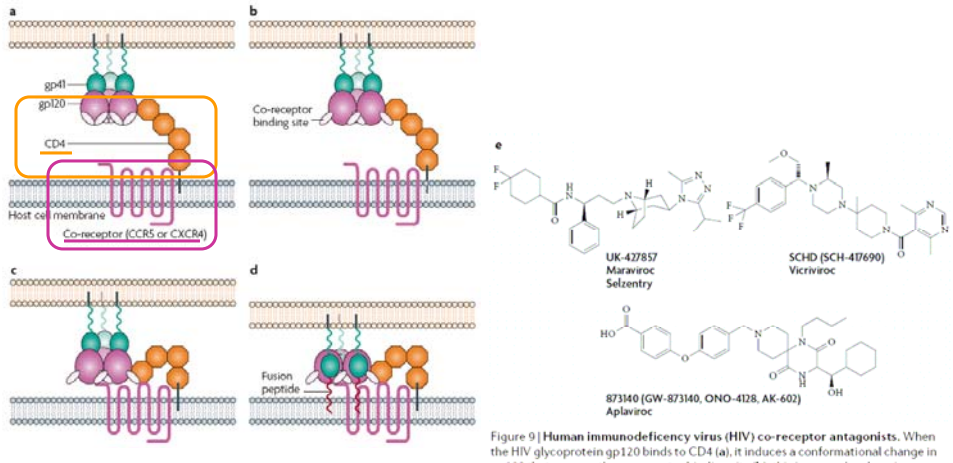
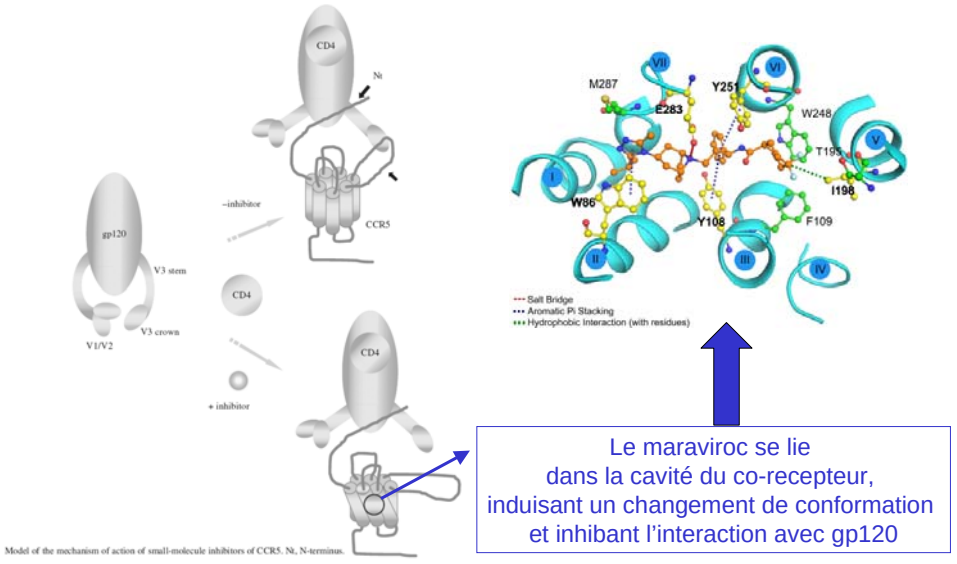


Figure 9 | **Human immunodeficency virus (HIV) co-receptor antagonists.** When the HIV glycoprotein gp120 binds to CD4 (**a**), it induces a conformational change in gp120 that exposes the co-receptor binding site (**b**); this is a complex domain comprising the V3 loop and specific amino-acid residues in CD4, collectively termed the 'bridging sheet'. Exposure of the co-receptor binding site permits binding of gp120 to the co-receptor (**c**). Co-receptor antagonists inhibit this step by binding to the co-receptor and changing its shape so that gp120 cannot recognize it. Co-receptor binding induces conformational changes in gp41 and insertion of the fusion peptide into the host cell membane (**d**), ultimately resulting in fusion of the viral envelope with the host cell membrane[95]. (**e**) Structural formulae of selected CCR5 antagonists.

