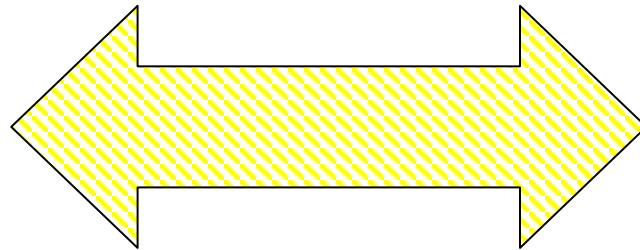
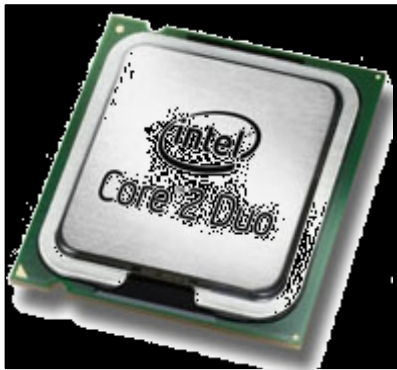


Implémentation matérielle des AC

Goulot d'étranglement

- Pour un traitement appliqué à une structure de donnée vectorielle comme une image, le processeur parcourt intégralement l'image,
- Ce parcours nécessite un accès continu à la mémoire qui ralentie le calcul.



Implémentation matérielle d'automates cellulaires

- III. Présentation des Automates cellulaires

- V. Exemple d'Architecture matérielle bio-inspirée

Naissance d'un automate cellulaire (AC)



- 1940, S. Ulam
- 1966, J. Von Neumann – Automates répliqueurs [1]
- 1970, J. H. Conway – Jeu de la vie [2]
- 1983, S. Wolfram, Analyse de leur comportement [3] [4]

[1] John von Neumann, Arthur W. Burks, *Theory of Self-Reproducing Automata*, University of Illinois Press (1966)

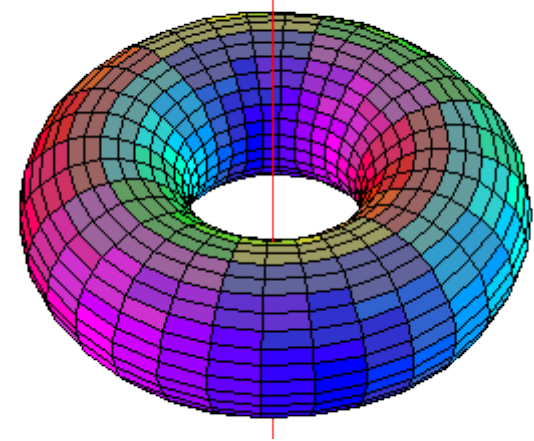
[2] Martin Gardner, *Mathematical Games. The fantastic combinations of John Conway's new solitaire game « life »*, Scientific American n°223 (Octobre 1970), p. 120-123

[3] Stephen Wolfram, *Universality and Complexity in Cellular Automata*, Physica D n°10 (Janvier 1984), p. 1-35

[4] Stephen Wolfram, *A New Kind of Science*, Wolfram Media (2002) - [ISBN 1579550088](#)

Jeu de la vie

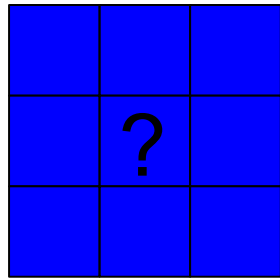
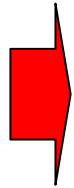
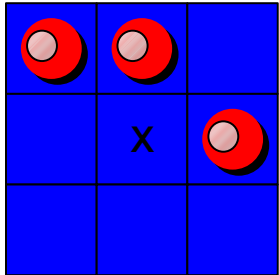
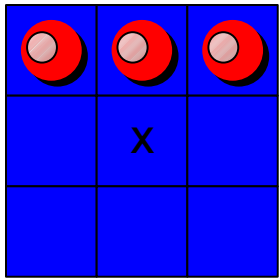
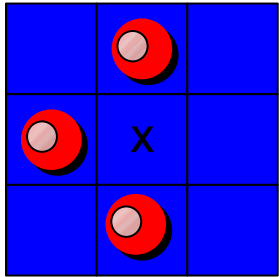
- Espace discret à 2 dimensions,
- Dont les bords sont liés : TORE,
- Automate cellulaire totalistique,
- Algorithme du jeu :
 1. Configuration initiale du monde, $t=0$
 2. Chaque cellule examine son voisinage
 3. Elle détermine son état futur en fonction de celui des voisins par des règles de transition
 4. Chaque cellule est modifiée, $t=t+1$, retour en 2



Règles du jeu de la vie

- Chaque cellule est dans un des 2 états:
 - Vivant,
 - Mort
- 3 règles :
 - R1, une cellule morte entourée d'exactly 3 cellules vivantes naît,
 - R2, une cellule vivante entourée de 2 ou 3 cellules vivantes reste en vie,
 - R3, dans tous les autres cas, elle meurt

Exemples



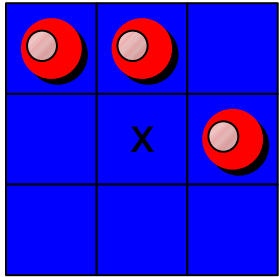
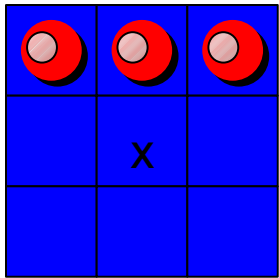
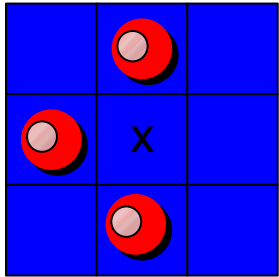
Vivant



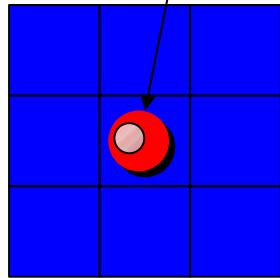
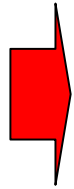
Mort

x = mort,
+ 3 voisins vivants

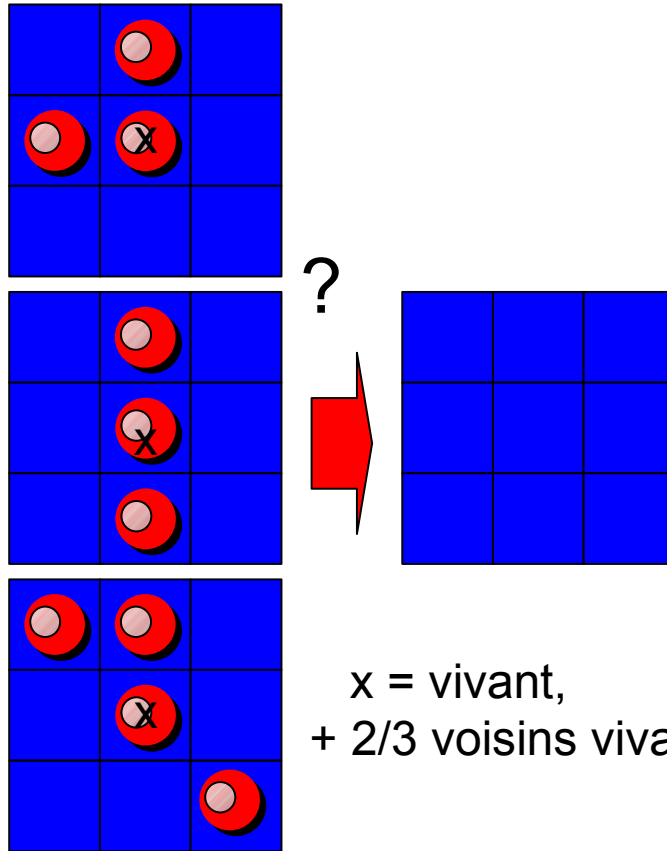
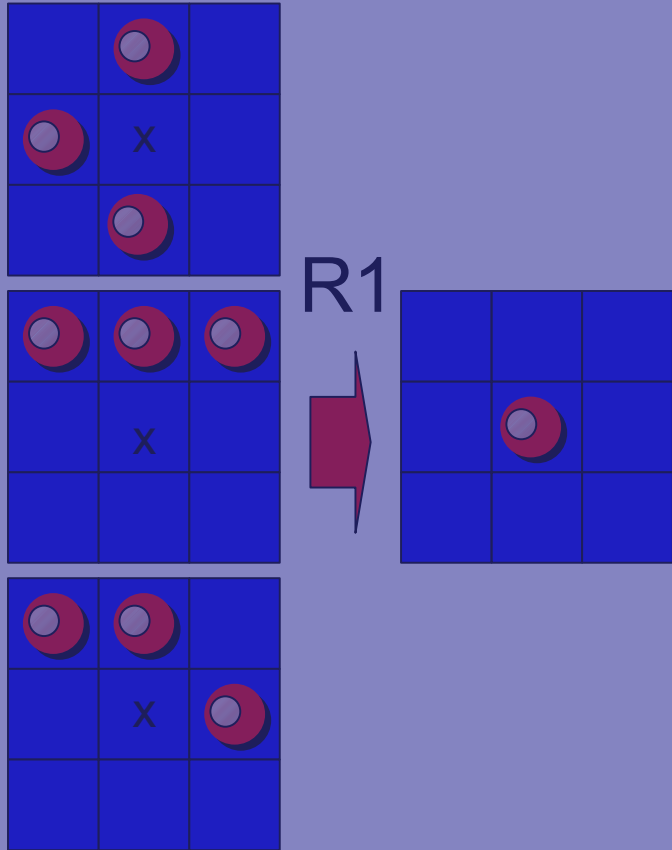
Exemples



R1

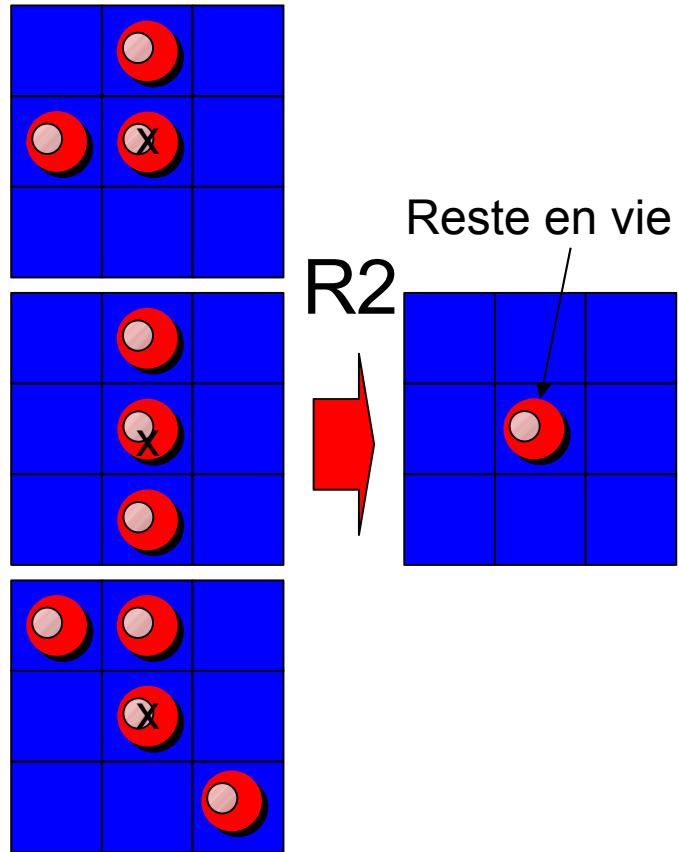
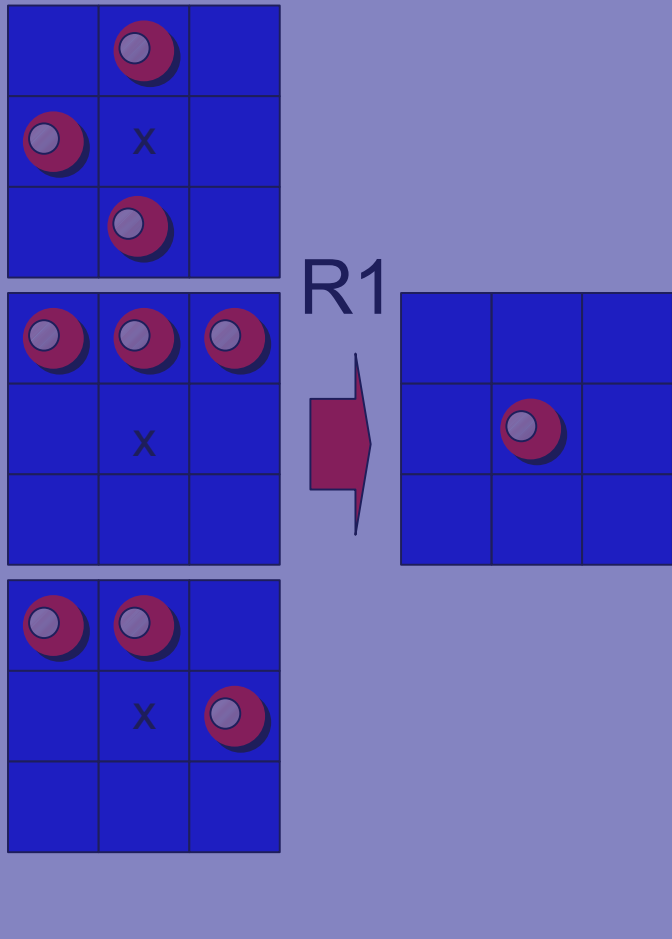


Exemples

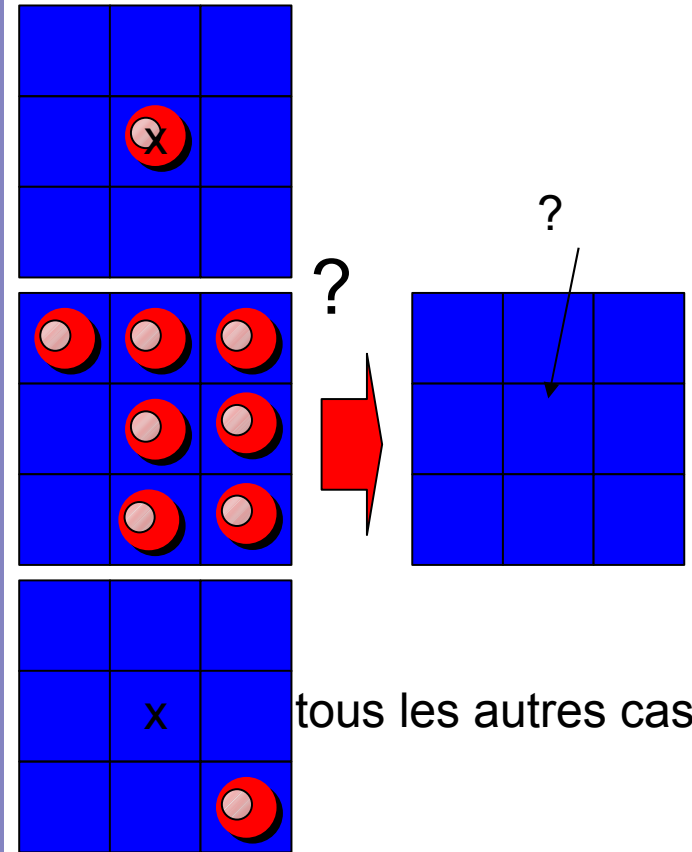
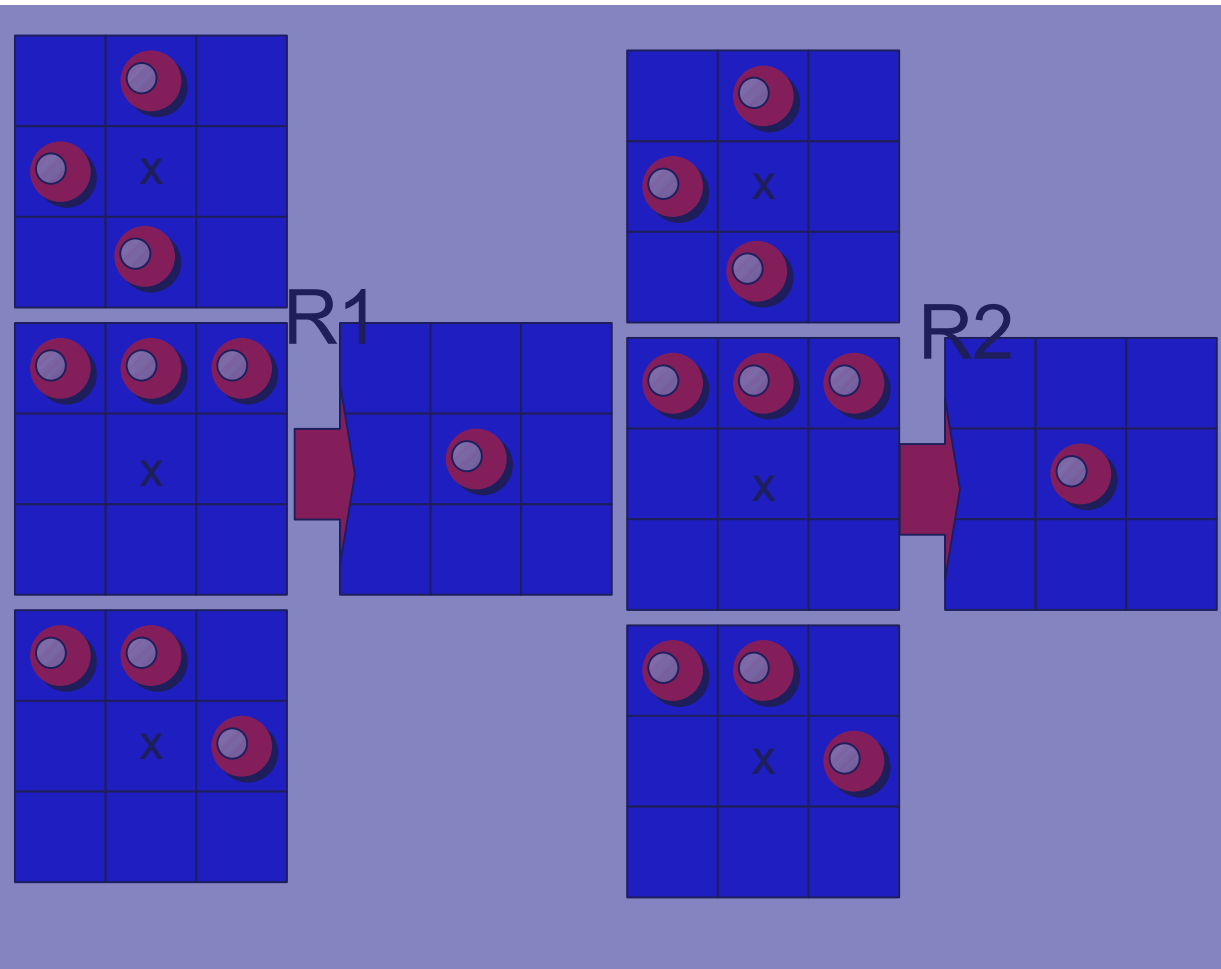


x = vivant,
+ 2/3 voisins vivants

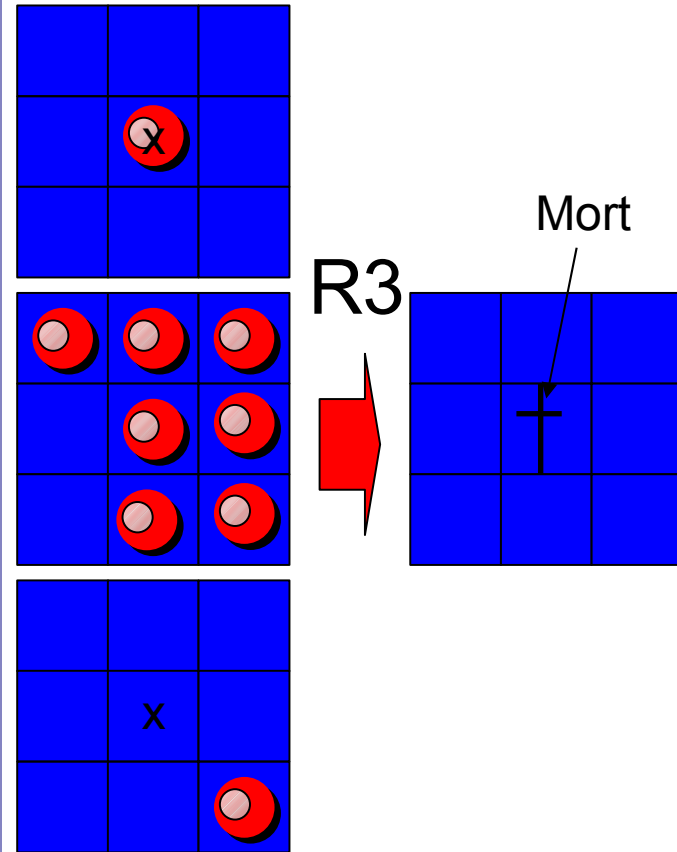
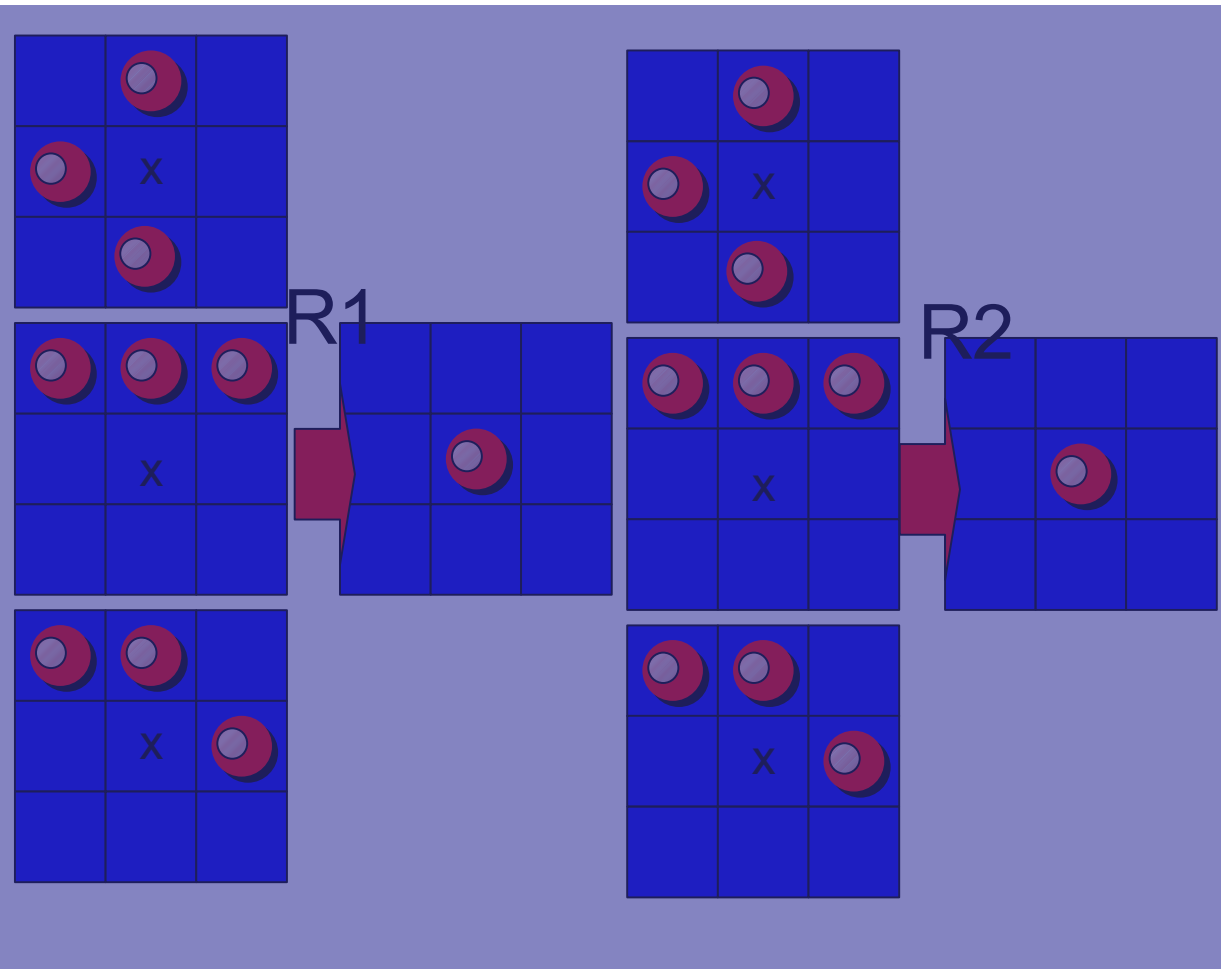
Exemples