De Clercq, Nature Rev. Drug Discov.(2007) 6:1001-1018

Antagonistes de CCR5



Model of the mechanism of action of small-molecule inhibitors of CCR5. Nt, N-terminus.

Le maraviroc se lie
dans la cavité du co-recepteur,
induisant un changement de conformation
et inhibant l'interaction avec gp120

Briz et al, JAC (2006) 57:619-27; Kondru et al, Mol Pharmacol. (2008) 73:789-800.

Maraviroc: propriétés pharmacologiques

Propriétés pharmacocinétiques

- résorption par voie orale
- métabolisme par CYP450, demi-vie ~ 10 h ; adminsitration 2X/jour

Effets secondaires principaux

- troubles gastro-intestinaux
- hépatotoxicité.
- risque accru d'infections possible (réponse immunitaire réduite par blocage de CCR5 ?)

Interactions médicamenteuses

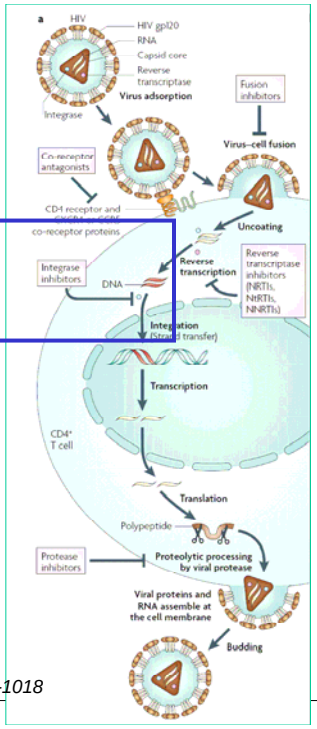
- maraviroc = substrat du CYP450 et de P-glycoprotéine ;
  dose à adapter en fonction des traitements reçus par le patient

Concomitant drug effect	Concomitant medication examples	Dosage
No net alteration in metabolism	Tipranavir plus ritonavir, nevirapine, all NRTIs, and enfuvirtide	300 mg BID
CYP3A inhibitors (with or without a CYP3A inducer)	Ritonavir, all boosted protease inhibitors (except tipranavir plus ritonavir), delavirdine, ketoconazole, itraconazole, clarithromycin, nefazadone, and telithromycin	150 mg BID
CYP3A inducers alone	Efavirenz, etravirine, rifampin, carbamazepine, phenobarbital, and phenytoin	600 mg BID

Usage clinique

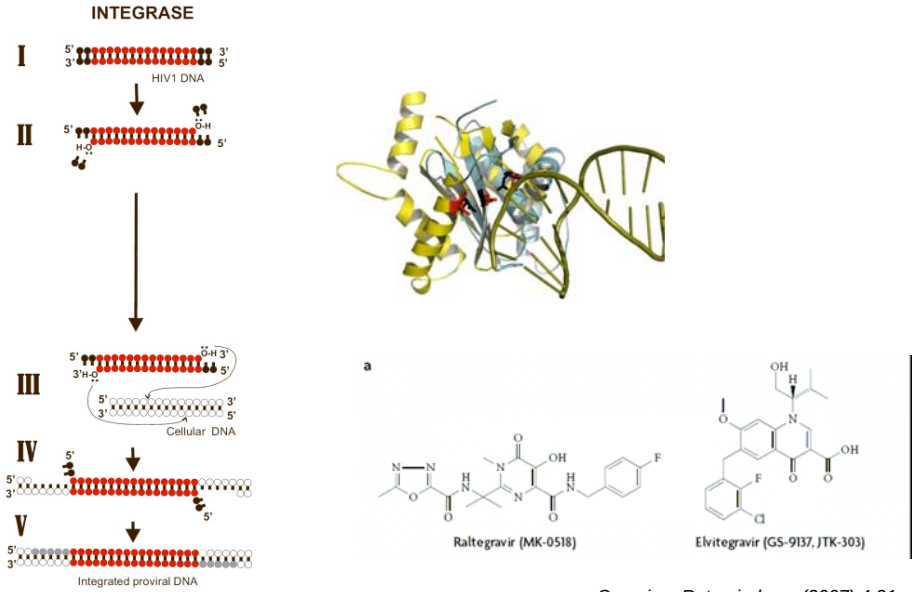
- uniquement dans les infections à HIV-1 ayant un tropisme pour CCR5
- en association avec d'autres antiviraux; patients phase avancée
  (souches multirésistantes)

Cible des médicaments actifs sur le HIV



De Clercq, Nature Rev. Drug Discov.(2007) 6:1001-1018

Inhibiteurs d'intégrase



Savarino, Retrovirology. (2007) 4:21

Raltegravir: propriétés pharmacologiques

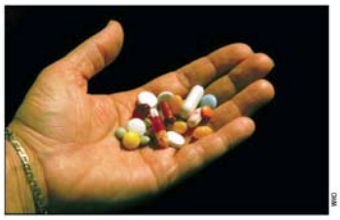
Propriétés pharmacocinétiques
- résorption par voie orale (400 mg 2x/jour)
- pas de métabolisme par CYP450 mais par glucurono-conjugaison

Effets secondaires principaux
- maux de tête, vertiges, fatigue, arthralgies
- troubles gastro-intestinaux (nausées, diarrhées)
- éruptions cutanées

Interactions médicamenteuses
- PAS d'interaction ~ CYP
- + rifampicine: ↓ des conc. sanguines de raltégravir par induction de la glucuronoconjugaison
- + inhibiteur de sécrétion d'acide gastrique: ↑ résorption orale

Usage clinique
- en association avec d'autres antiviraux; patients phase avancée (souches multirésistantes)

PHARMACOTHERAPIE DU SIDA



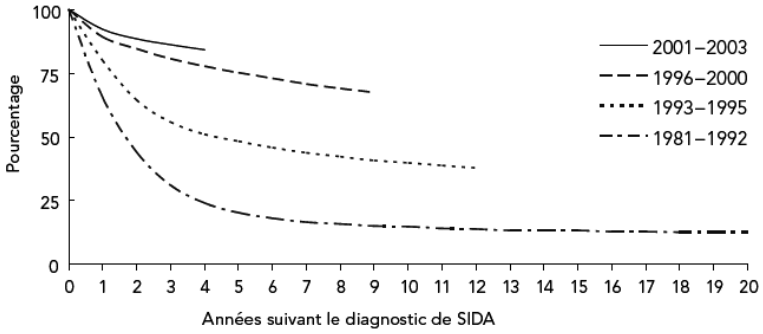
Buts du traitement

- ↓ charge virale
  0.5-0.75 $\log_{10}$ en 4 semaines ou 1 $\log_{10}$ en 8 semaines
- charge virale non détectable à 4-6 mois
  (< 50 - 20 copies)
- restaurer ou préserver la fonction immunitaire
- réduire la morbidité et la mortalité

Trithérapie pour éviter la sélection de résistance

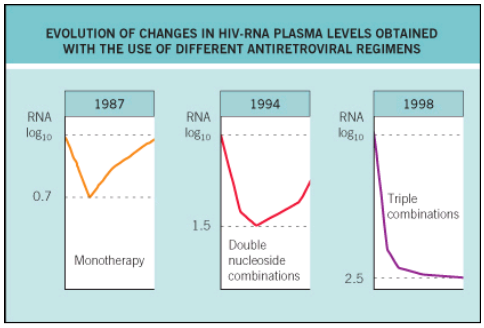
Grâce au HAART la survie des patients s'améliore

Pourcentage de personnes encore en vie en juin 2006, par cohortes selon les années suivant le diagnostic de SIDA entre 1981 et 2003 et par année de diagnostic



Source : CDC Twenty-five years of HIV/AIDS – Etats-Unis, 1981-2006. MMWR 2006.