Exemples



Examples



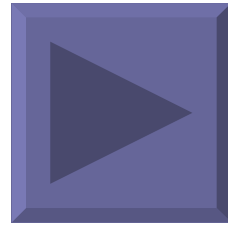
Ou ça va ? Dynamique des AC

Convergence des automates cellulaires :

- Configurations stables (points fixes),
- Oscillateurs,
- Vaisseaux spatiaux (attracteurs cycliques)

- Comportements émergents

Exemple



Applications

- Analyse du trafic routier,
- Cryptographie,
- Simulation économique,
- Évolution/croissance de l'univers,
- Virus informatiques,
- Comportements sociologiques (colonies de fourmis...),
- ...
- Analyse empirique des phénomènes émergents

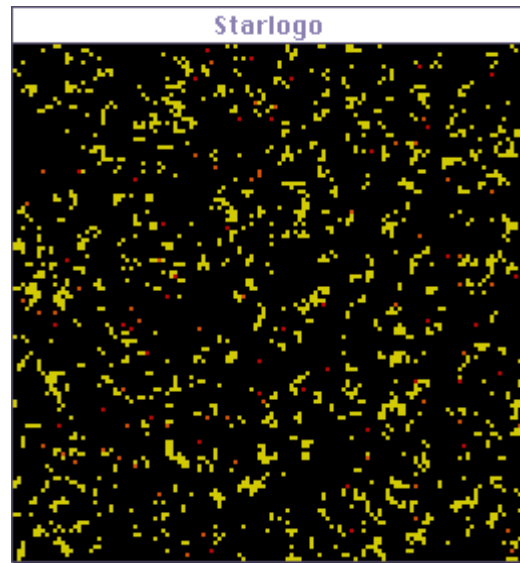
Théorie générale de Automates cellulaires

- $A = \{d, G, S, f\}$, avec
- d , le nombre de dimensions,
- G , le voisinage cellulaire,
- S , un ensemble fini d'états,
- f , la fonction de transition

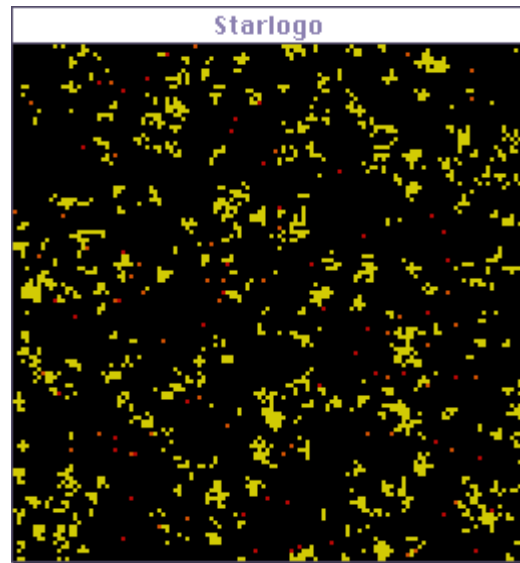
Application aux termites

- 2 dimensions,
- Voisinage identique,
- plusieurs états :
 - Thermite (rouge) avec ou sans nourriture,
 - Réserve de Nourriture (jaune),
- Les règles changent :
 - Si une thermite est en contact d'une réserve de nourriture elle la prend,
 - Sinon, elle se déplace au hasard,
 - Si plus tard elle est en contact d'une réserve de nourriture elle dépose sa propre nourriture

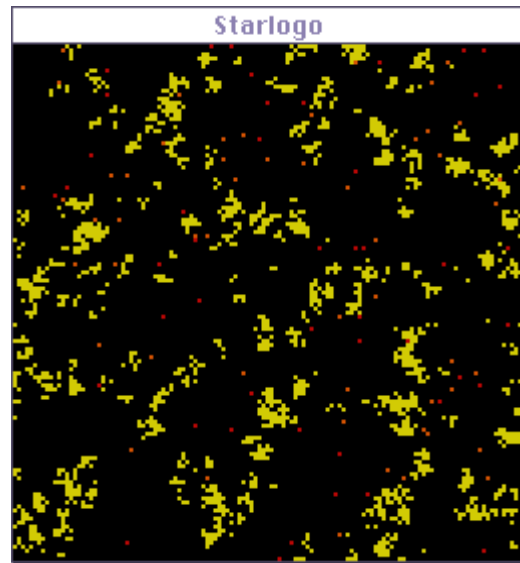
Application aux thermites



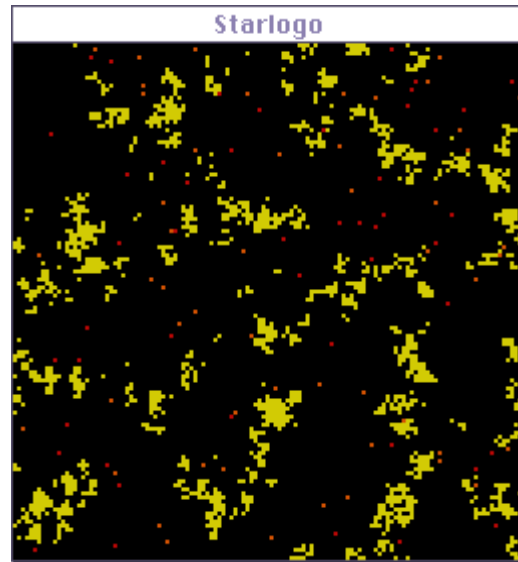
Application aux thermites



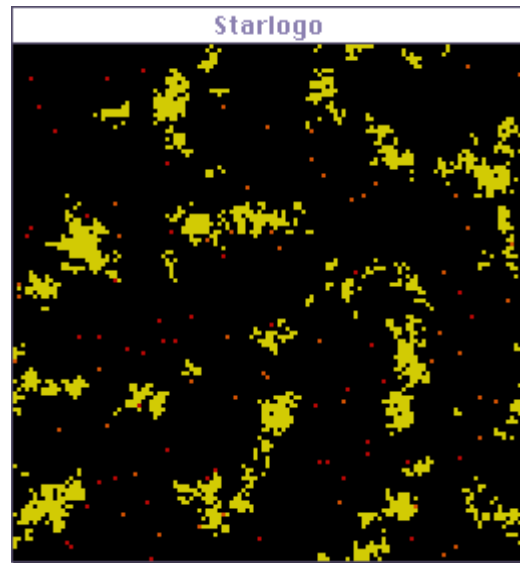
Application aux thermites



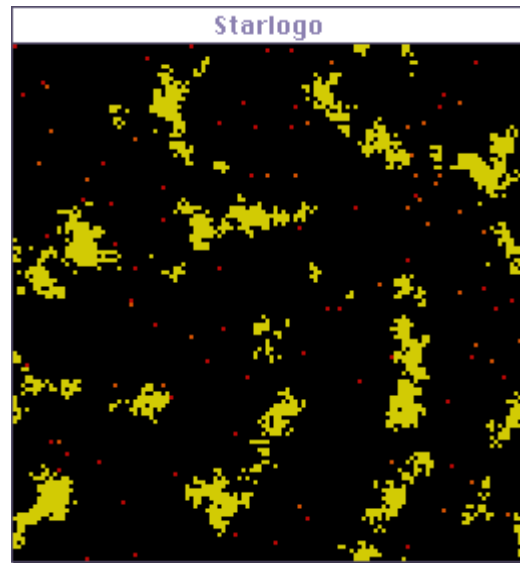
Application aux thermites



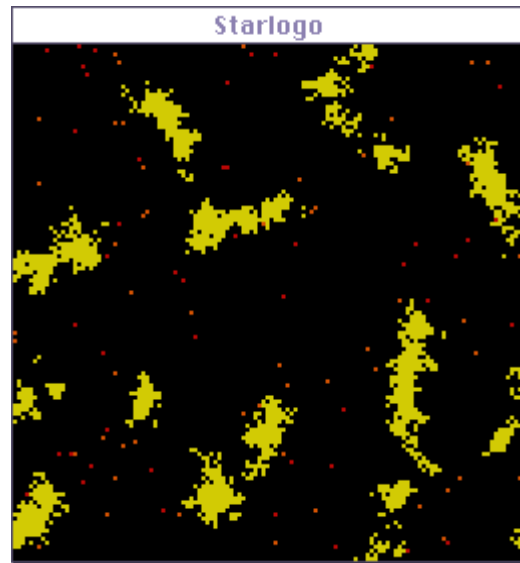
Application aux thermites



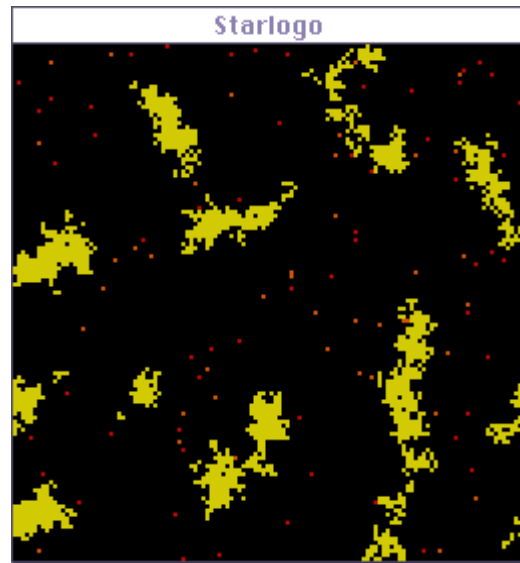
Application aux thermites



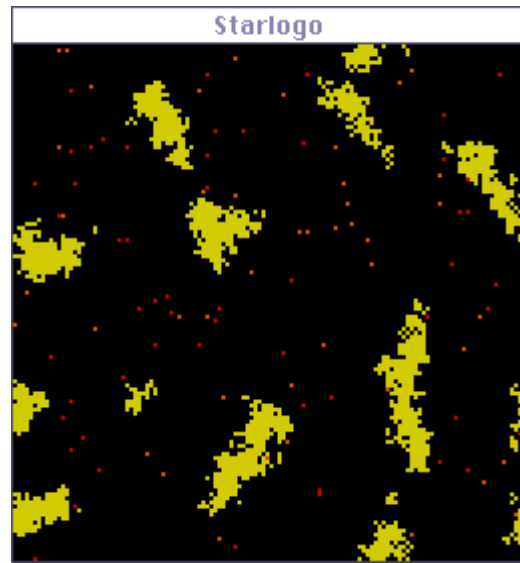
Application aux thermites



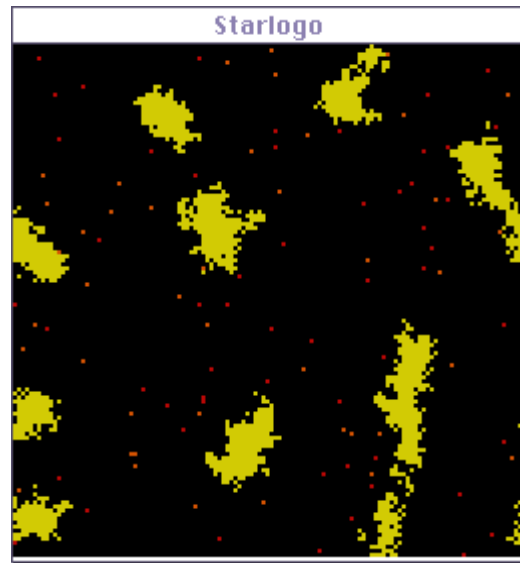
Application aux thermites



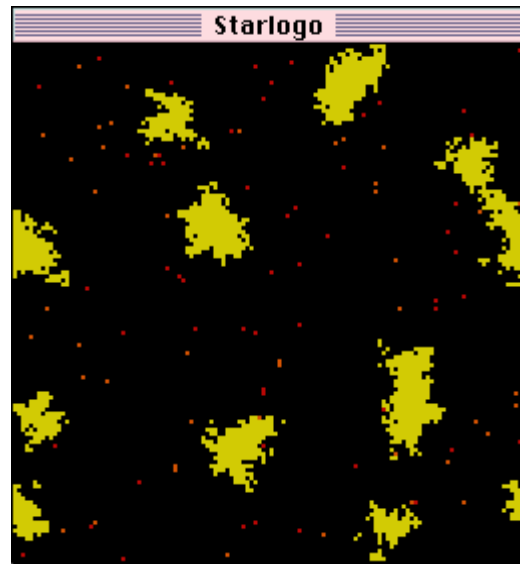
Application aux thermites



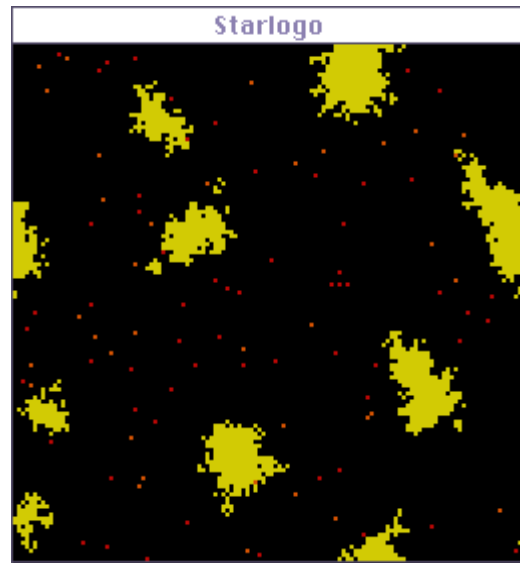
Application aux thermites



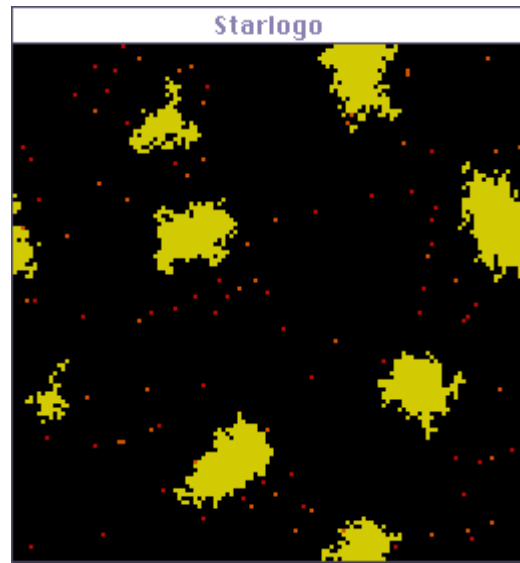
Application aux thermites



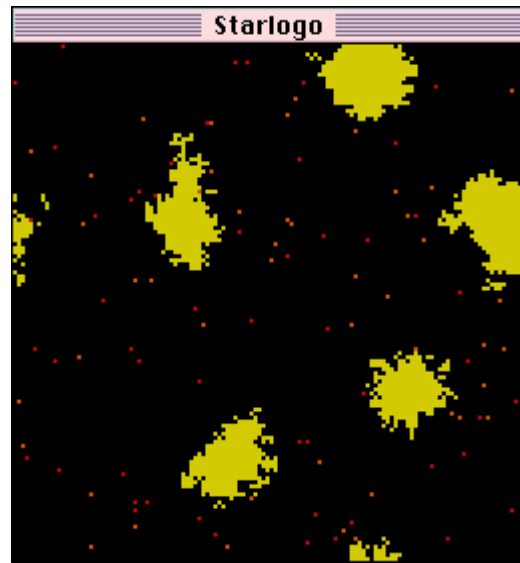
Application aux thermites



Application aux thermites



Application aux thermites



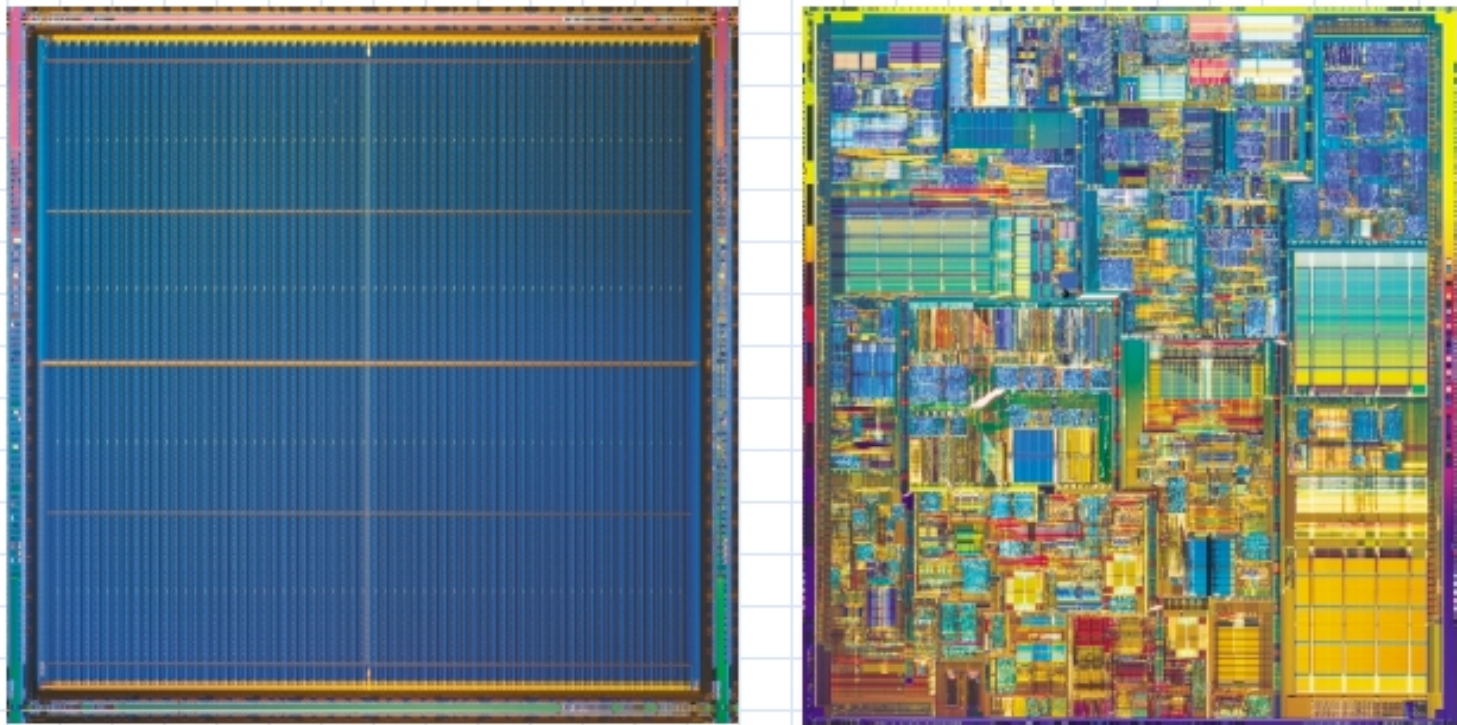
Conclusion sur les AC

- Les automates cellulaires sont des machines Universelles (au sens de Turing)
- Au même titre que les ordinateurs actuels
- Les automates cellulaires ont des propriétés supplémentaires :
 - Pas de contrôle centralisé,
 - Architecture fortement parallèle
 - Donc plus robuste,
 - Peut-être plus facile à programmer ...