Grâce au HAART la survie des patients s'améliore



Algorithme de traitement proposé par l'OMS (1/3)

TABLE 6. RECOMMENDATIONS FOR INITIATING ART IN PLHIV

WHO clinical stage[a]	CD4 cell count	Recommendation
1	<200/mm³	Treat
	200–350/mm³	Consider treatment[b]
2	<200/mm³	Treat
	200–350/mm³	Consider treatment[b]
3	200–350/mm³	Treat
4	Regardless of CD4 count	Treat

1. asymptomatique, adénopathie
2. Candidose, infections respiratoire, herpes
3. Candidose récurrente, ulcération de la bouche, infections pulmonaires sévères, diarrhée inexpliquée
4. Infections opportunistes

www.euro.who.int/document/e90840.pdf

Algorithme de traitement proposé par l'OMS (2/3)

TABLE 7. RECOMMENDED FIRST-LINE HAART

ARV drug classes	HAART regimens
2 NRTIs + 1 NNRTI	ZDV + 3TC + (**EFV**[a] or NVP) or TDF + FTC + (**EFV**[a] or NVP) or ABC + 3TC + (**EFV**[a] or NVP)

[a] EFV is highlighted as the preferred NNRTI.

TABLE 8. CRITERIA FOR TREATMENT SUCCESS

	Virological		Immunological	Clinical
Marker	Viral Load		CD4 cell count	Clinical stage
Time[a]	24 weeks	48 weeks	24–48 weeks	By 12 weeks of treatment initiation should be asymptomatic or have few symptoms
Suggested ranges[a]	<400 copies/ml	<50 copies/ml	Increase from baseline by at least 50-100 cells/mm³	Stage 1 or 2[b]

www.euro.who.int/document/e90840.pdf

Algorithme de traitement proposé par l'OMS (3/3)

TABLE 9. RECOMMENDED SECOND-LINE HAART FOR ADULTS AND ADOLESCENTS

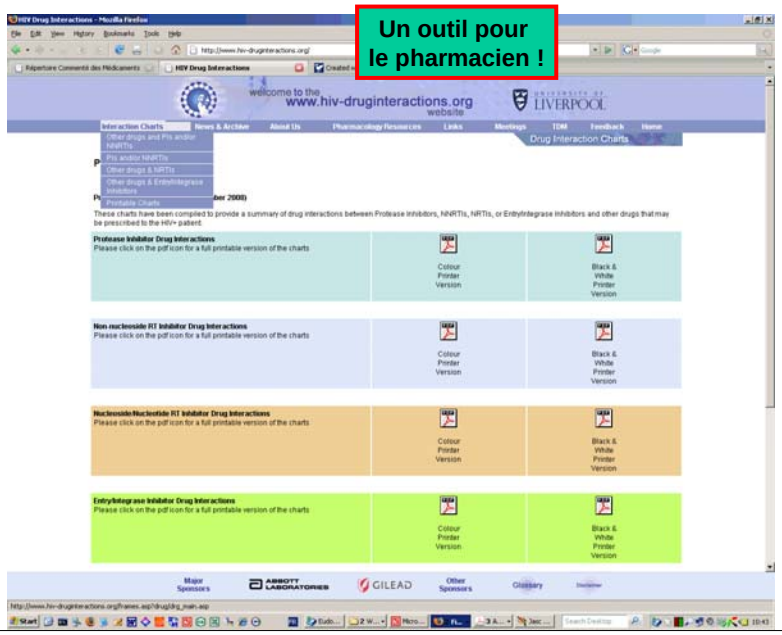
First-line HAART regimens	Second-line HAART regimens after treatment failure
ZDV + 3TC + (EFV or NVP)	**LPV/r**[a] (or ATV/r, SQV/r, FPV/r, IDV/r) + ddI + ABC or **LPV/r**[a] (or ATV/r, SQV/r, FPV/r, IDV/r) + TDF + ABC or **LPV/r**[a] (or ATV/r, SQV/r, FPV/r, IDV/r) + TDF + (ZDV + 3TC)[b]
TDF + FTC + (EFV or NVP)	**LPV/r**[a] (or ATV/r, SQV/r, FPV/r, IDV/r) + ddI + ABC or **LPV/r**[a] (or ATV/r, SQV/r, FPV/r, IDV/r) + ddI + ZDV
ABC + 3TC + (EFV or NVP)	**LPV/r**[a] (or ATV/r, SQV/r, FPV/r, IDV/r) + ddI + ZDV or **LPV/r**[a] (or ATV/r, SQV/r, FPV/r, IDV/r) + ZDV + TDF (+ 3TC)[b]

Adapter le choix en fonction des risques de résistance croisée et d'interaction médicamenteuse…

www.euro.who.int/document/e90840.pdf

Gare aux interactions médicamenteuses ….