Implémentation matérielle d'automates cellulaires

- V. Exemple d'Architecture matérielle bio-inspirée

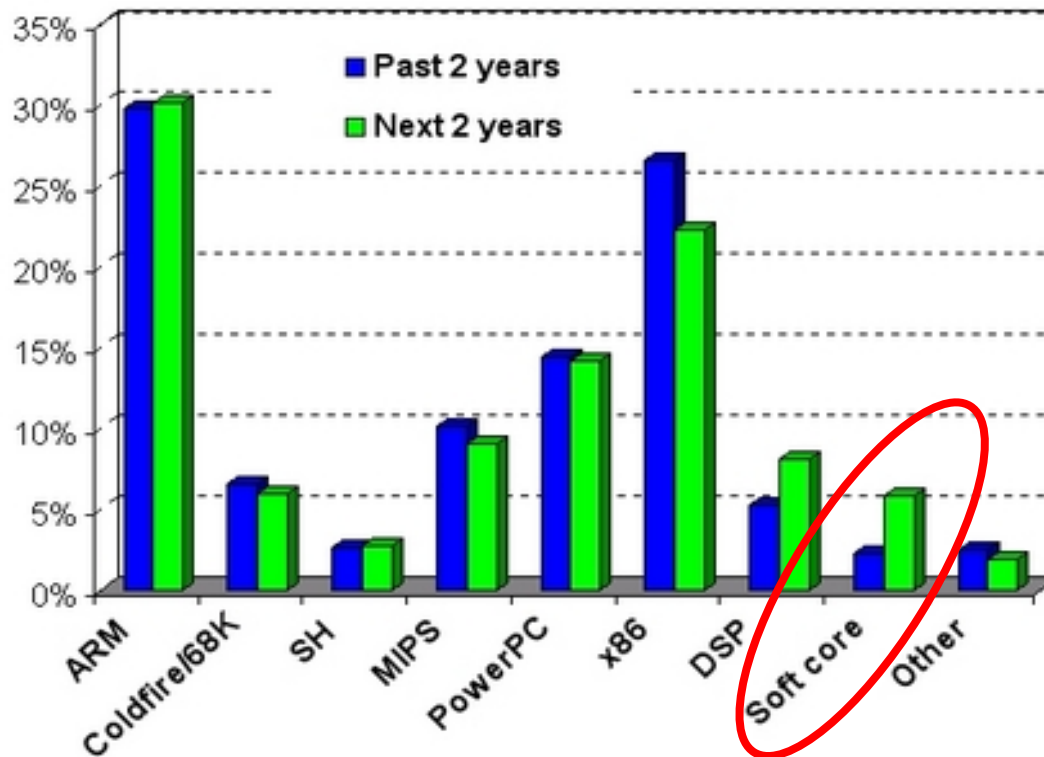
Définition du substrat



Les figures sont à des échelles différentes

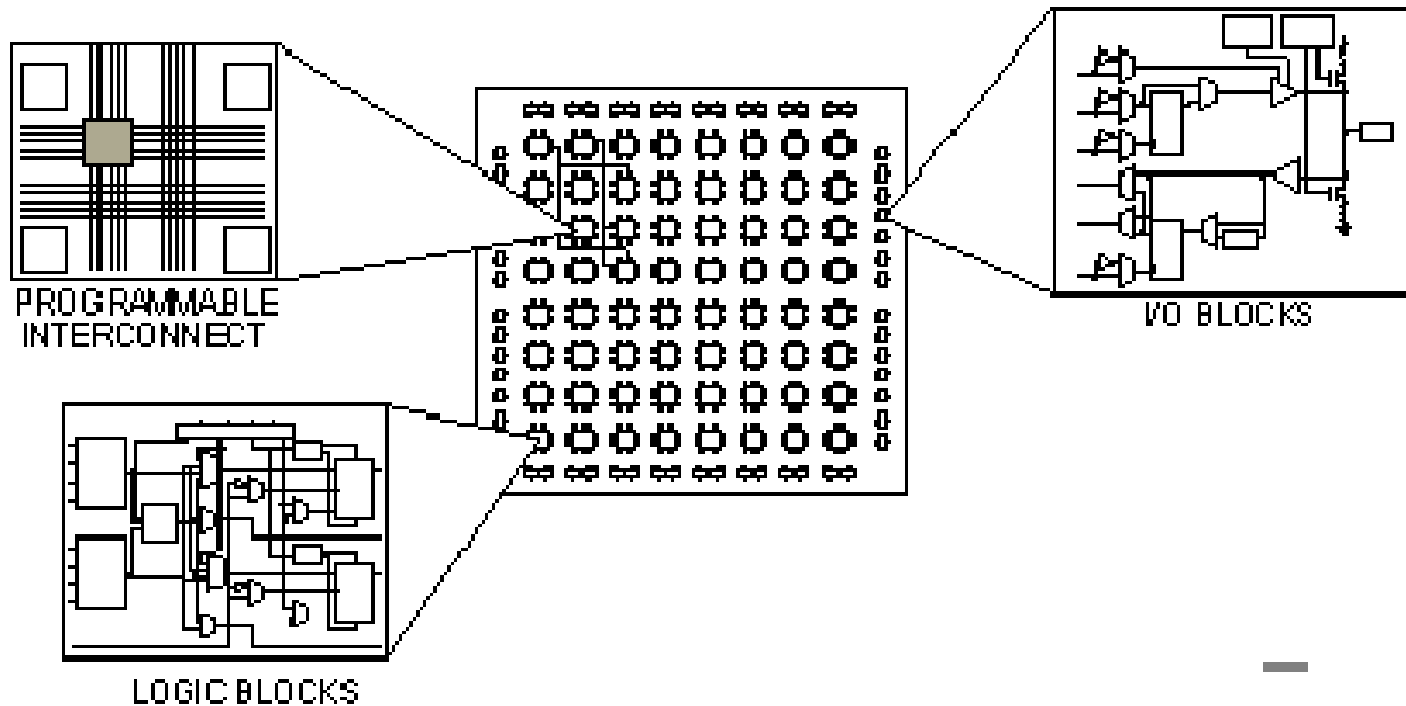
Architectures de traitement utilisées dans l'embarqué

Embedded processor preference trends

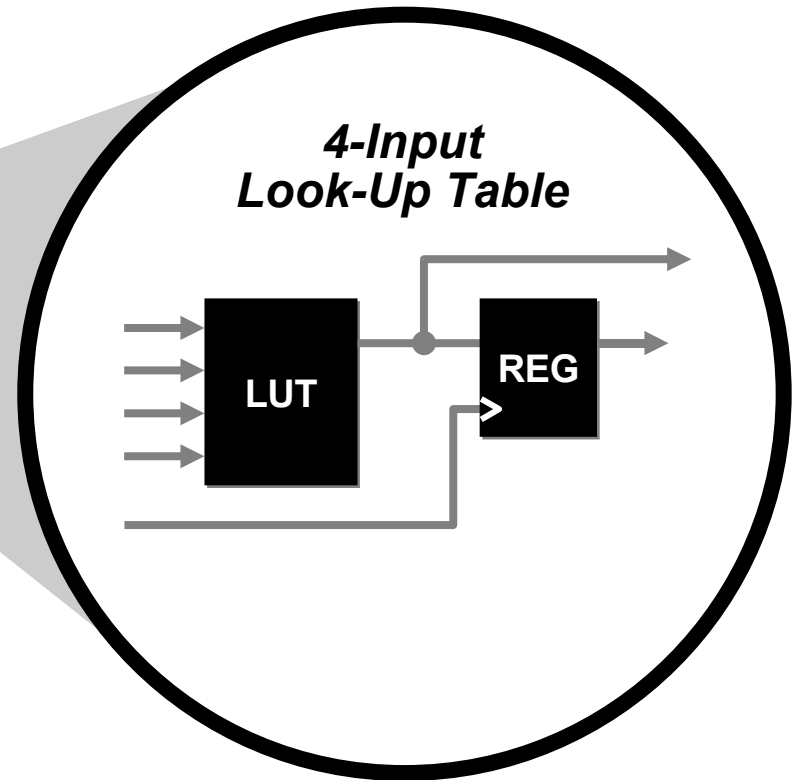
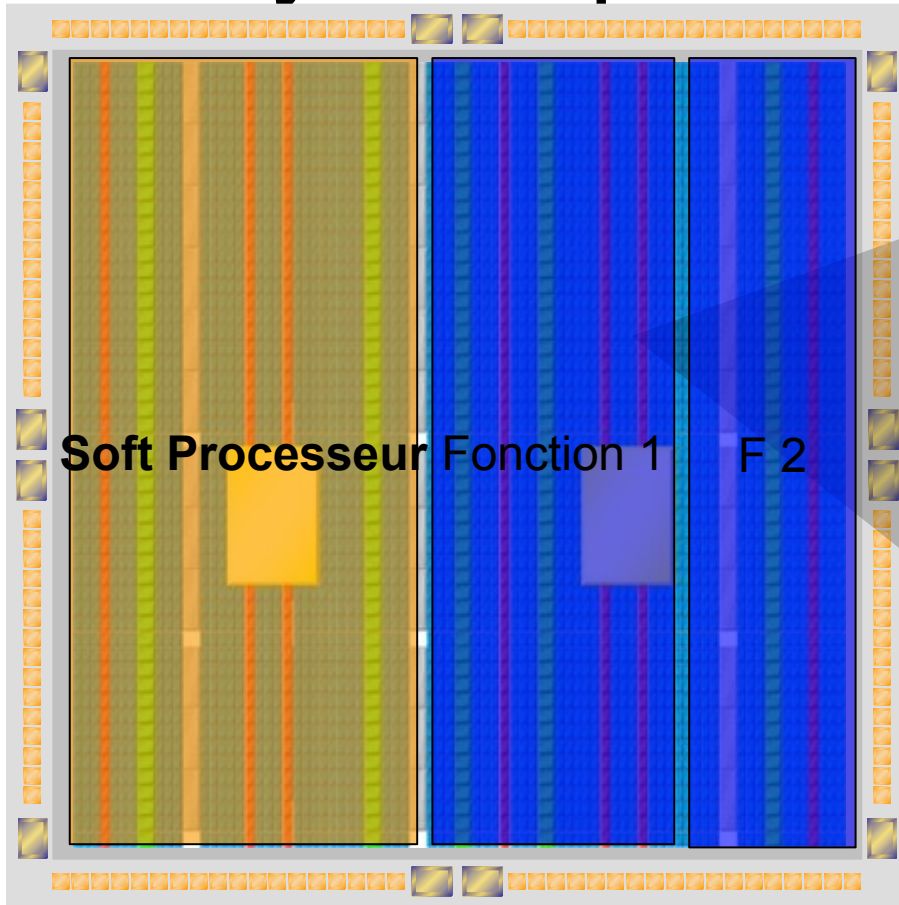


[LinuxDevices-2006]

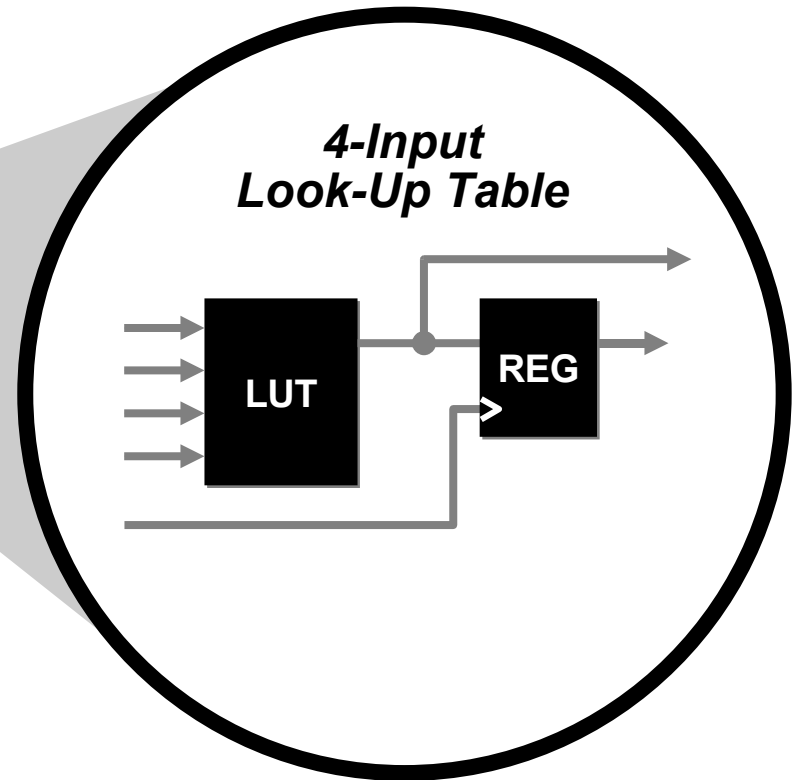
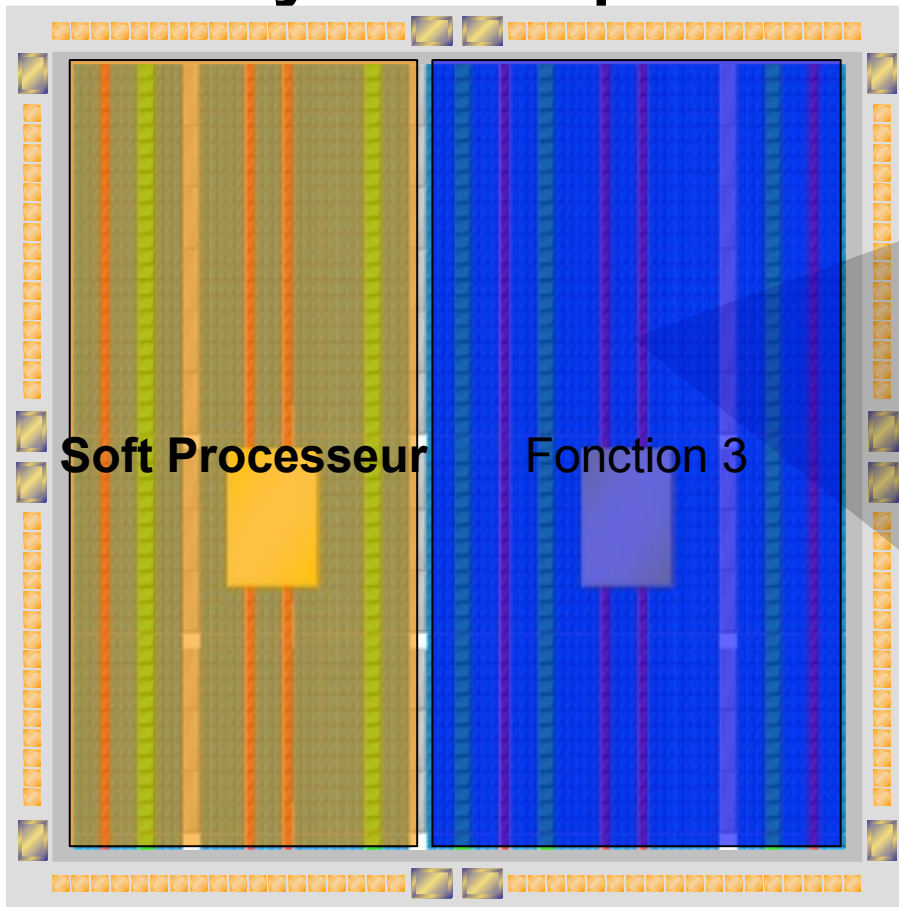
Structure régulière d'un FPGA



Propriété de reconfiguration dynamique – technologie 1D

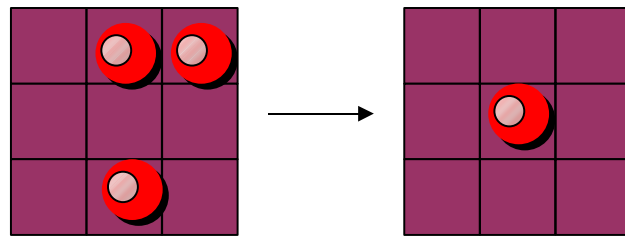


Propriété de reconfiguration dynamique – technologie 1D

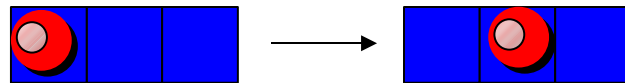


Implémentation de l'automate cellulaire

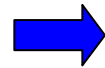
- L'ensemble des règles de transition est codé dans la LUT



G = 9

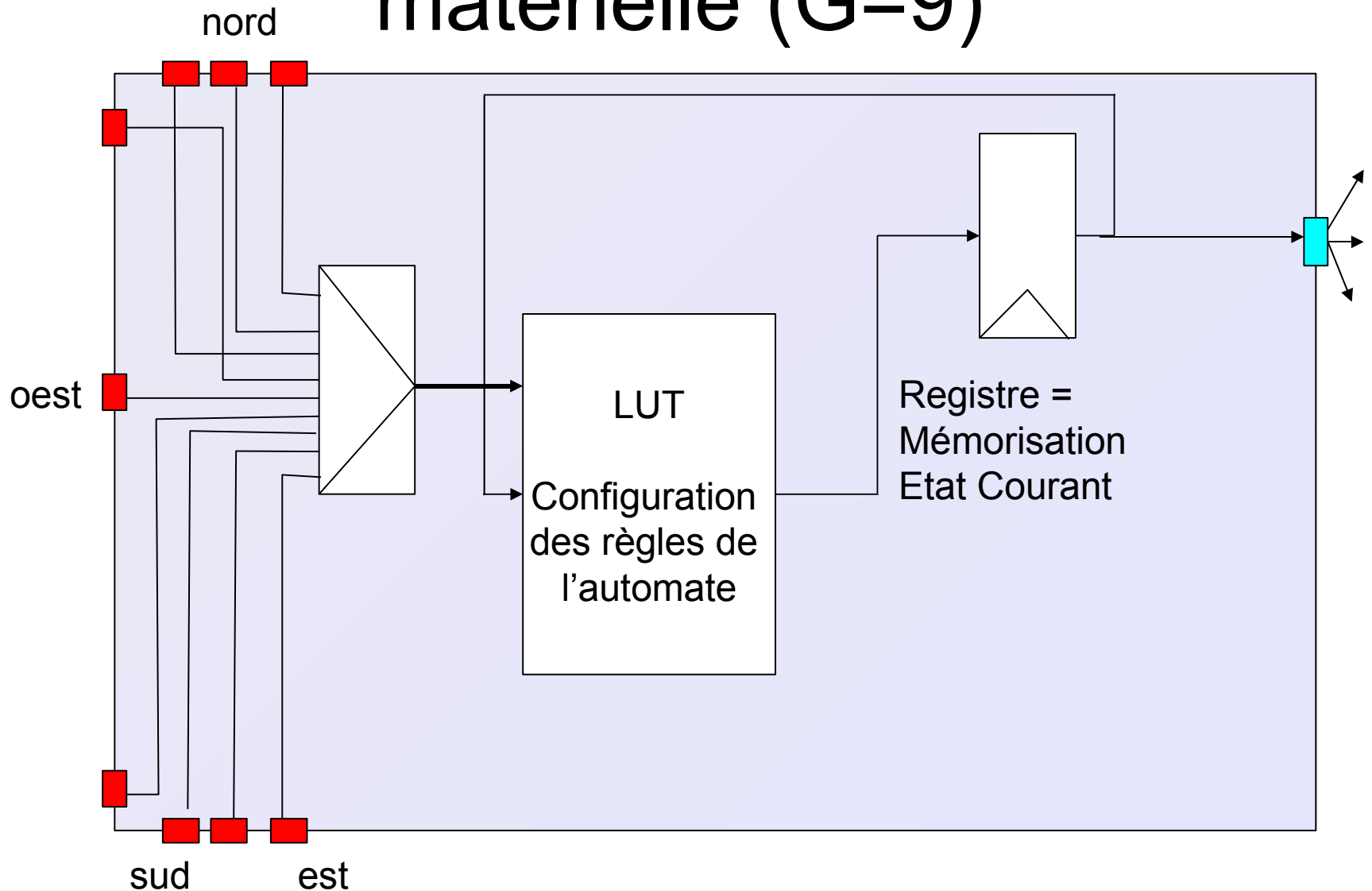


G = 3

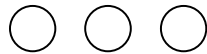
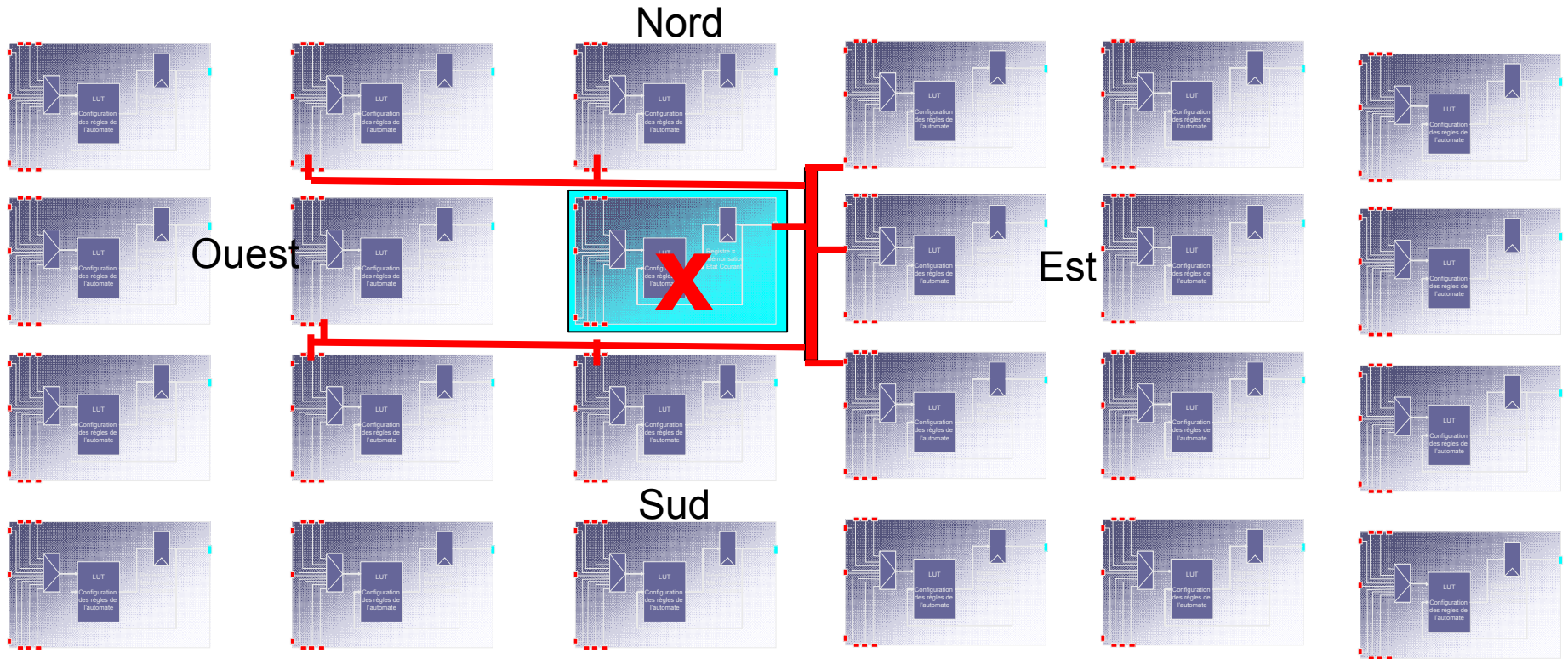


ouest	Etat courant	est	État futur
0	0	0	0
			1
0	1	0	0
0	1	1	1
1	0	0	1
1	0	1	0
1	1	0	1
1	1	1	0

Architecture simplifiée d'une cellule matérielle (G=9)



Architecture cellulaire



Applications simulées de cette architecture

- Exemples simples, calculable en $O(n)$:
 - La manipulation géométrique d'images,
 - Le calcul de plus court chemin dans un graphe,
 - Le tri de données

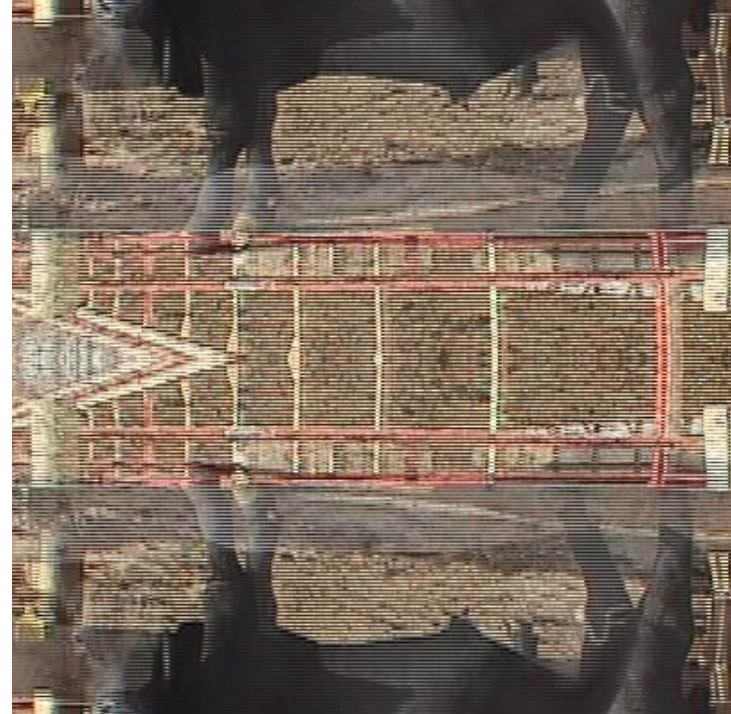
Exemple d'application

- Au lieu de considérer un ensemble d'état booléen $\{0, 1\}$, on prend maintenant n'importe quelle valeur réelle.
- L'état initial de l'automate peut donc représenté n'importe quelle structure de données,
- Exemple : une image,
- Objectif : réaliser un traitement géométrique



N = 0

Symétrie horizontale



N = 200

Image 400x400



**N = 400
cycles**



N = 800



N = 0

N = 200

Image 400x400

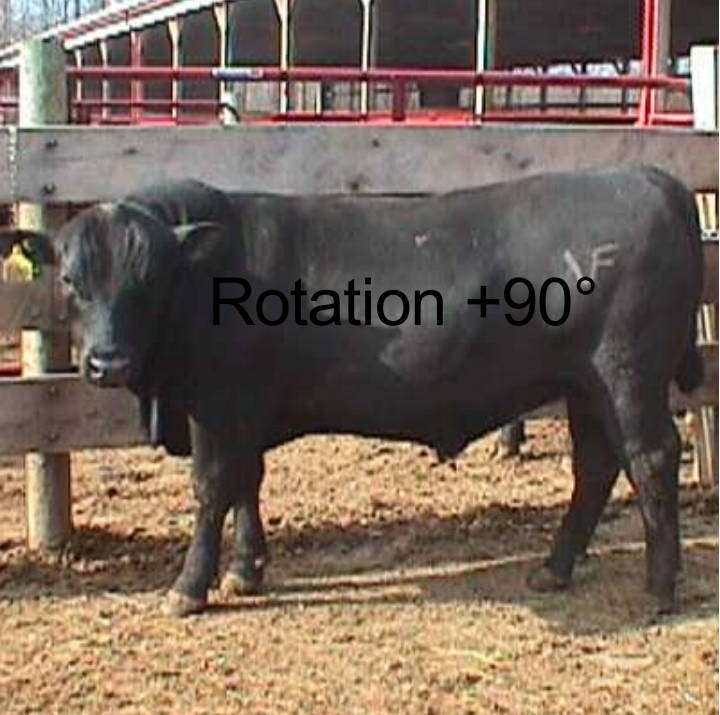


**N = 400
cycles**

N = 800



Image 400x400



Rotation $+90^\circ$

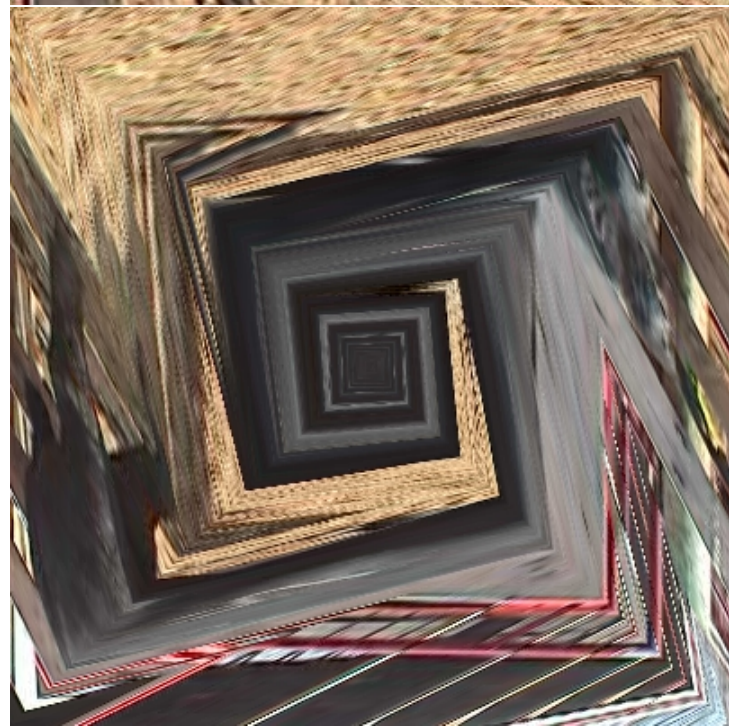
$N = 0$

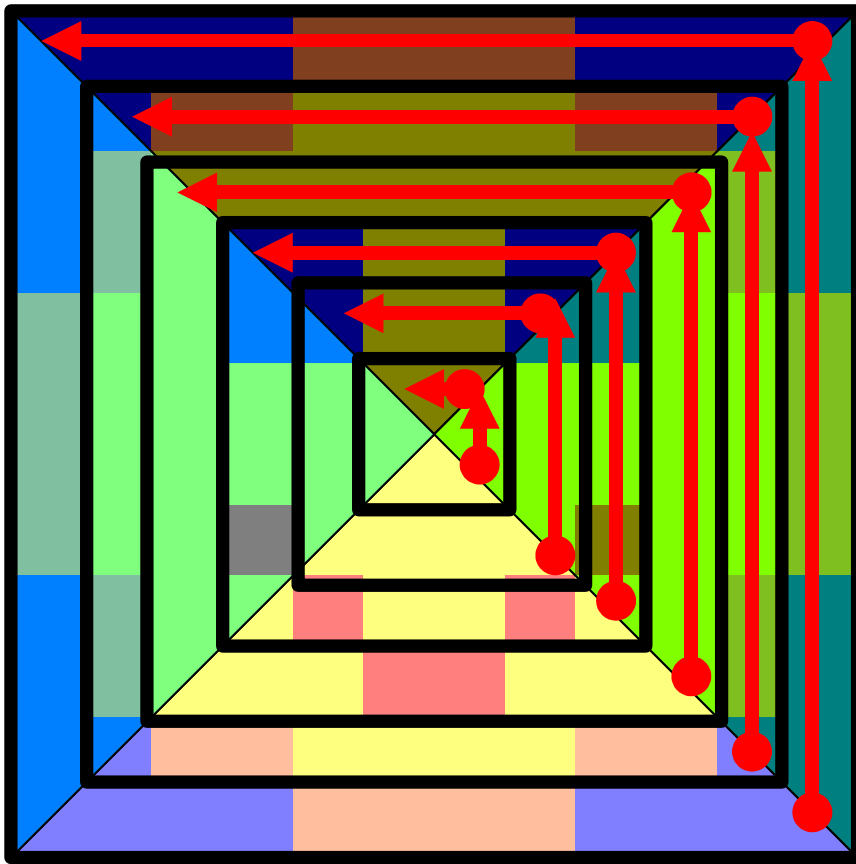
$N = 200$



$N = 399$
cycles

$N = 798$





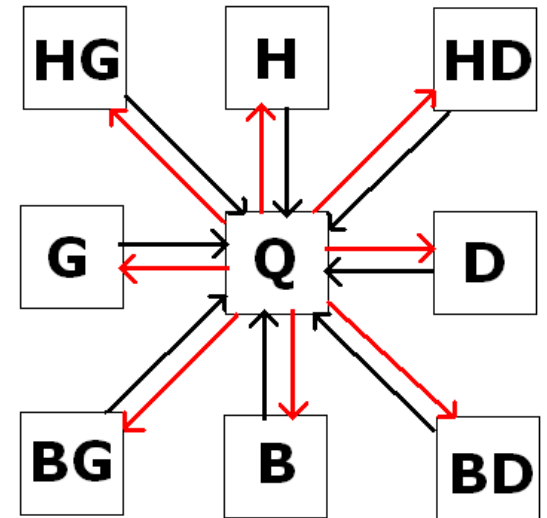
(Exemple Image 12x12)

Rotation d'images

Un pixel correspond à une cellule de l'automate cellulaire

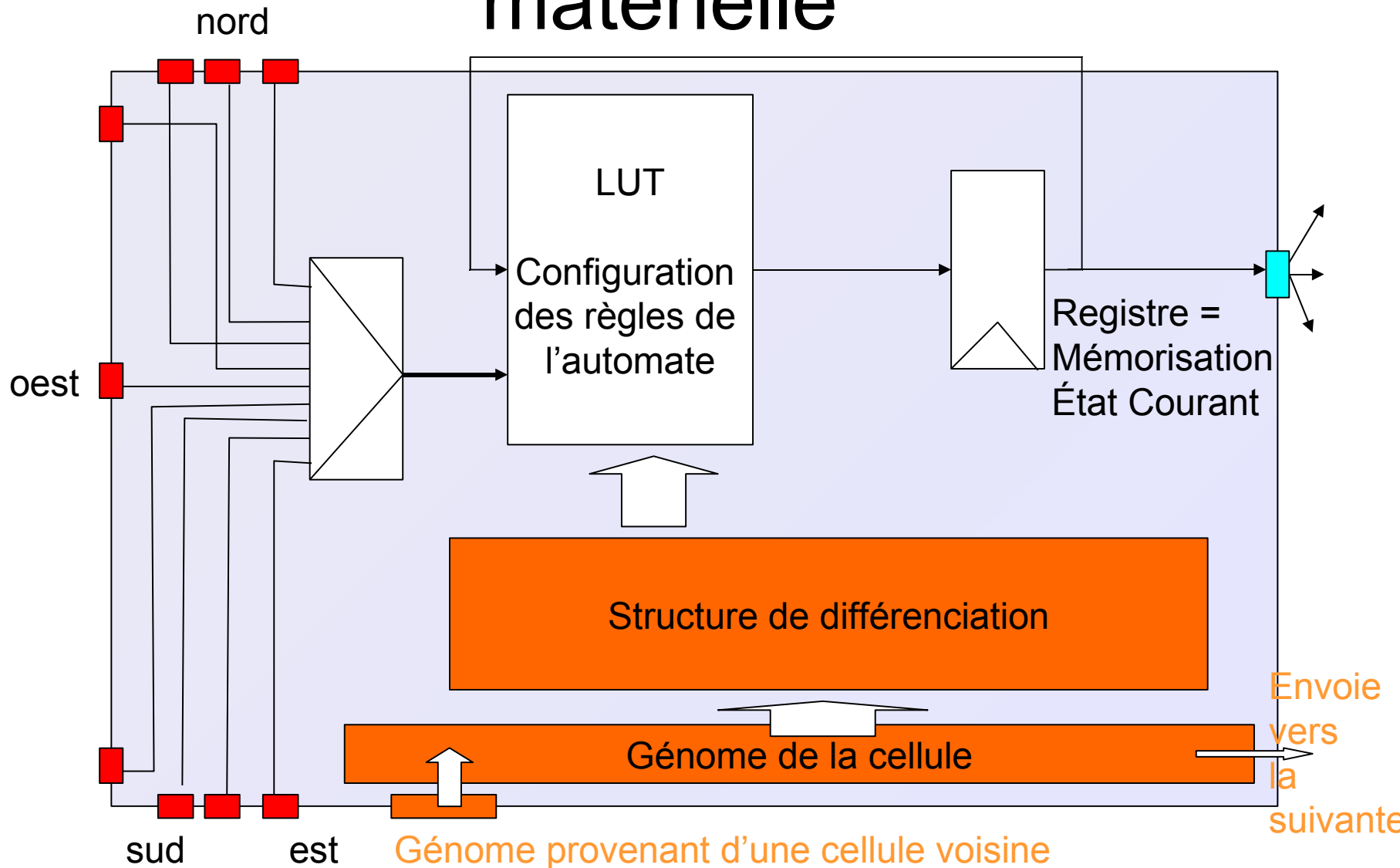
Structure à 2 dimensions

Voisinage de 9 cellules



L'automate n'est plus homogène, la règle dépend de la position de la cellule (différentiation)

Architecture simplifiée d'une cellule matérielle



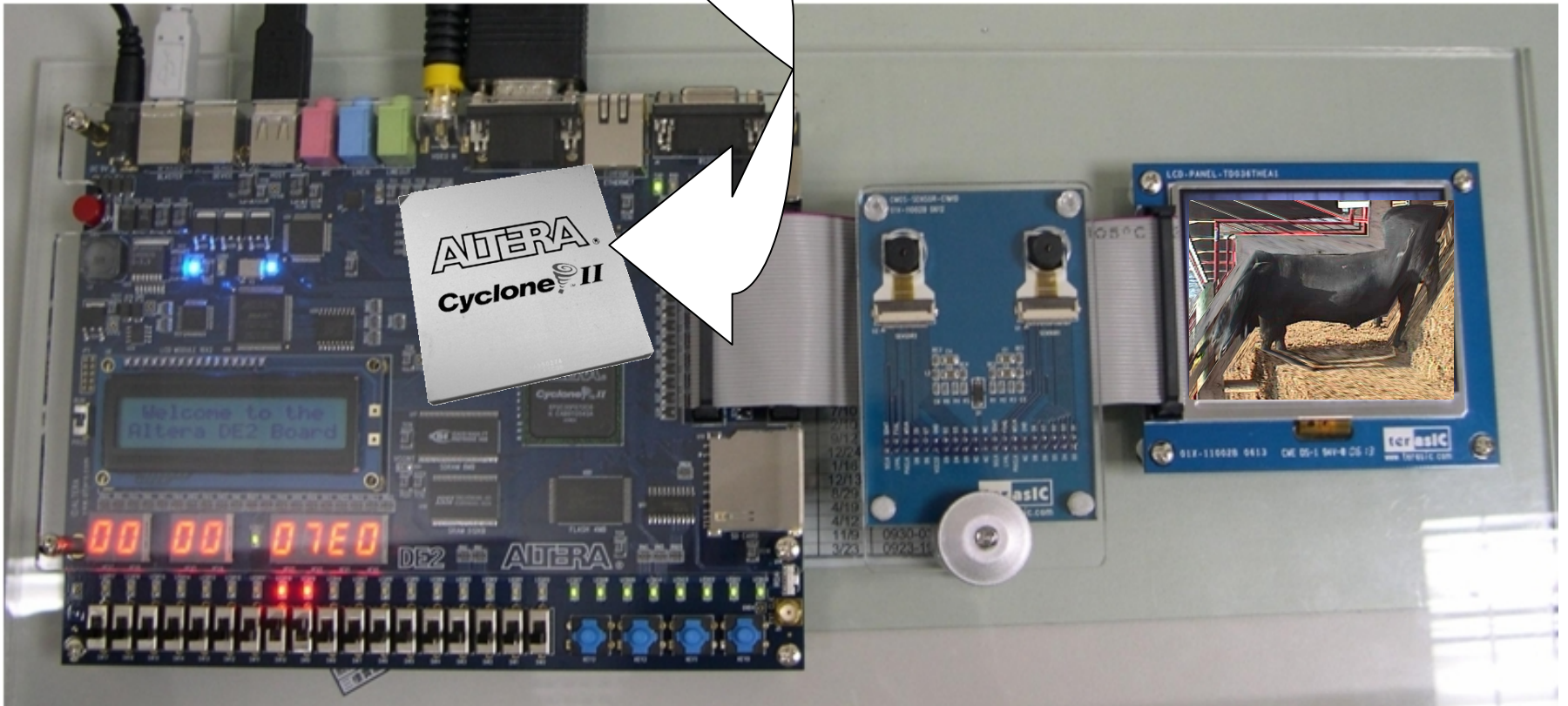
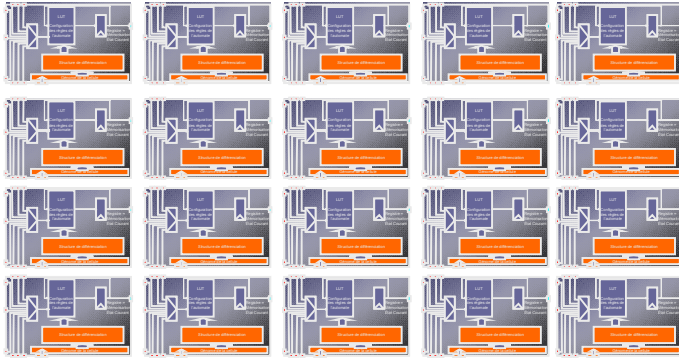
Architecture cellulaire répliquative



Phases d'exécution de cette architecture

1. Implantation d'un embryon
2. Réplication de la cellule mère
3. Phase de différenciation
4. Phase d'exécution

Suite des travaux

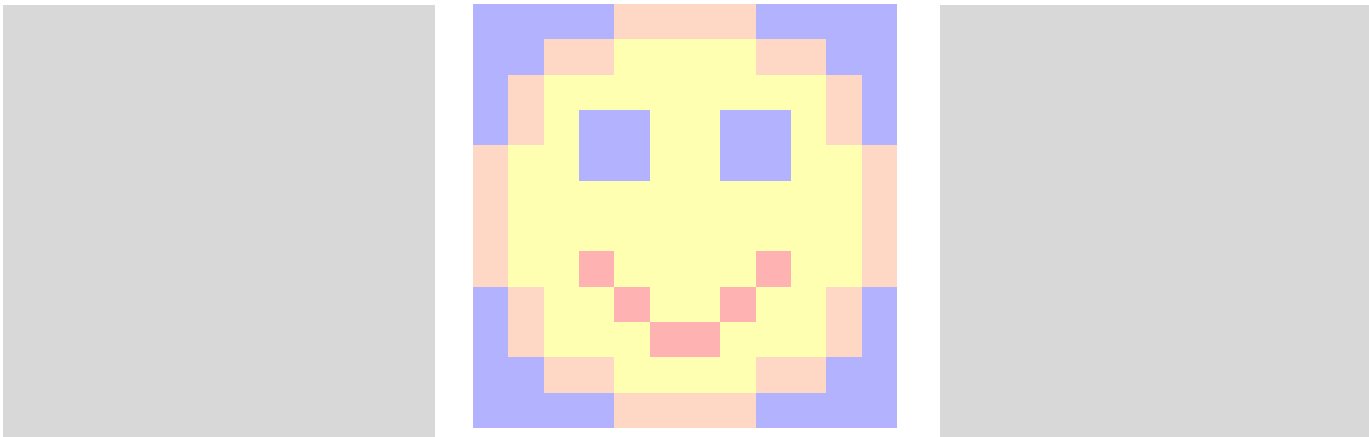


Suite des travaux, utilisation de la reconfiguration dynamique

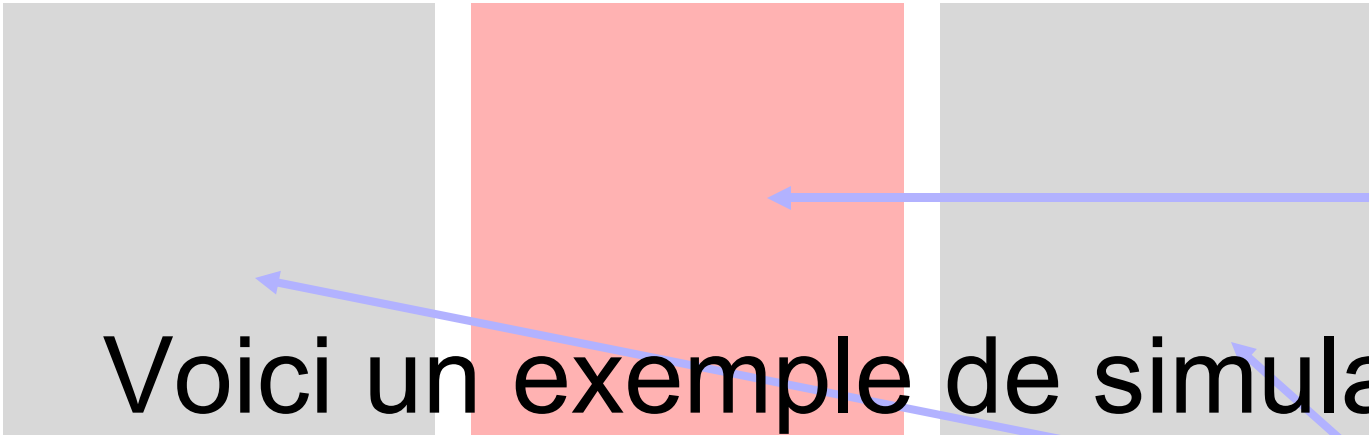
- Pour la réplication des cellules,
- Pour reproduire les mécanismes d'évolution de leur génotype,

- Pour fournir des systèmes auto-programmables,
- Pour développer des systèmes plus robustes et plus autonomes.

- Encore beaucoup de travail ...