Un outil pour le pharmacien !



Suivi des patients

TABLE 10.	FREQUENCY OF LABORATORY TESTING, GENERALLY AND WITH SPECIFIC ARV USE							
	Baseline	Week 2	Week 4	Week 8	Week 16	Week 24	Week 36	Week 48
Viral load	X			X		X	X	X
CD4 count	X			X		X	(X)	X
Complete blood count	X		X	X	X (ZDV)	X	(X)	X
Liver Function Test (LFT)	X	X (NVP)	X	X (NVP, ZDV, PIs)	X (NVP, PIs)	X	(X)	X
Cholesterol triglycerides	X (PIs)				X (PIs)			X (PIs)
Renal function test	X	X (TDF)	X (TDF, IDV)			X	(X)	X

X: laboratory tests to be performed irrespective of the ARVs being administered; **X (ARV)**: laboratory tests to be performed if an ARV in parentheses is being administered; **(X)**: optional test.

www.euro.who.int/document/e90840.pdf

Prévention de la transmission foeto-maternelle

REVERSE TRANSCRIPTASE INHIBITORS						
		FDA approved				
Agent	Transmission to fetus prevented*	Neonates	Children	FDA pregnancy category[dagger]	Placental transfer (%)
Zidovudine℞	Yes	Yes	Yes	C	85
Didanosine℞	No	Yes	Yes	B	50
Lamivudine℞	Yes	No	≥3 months	C	100
Stavudine℞	No	No	≥1 months	C	76 (rhesus monkeys)
Zalcitabine℞	No	No	No	C	30-50 (rhesus monkeys)
Abacavir	No	No	≥3 months	C	Yes (rats)
Nevirapine℞	Yes	No	≥2 months	C	100
Delavirdine	No	No	No	C	?
Efavirenz℞	No	No	≥3 years	C	100 (rhesus monkeys)
Tenofovir	No	No	No	B	Yes (rat, monkey)

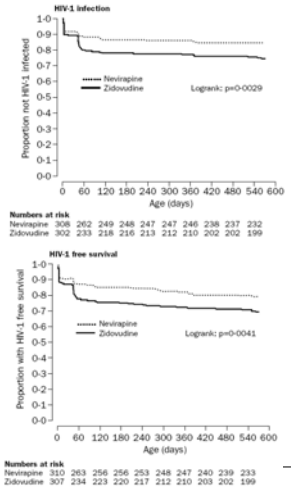
PROTEASE INHIBITORS					
		FDA approved			
Agent	Transmission to fetus prevented*	Neonates	Children	FDA pregnancy category[dagger]	Placental transfer
Nelfinavir	No	No	≥2 years	B	Minimal
Indinavir	No	No	No	C	Minimal
Ritonavir℞	No	No	≥2 years	B	Minimal
Saquinavir℞	No	No	No	B	Minimal
Amprenavir℞	No	No	≥4 years	C	?
Lopinavir/ritonavir	No	No	≥6 months	C	?

Ne passent pas
la barrière placentaire

Prévention de la transmission foeto-maternelle

→ Traitement suggéré:

- AZT or AZT/3TC – pendant la gestation et continuer pendant l'accouchement
- Nevirapine – 1 dose à la mère et à l'enfant (zones défavorisées)



Methods From November, 1997, to April, 1999, HIV-1 infected pregnant women in Kampala, Uganda, were randomly assigned nevirapine (200 mg at labour onset and 2 mg/kg for babies within 72 h of birth; regimen A) or zidovudine (600 mg orally at labour onset and 300 mg every 3 h until delivery, and 4 mg/kg orally twice daily for babies for 7 days, regimen B). Infant HIV-1 testing was done at birth, age 6–8 and 14–16 weeks, and age 12 months by HIV-1 RNA PCR, and by HIV-1 antibody at 18 months.