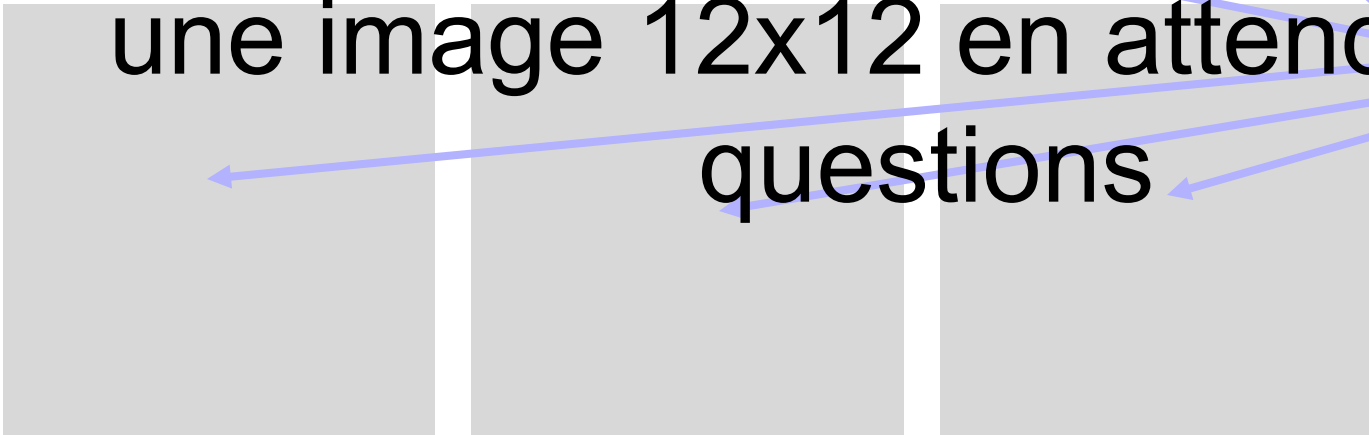


L'état d'une cellule est caractérisés par 9 variables d'état (1 cellule = 1 pixel)

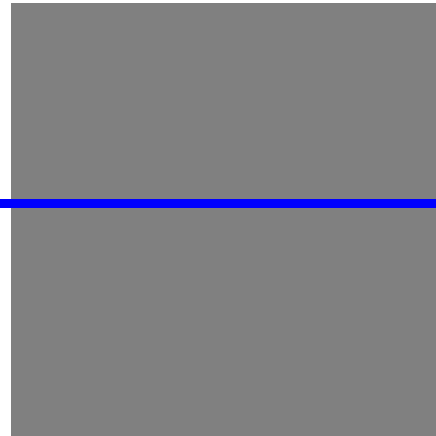
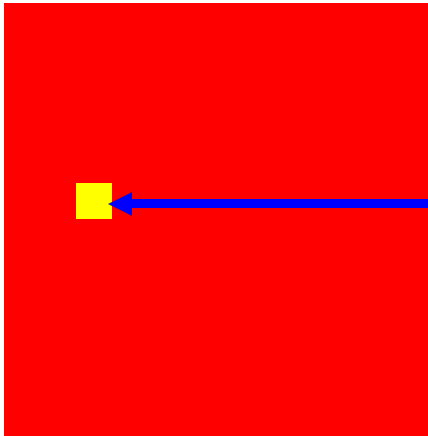
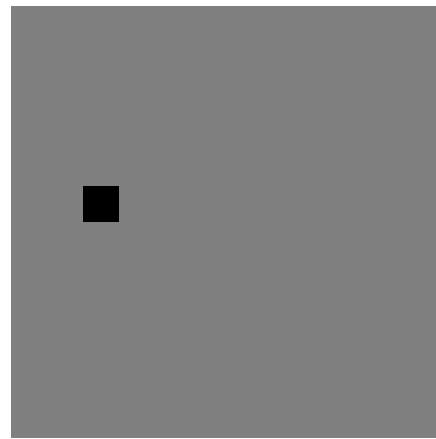
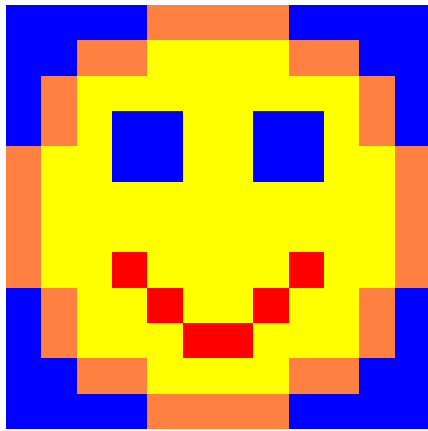
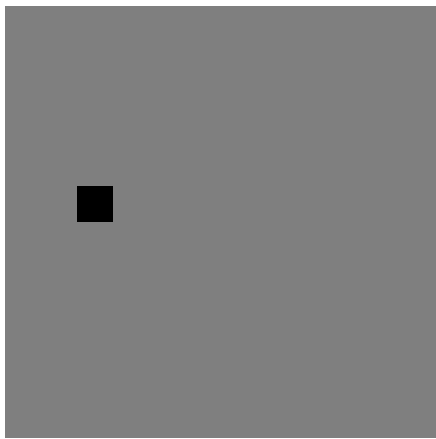


Rouge:
= Phase Repos
= Les cellules sont prêtes à recevoir leur génotype.

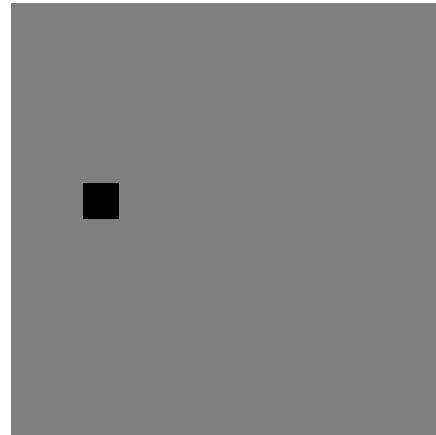
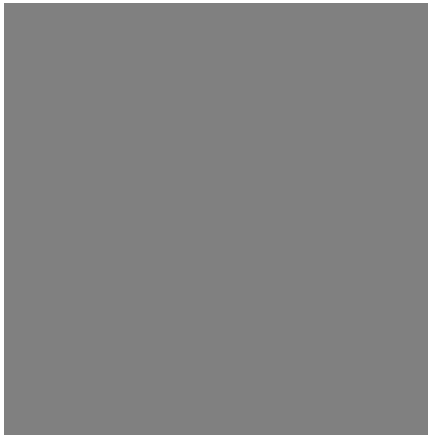
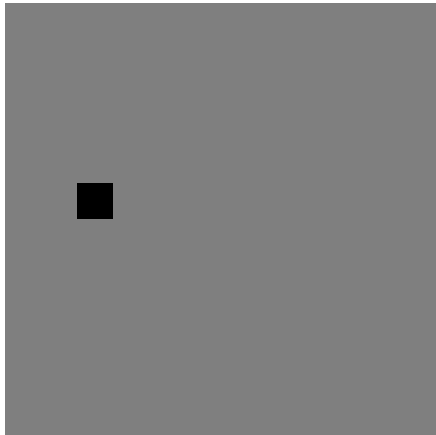
Voici un exemple de simulation sur une image 12x12 en attendant vos questions

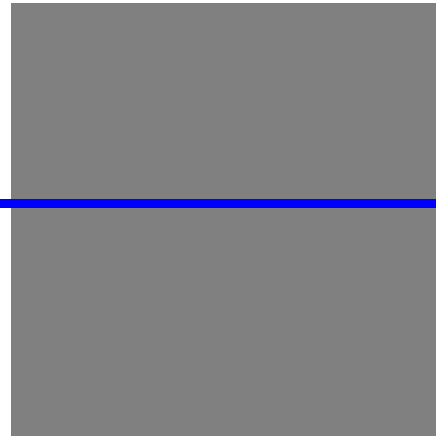
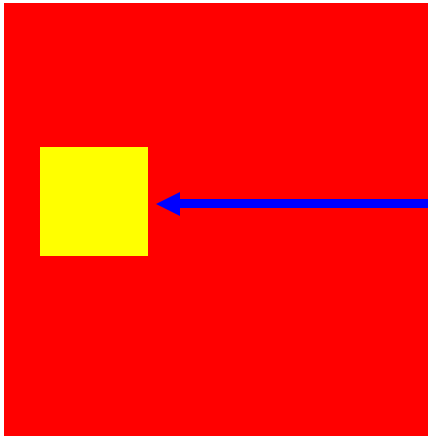
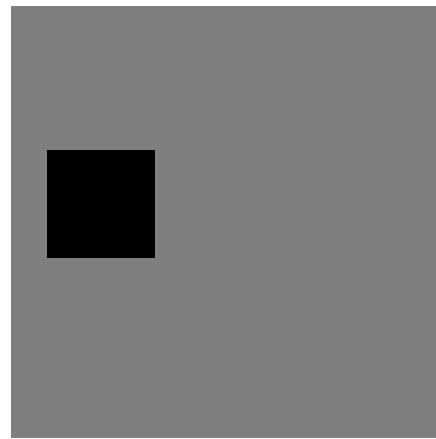
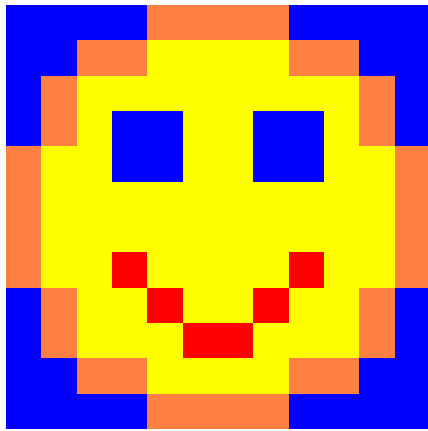
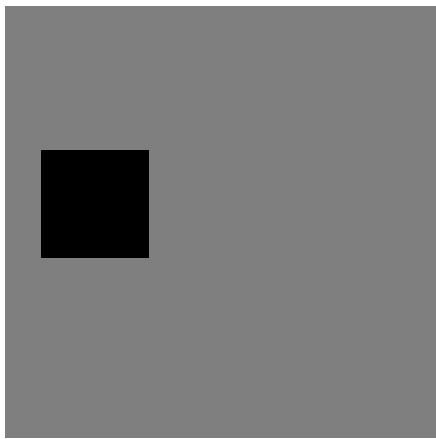


Autres variables d'état : non définies

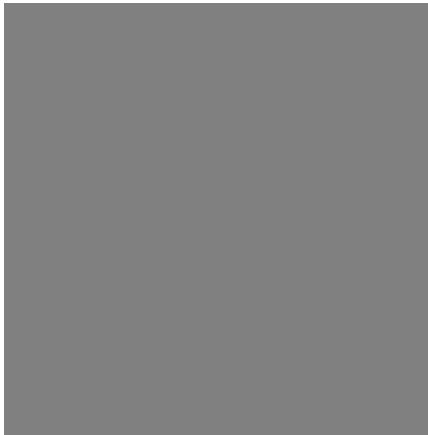


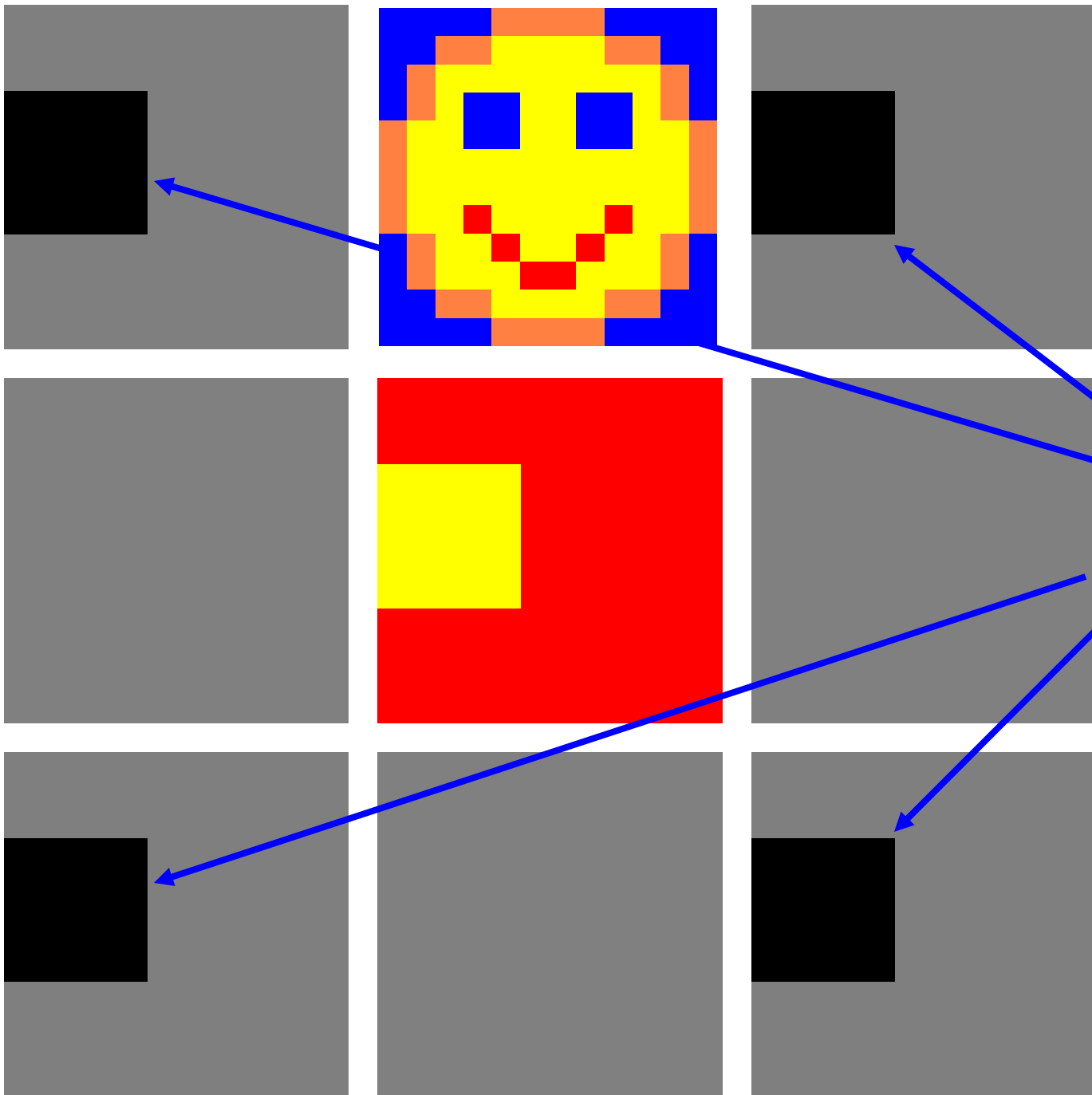
Une cellule reçoit la
totalité du génotype
(par l'utilisateur)



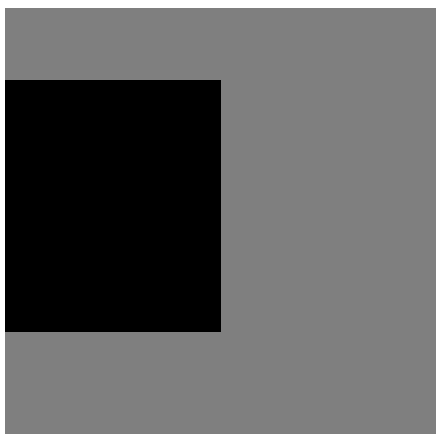
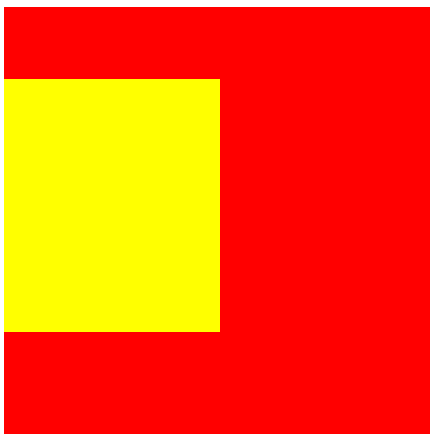
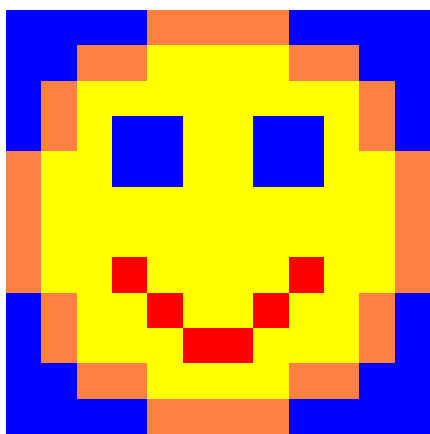


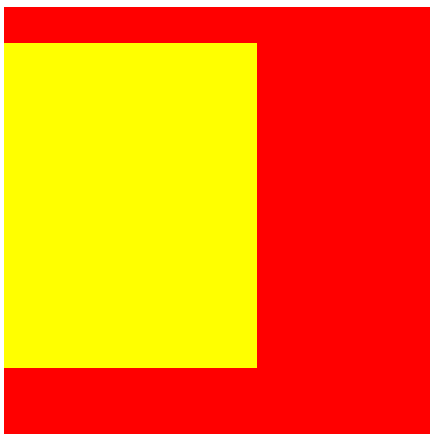
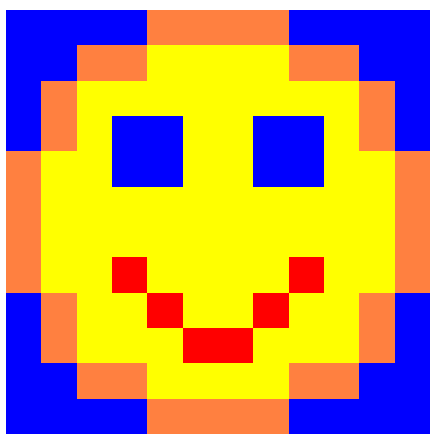
Cette cellule se reproduit de proche en proche

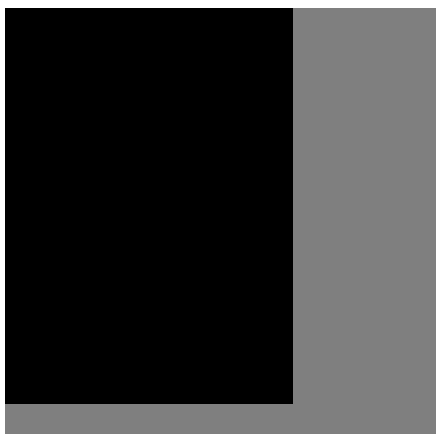
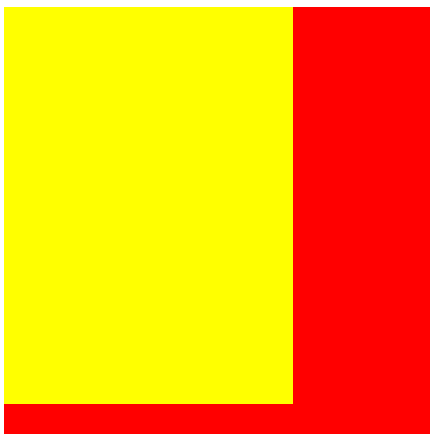
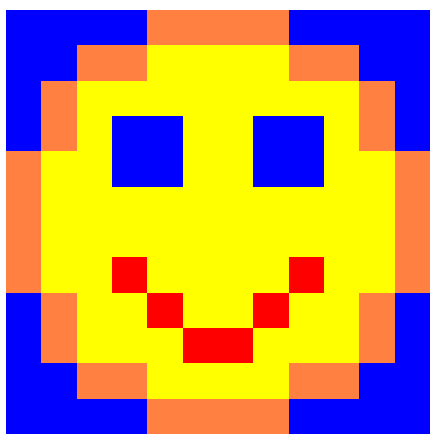


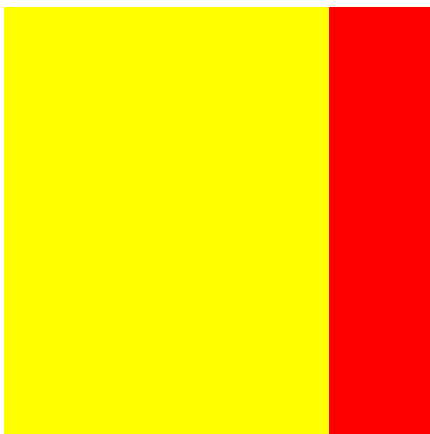
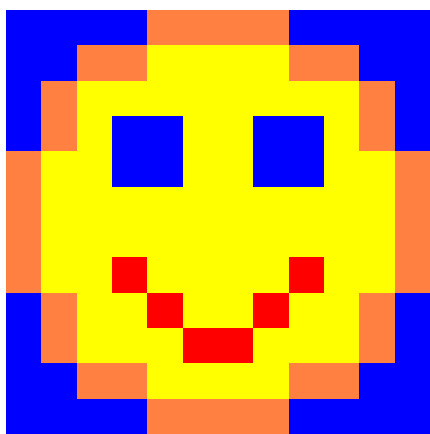


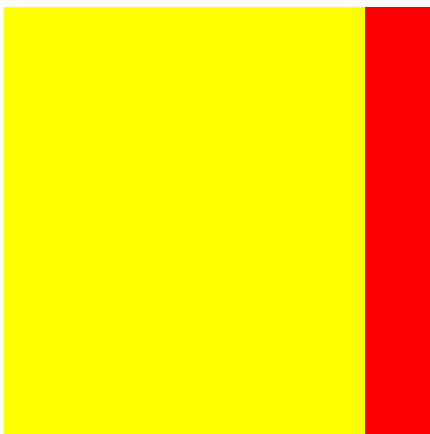
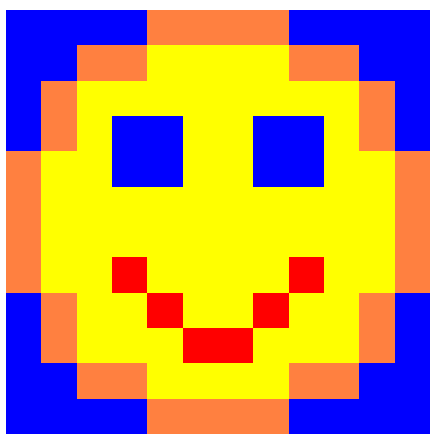
Dans le génotype se trouve l'information initialisant ces 4 variables

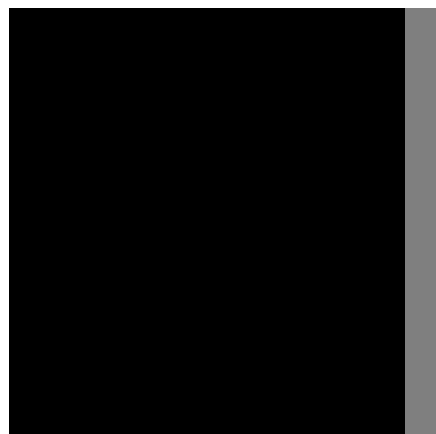
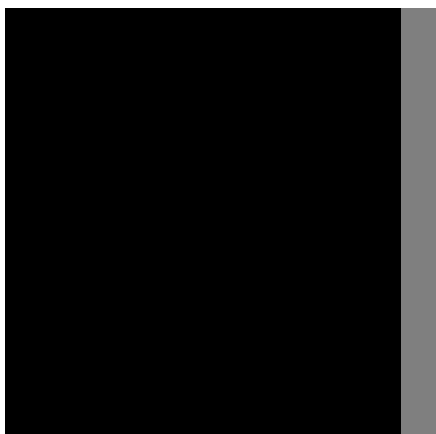
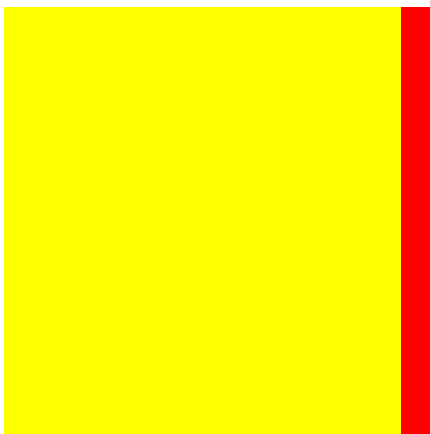
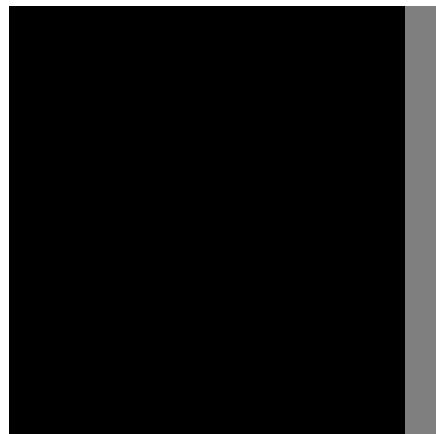
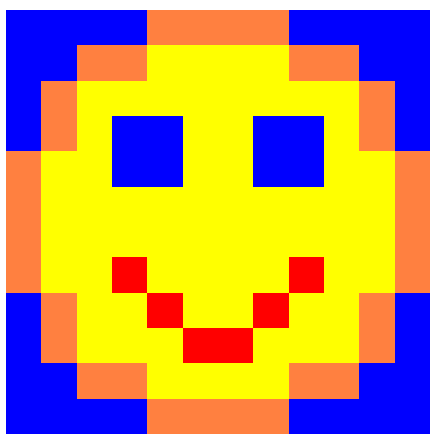
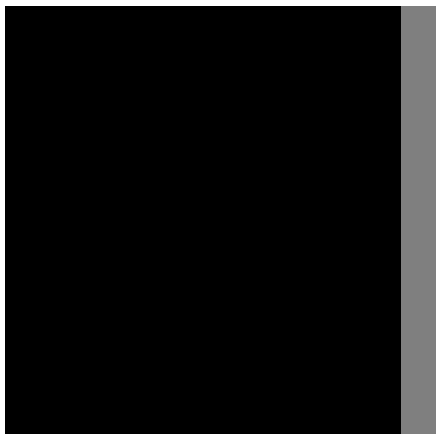


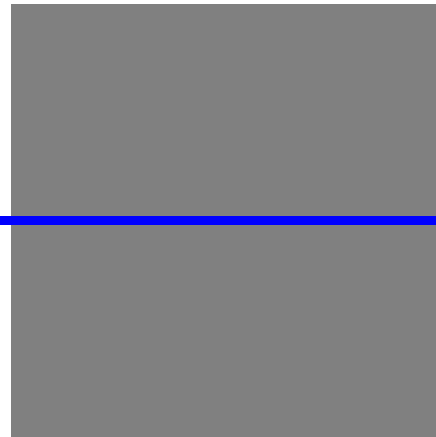
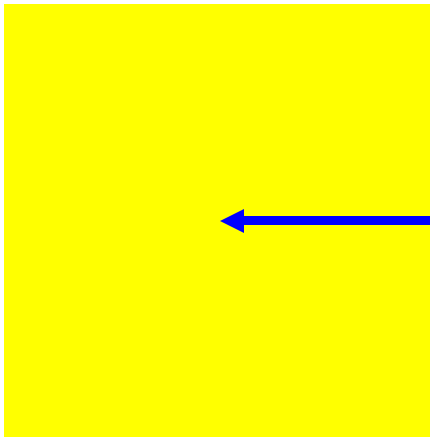
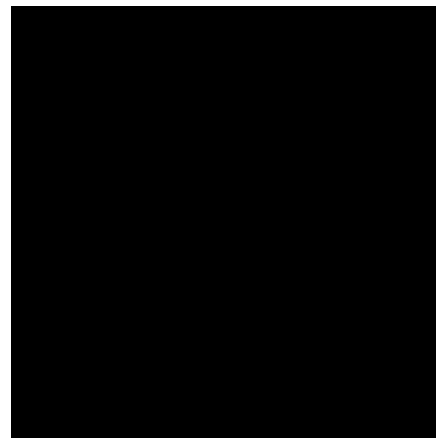
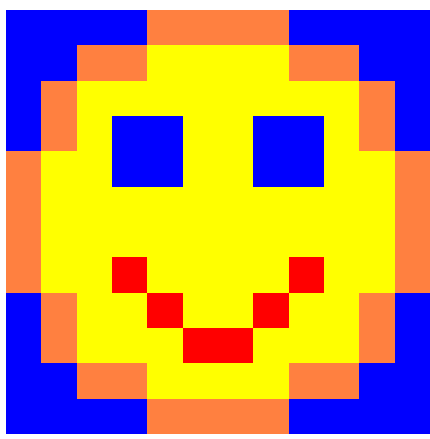
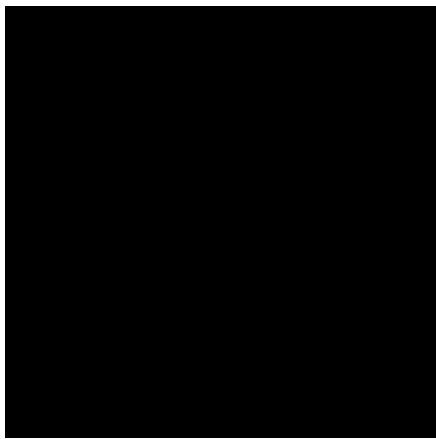




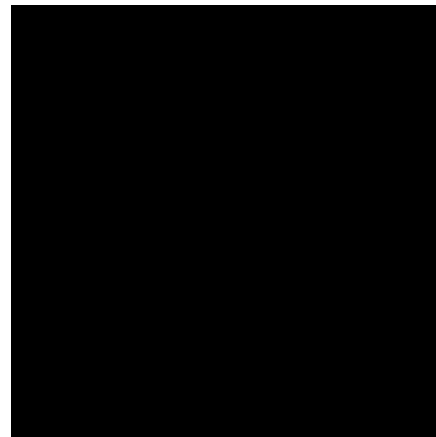


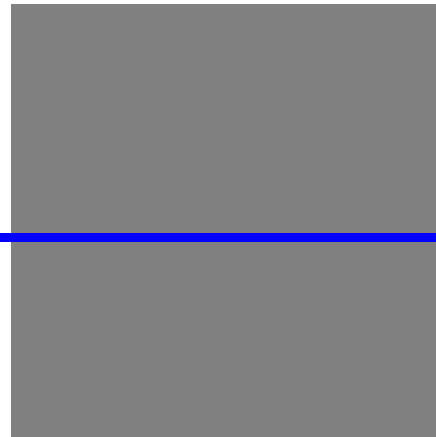
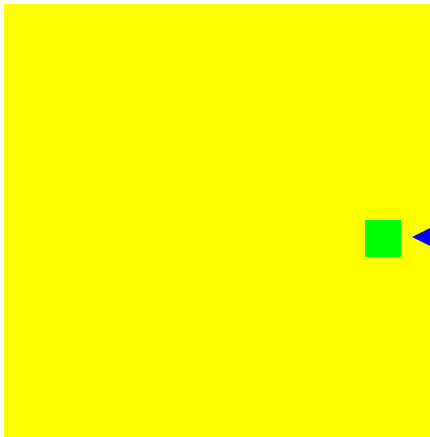
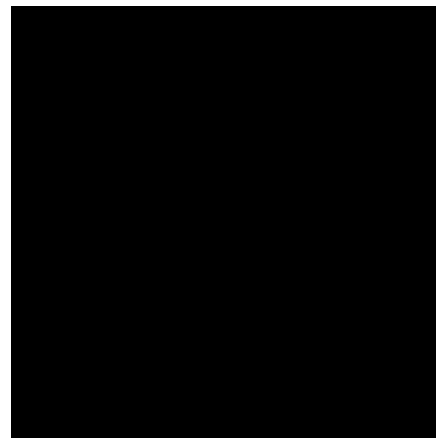
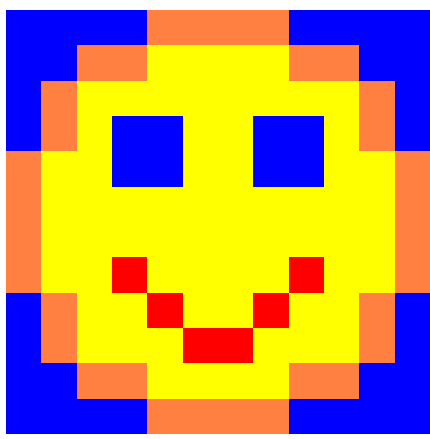
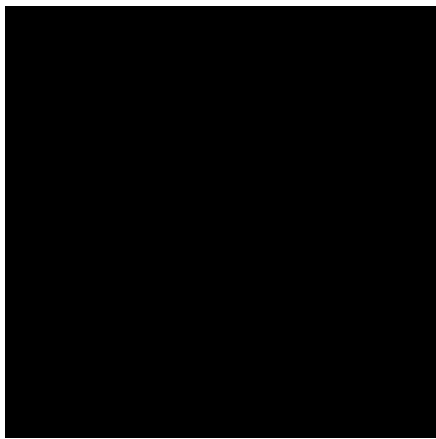




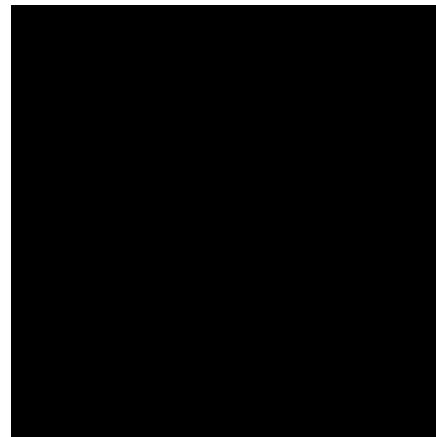


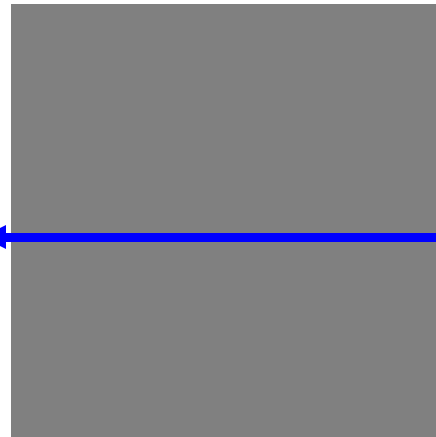
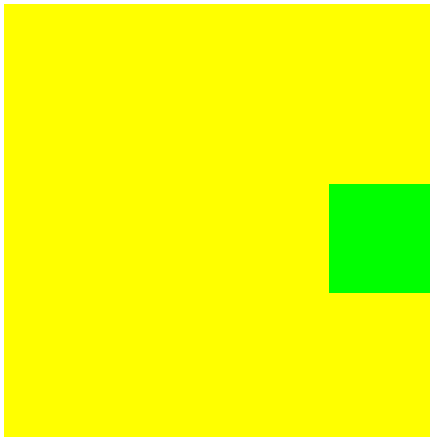
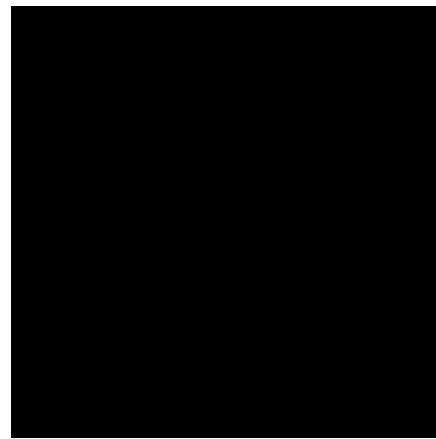
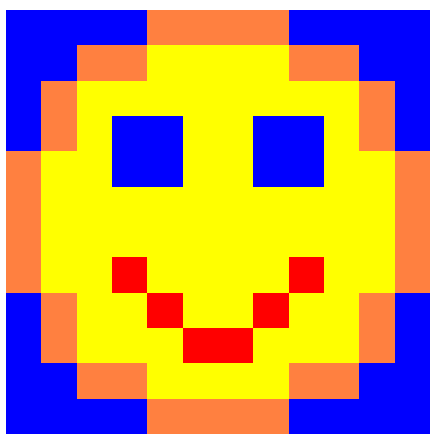
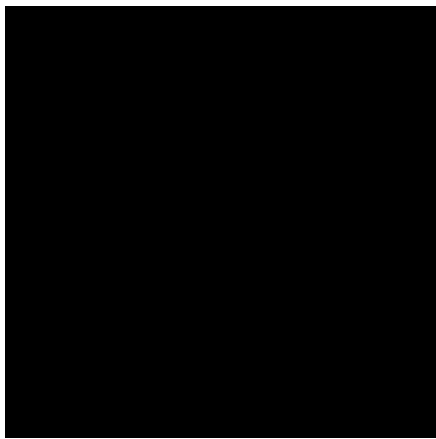
La phase de reproduction est achevée (tout jaune)



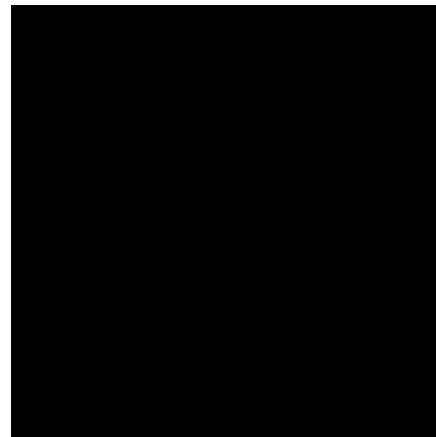
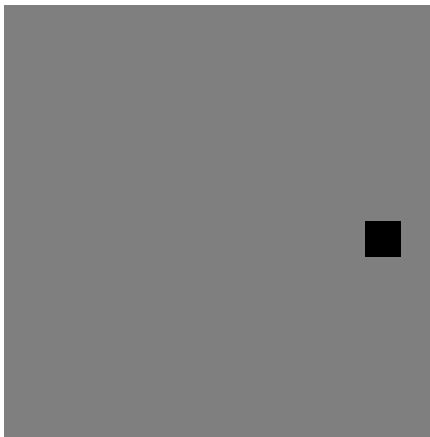


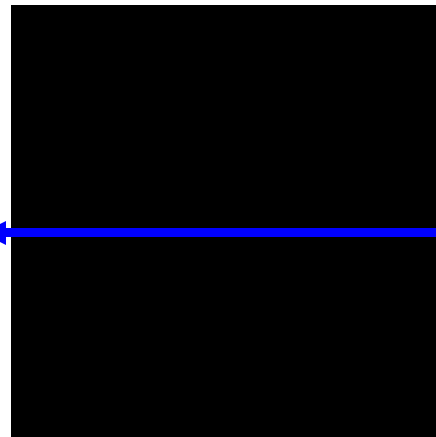
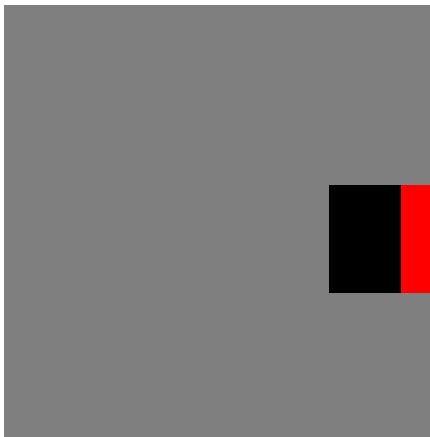
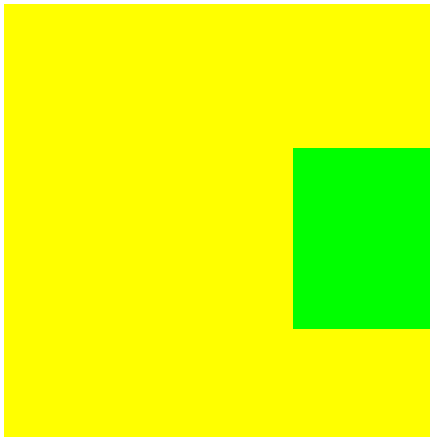
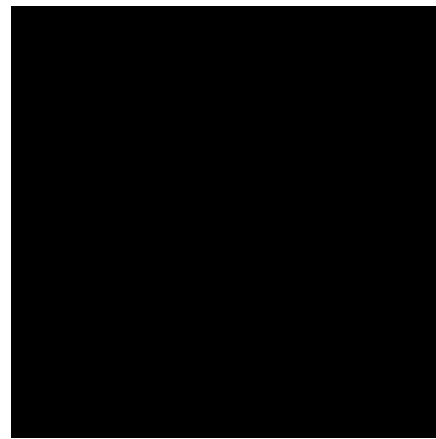
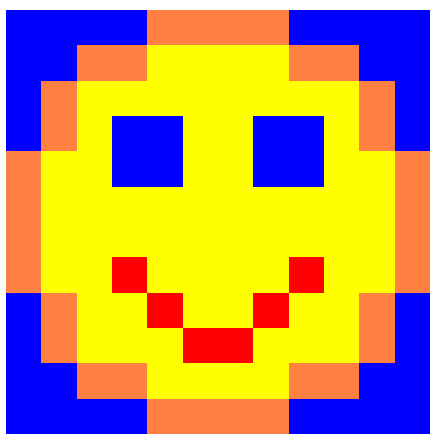
Une cellule reçoit
l'ordre de se
différencier
(par l'utilisateur)





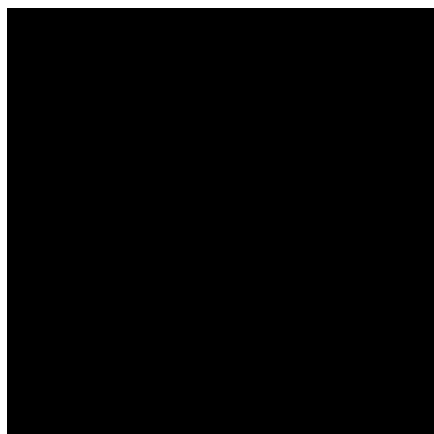
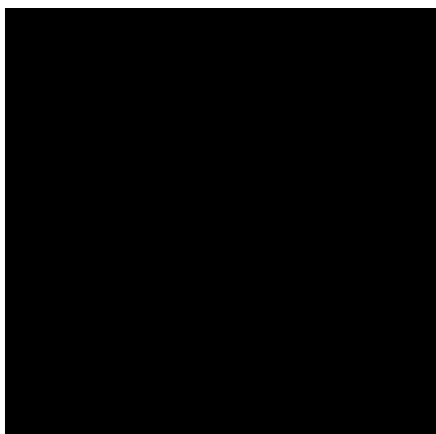
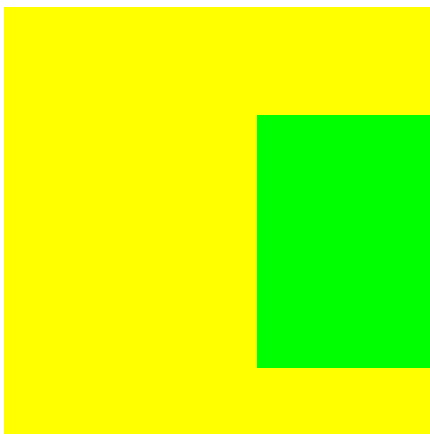
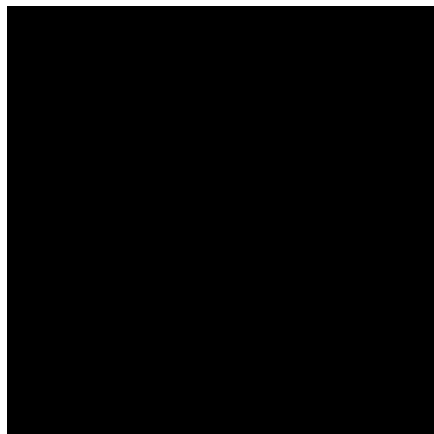
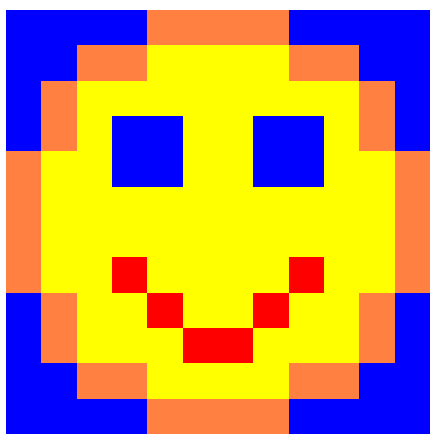
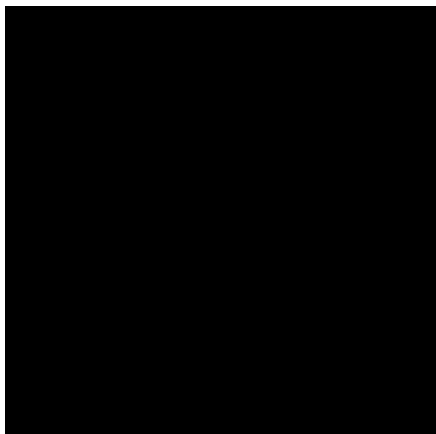
Cette cellule place
son voisinage en
phase de
différenciation