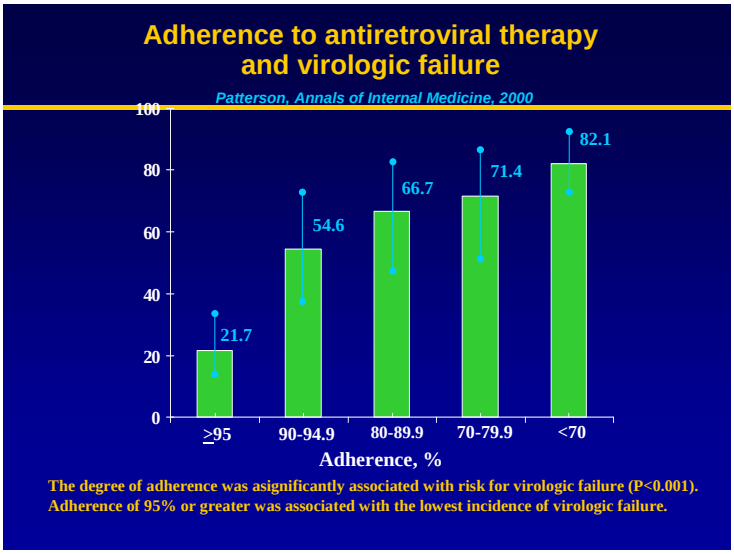
Traitement court:
la nevirapine
est plus efficace !

Jackson et al, Lancet (2003) 362:859-68.

Prévention lors d'une exposition accidentelle à un matériel contaminé

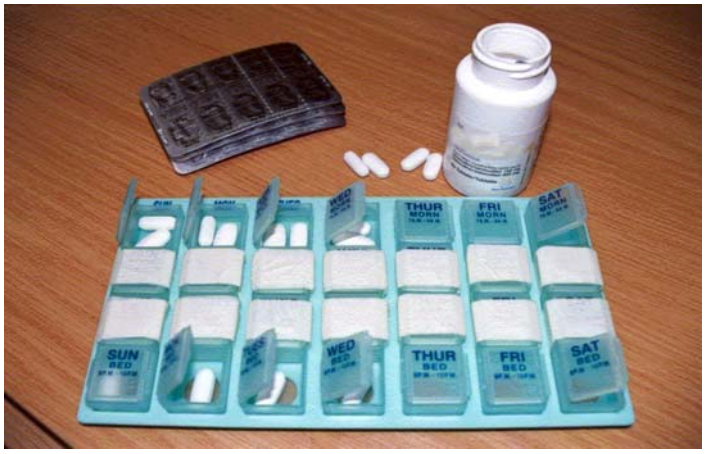
- traitement administré le plus rapidement possible ; 4 semaines
- association puissante : 2 NRTI et 1 IP
  (zidovudine-lamivudine-indinavir)
  [bonne tolérance et interactions médicamenteuses limitées]
- surveillance clinique et biologique à maintenir plus longtemps.

Importance de l'adhérence au traitement



J. Nachega, 2006

Comment améliorer la compliance ?



Comment améliorer la compliance ?

Simplification des régimes thérapeutiques: comparaison entre 1996 et 2004

1996:

ddI + d4T + SQV

-24 gélules/jour:

-SQV: 6 gel 3 X/jour avec la nourriture

-ddI: 2 gel 2 X jour ½ hr avant ou 2 h après repas

-d4T: 1 co 2 X /jour

2004:

TDF/FTC or ABC/3TC + EFV

- 1 co 2 X/ jour + 1 co 1X/jour

pas restriction par rapport au repas

Comment améliorer la compliance ?

Reasons for Missing Doses of Antiretroviral Therapy

US	Africa
Chesney	*Weidle, Orrell, Nachega, Brown,*
• Simply forgot	• Forgot
• Slept through dose	• Away from home
• Away from home	• Schedule difficulties
• Change in routine	• Ran out of pills
• Busy with other things	• Cost
• Too sick	• Home language
• Depressed	• Fear of stigmatization by sexual partner

J. Nachega, 2006

.. Un rôle de choix pour le pharmacien !