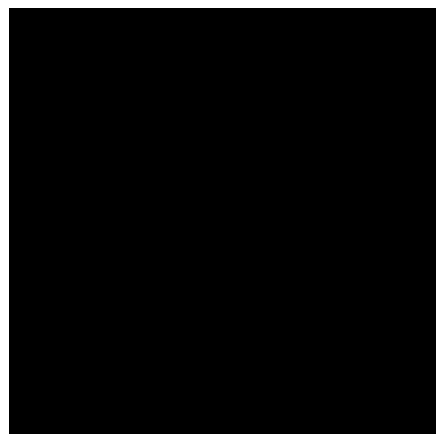
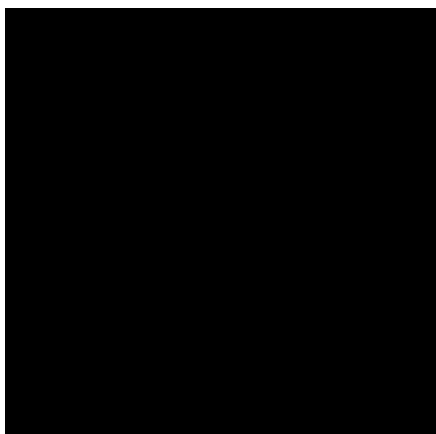
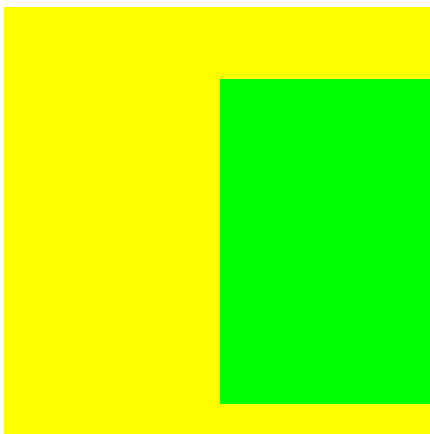
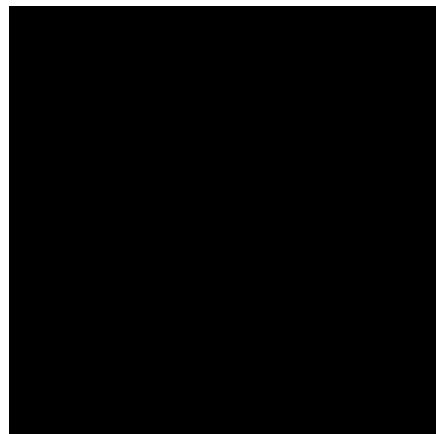
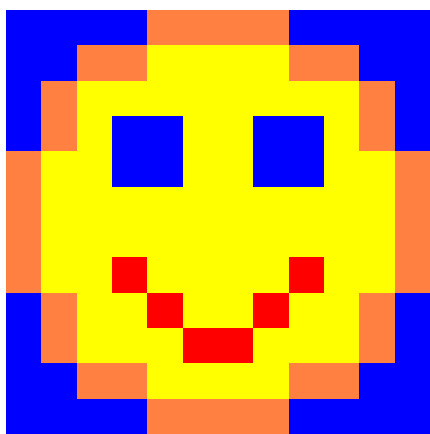
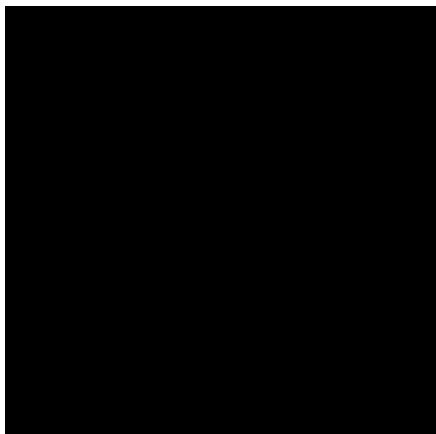


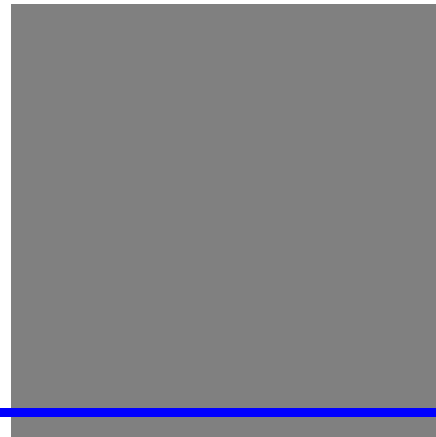
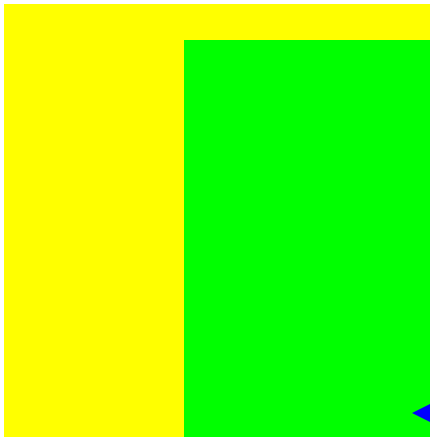
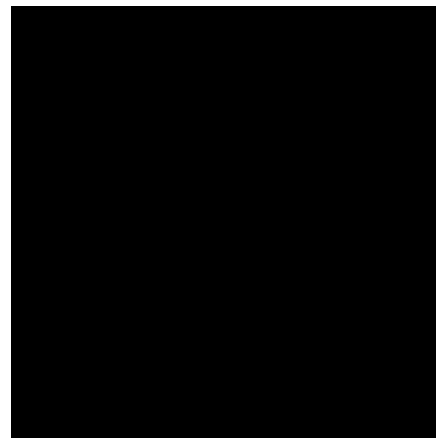
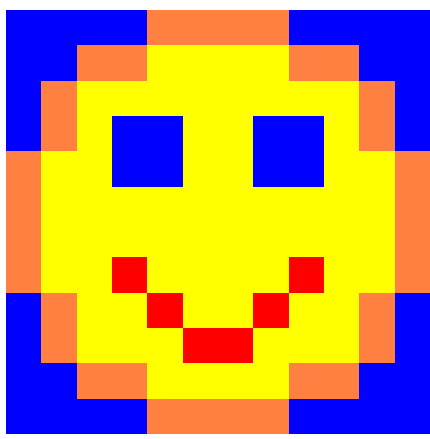
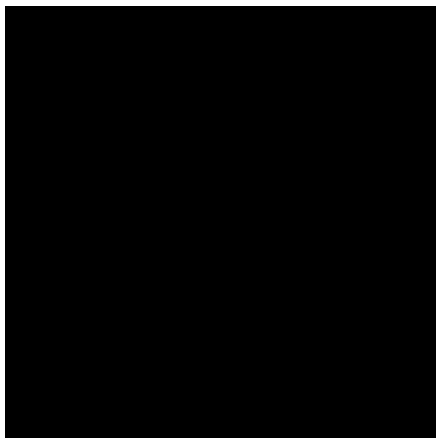


Ce qui permet de
calculer la
configuration de
l'automate cellulaire



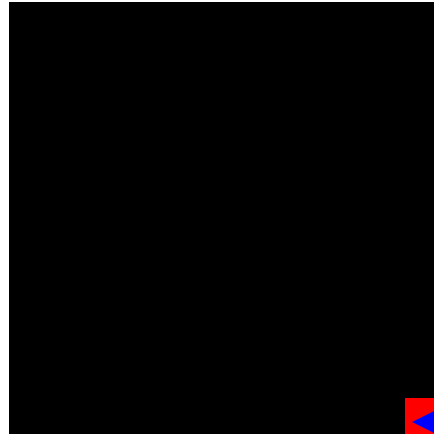
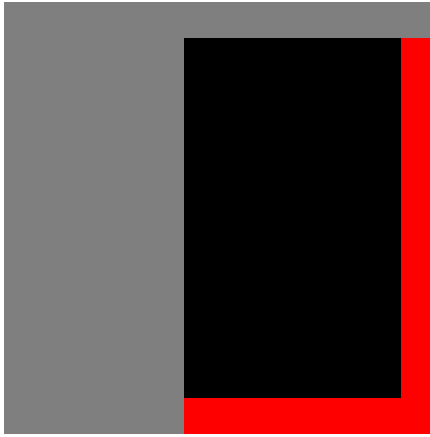
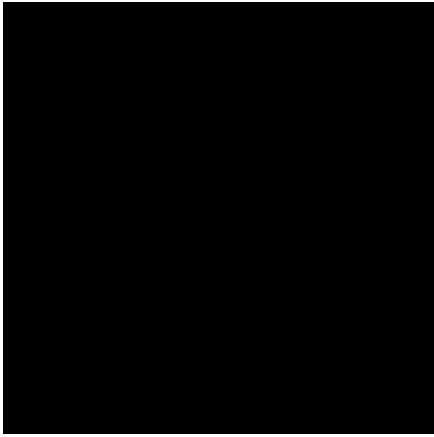
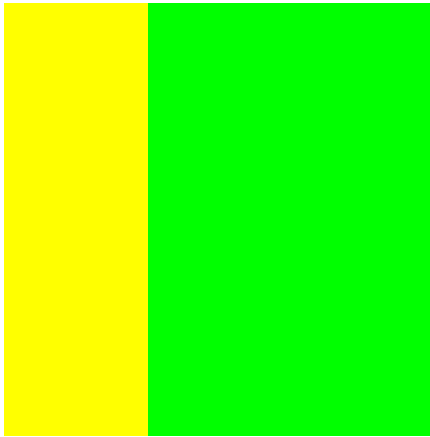
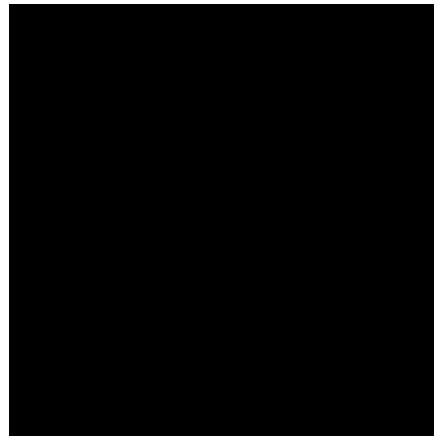
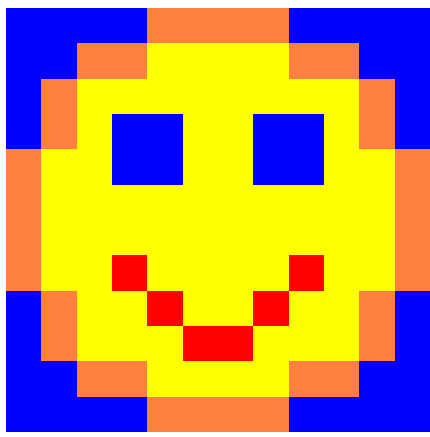




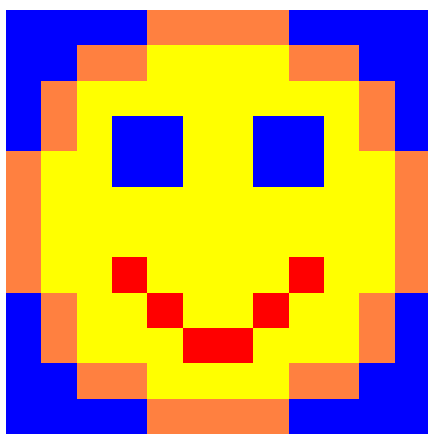
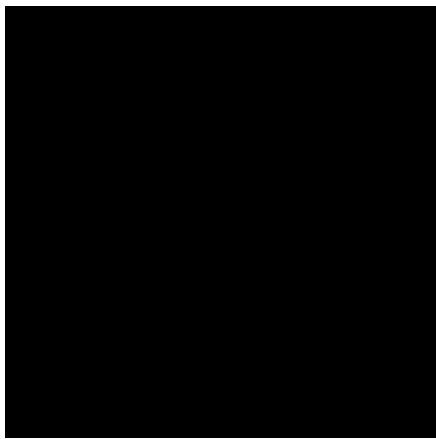


La différenciation
atteint le bord Bas
Droit



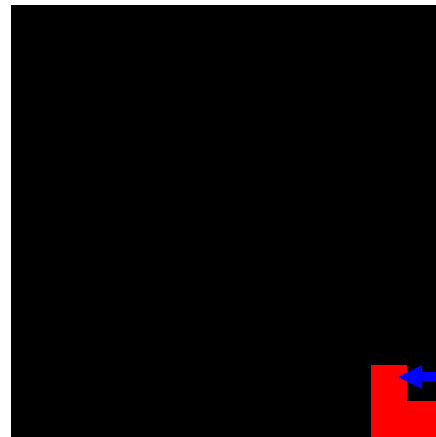
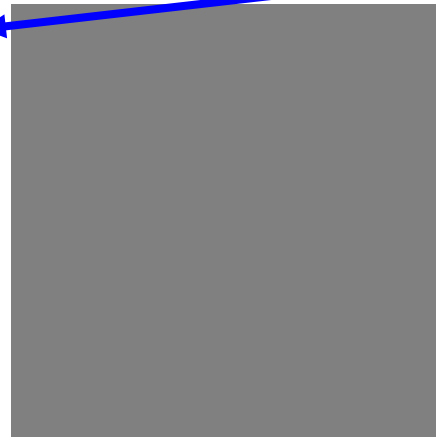
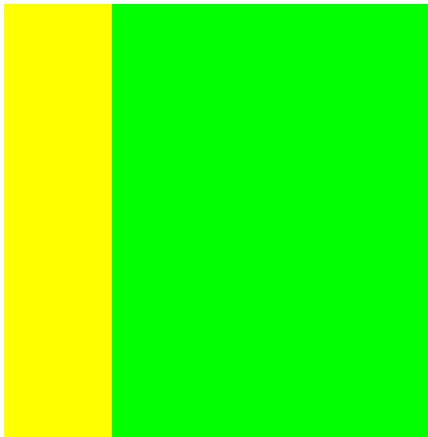


Cette variable est déclenché

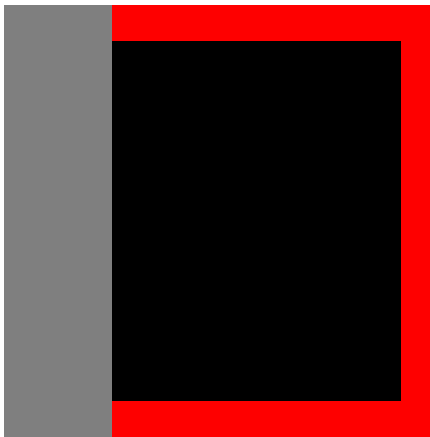
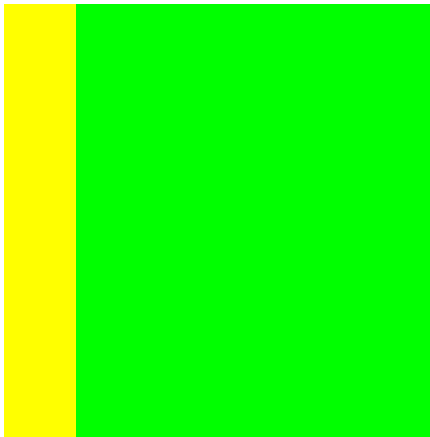
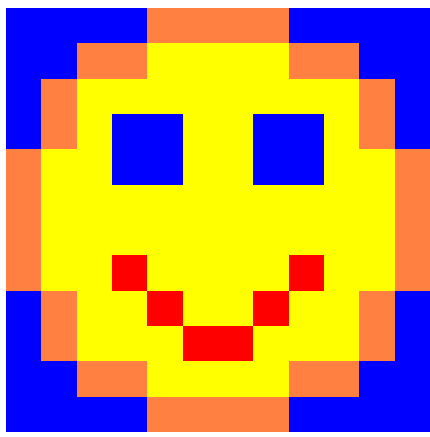


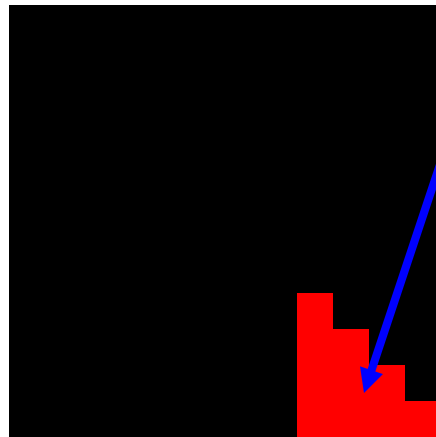
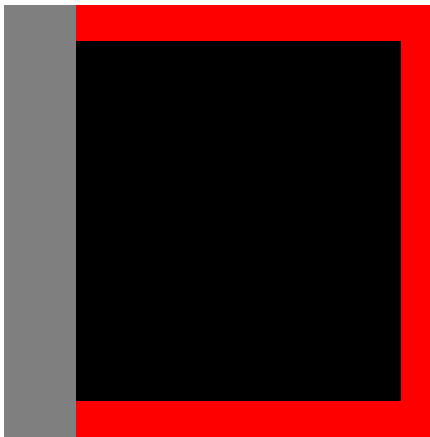
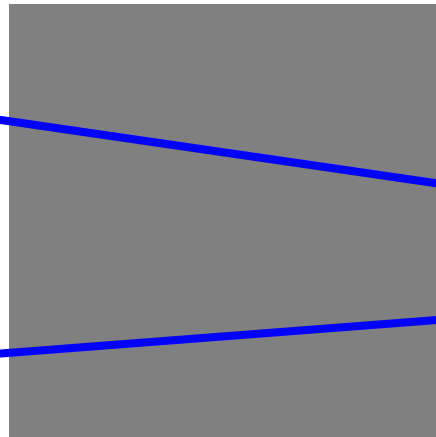
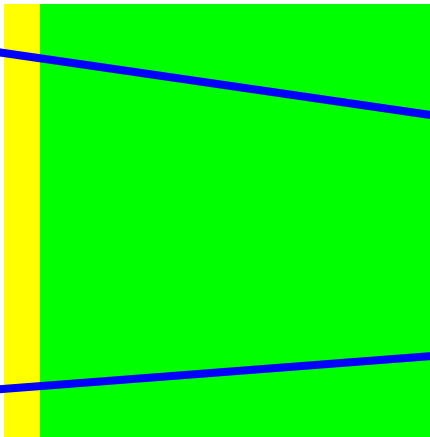
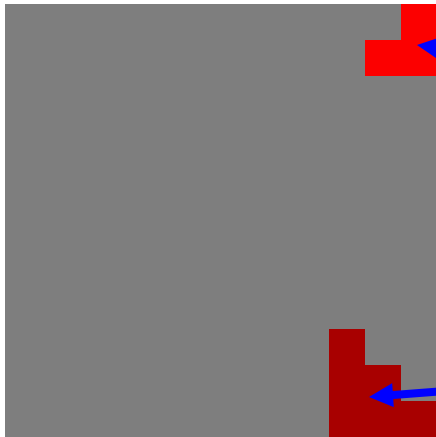
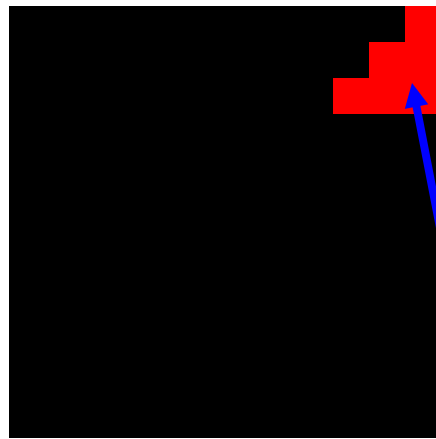
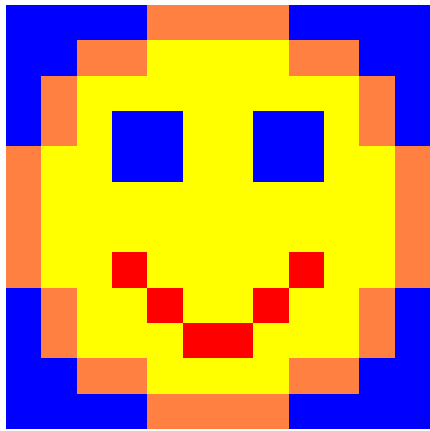
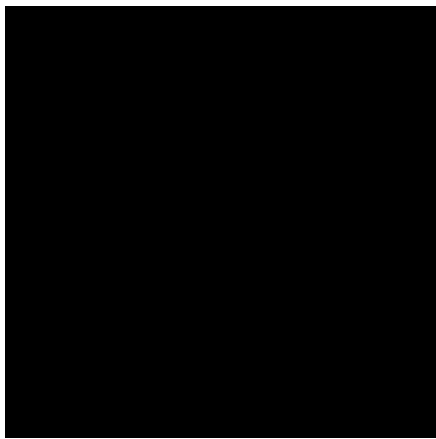
Cette variable est déclenchée car

Différenciation atteint le bord Haut Droit

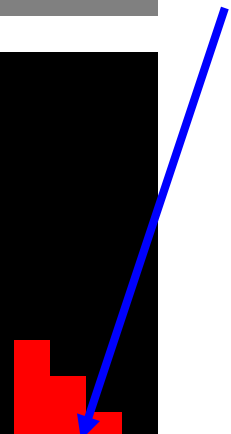
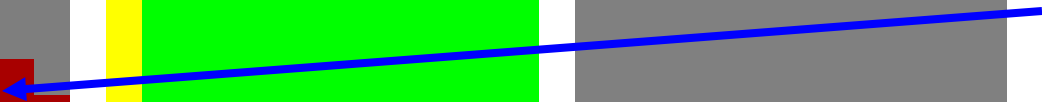
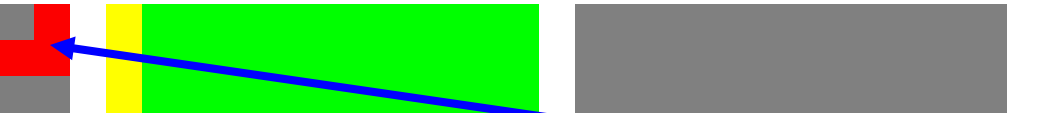


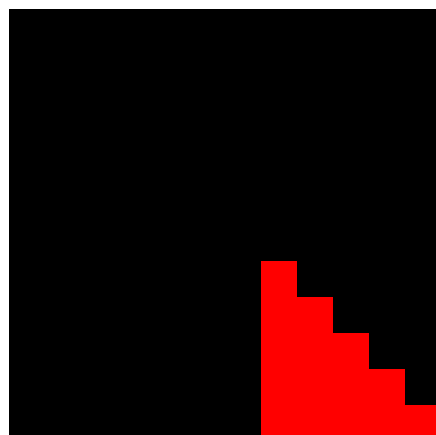
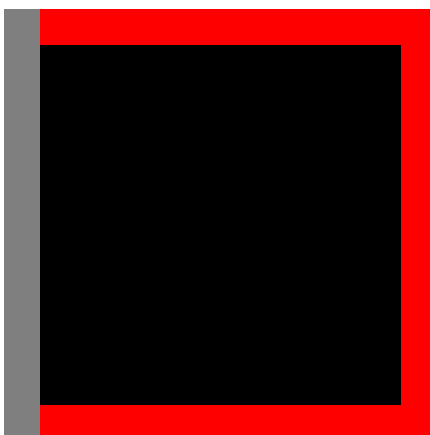
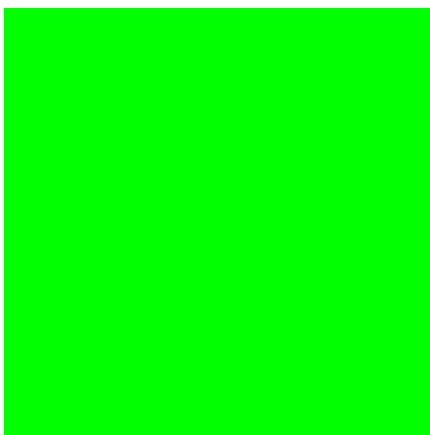
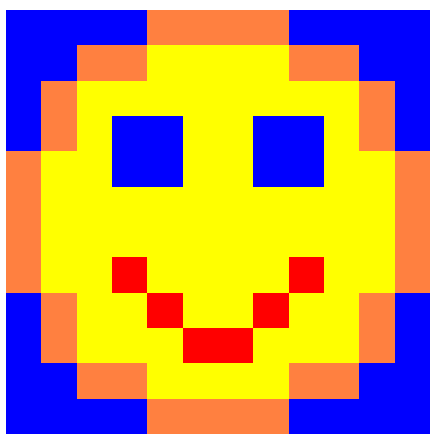
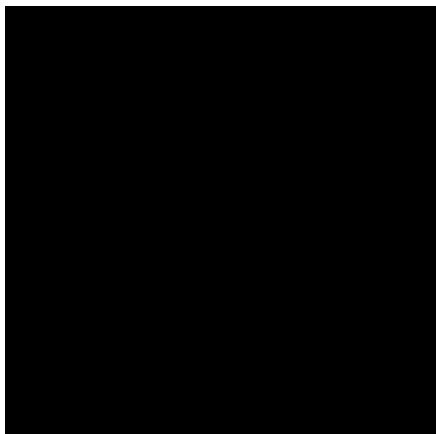
Propagation de cette variable d'état

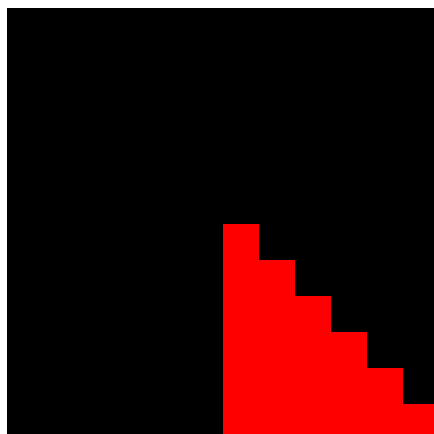
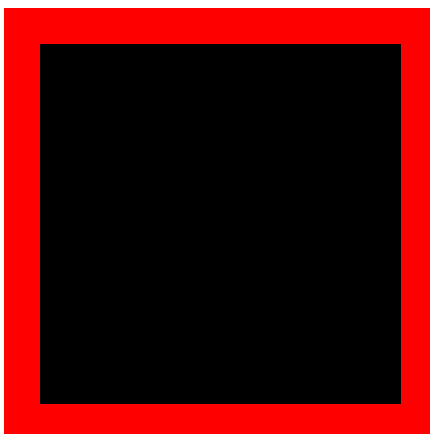
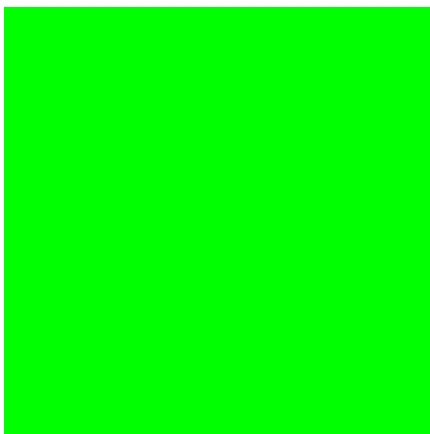
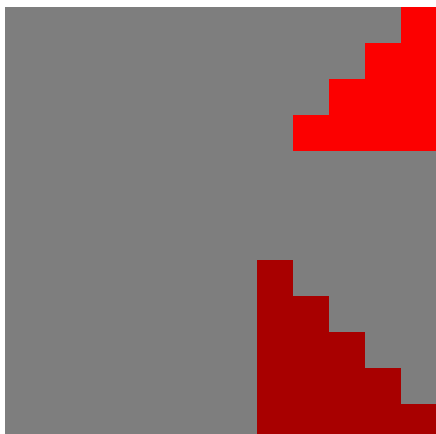
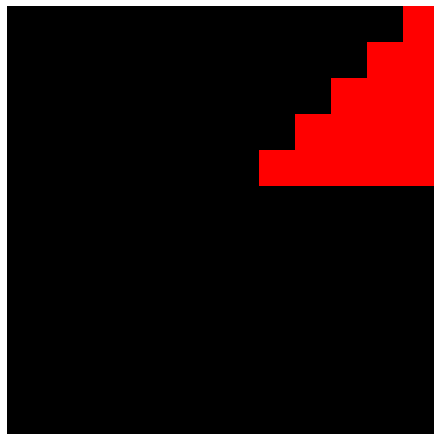
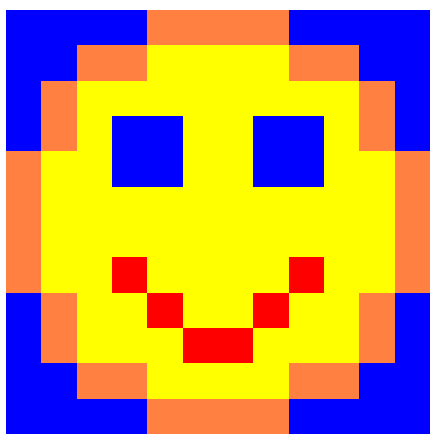
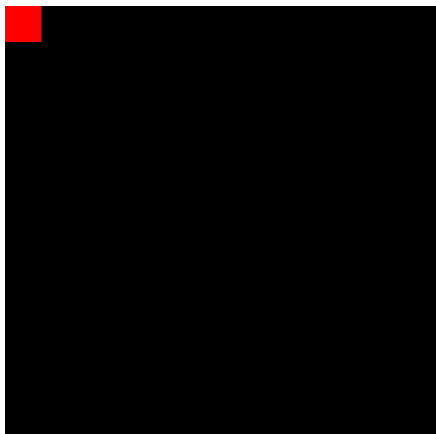


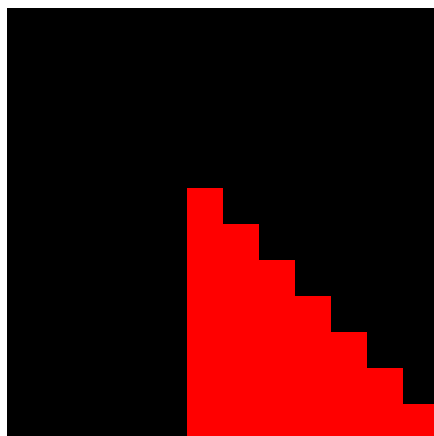
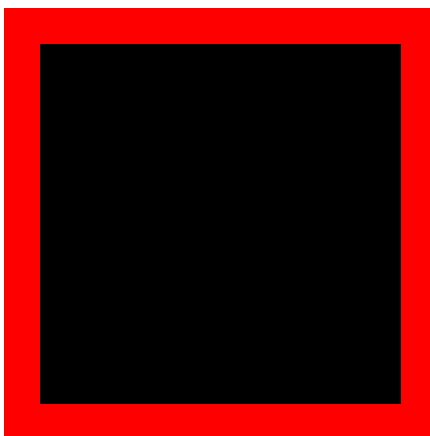
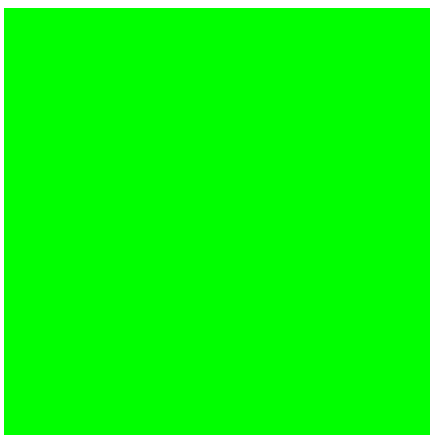
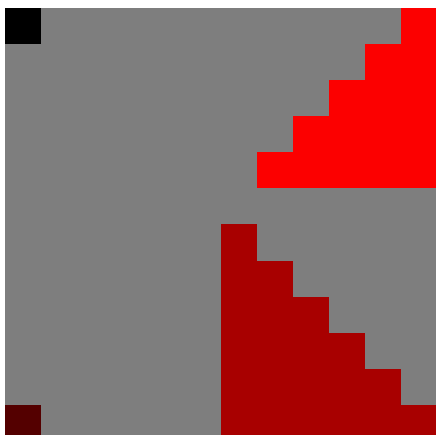
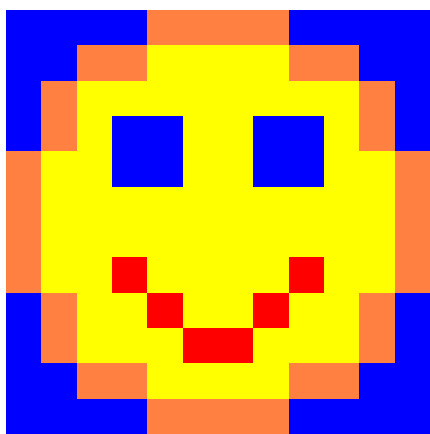


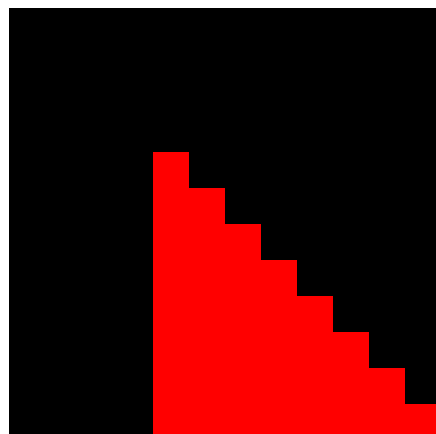
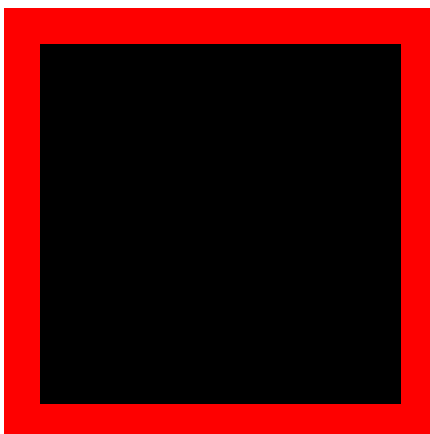
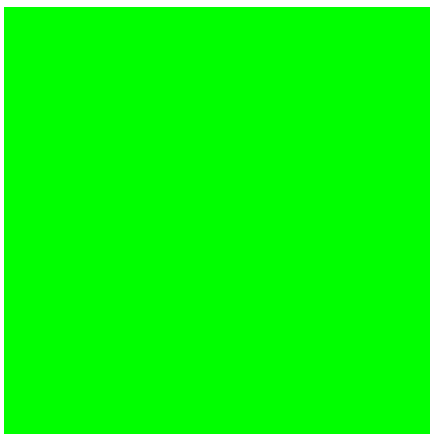
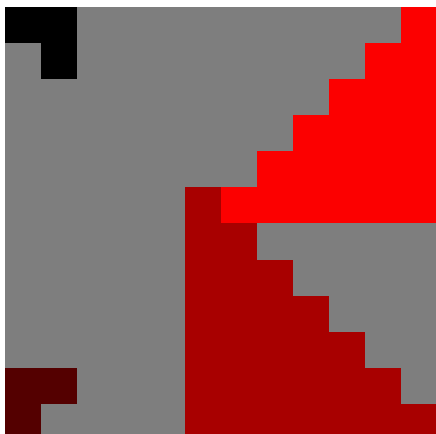
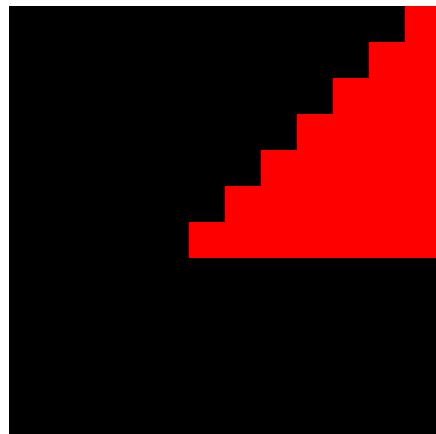
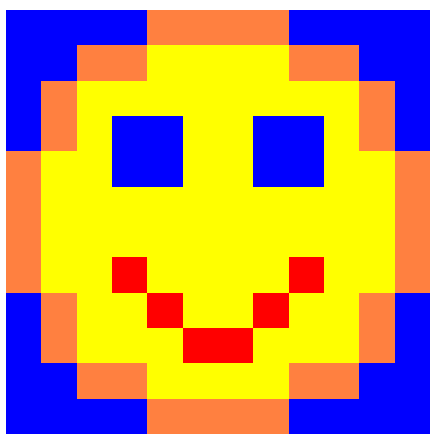
La propagation
des variables des
extrémités
permettent de
calculer état

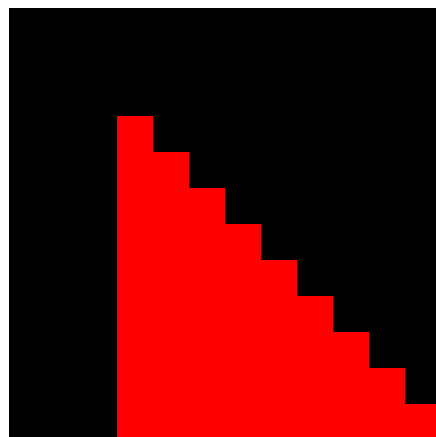
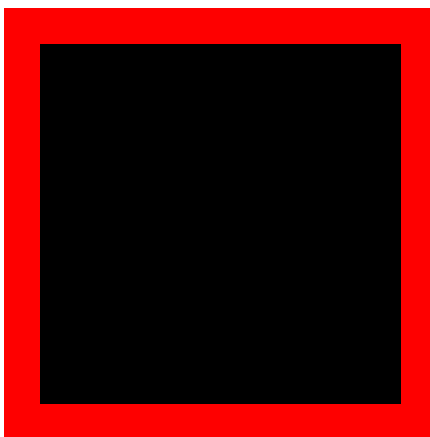
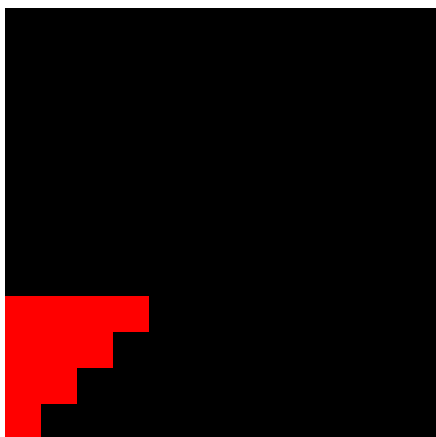
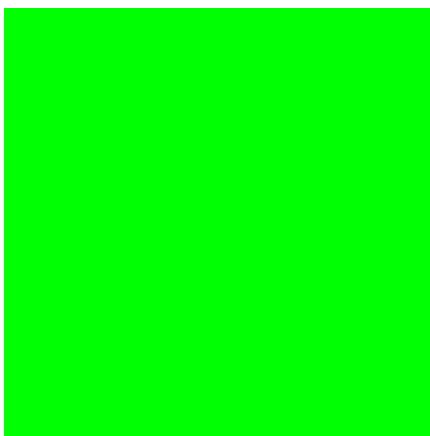
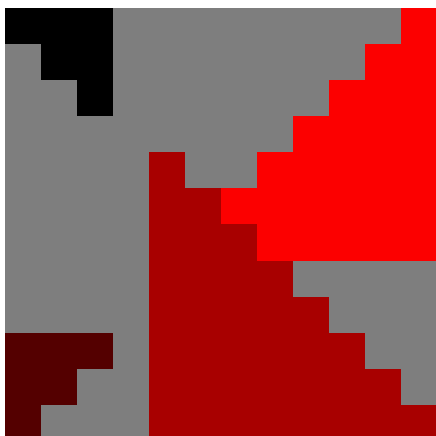
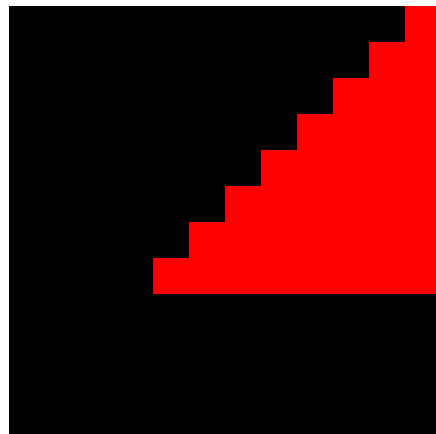
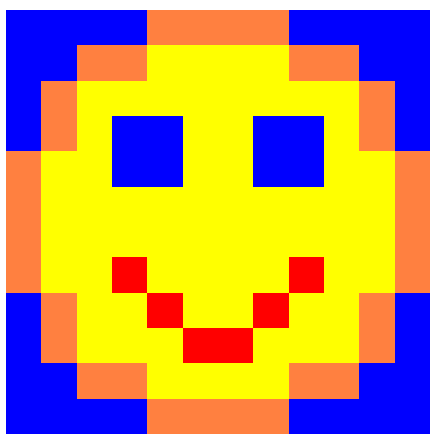


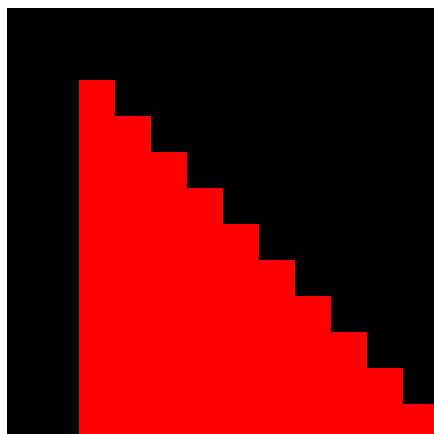
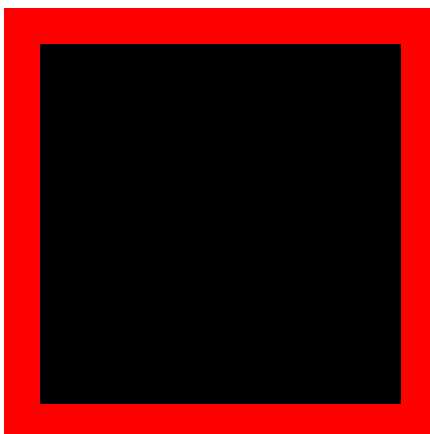
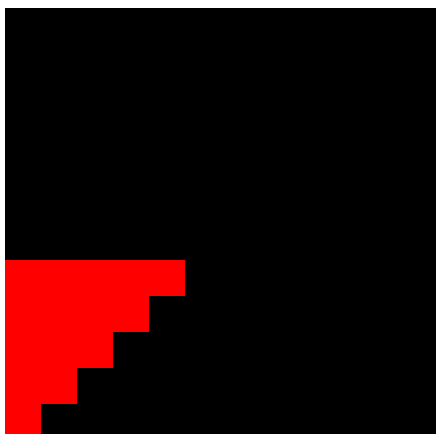
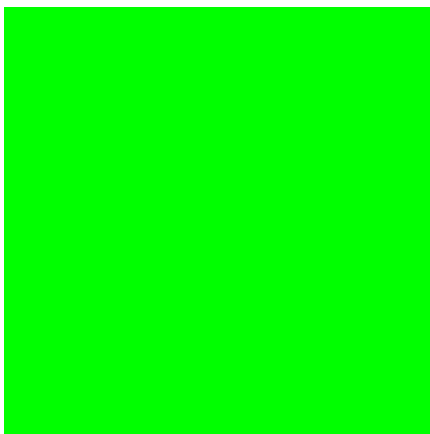
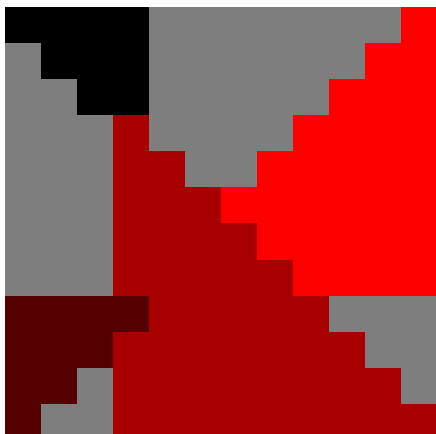
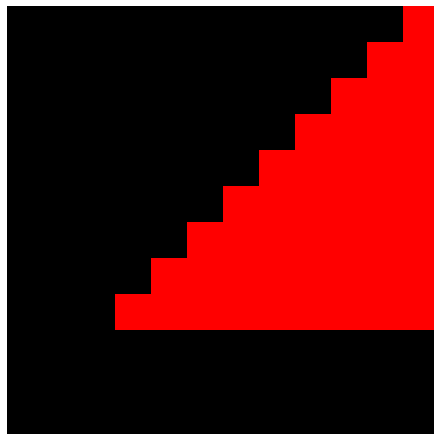
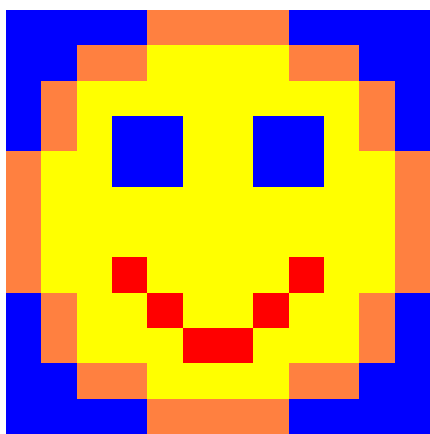


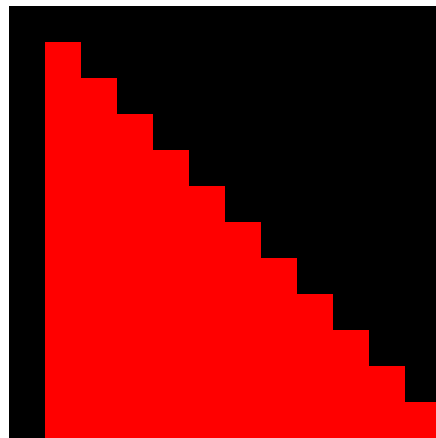
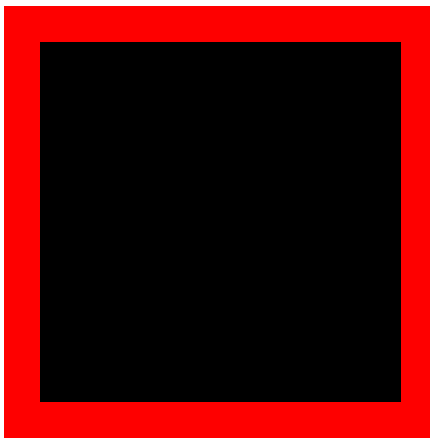
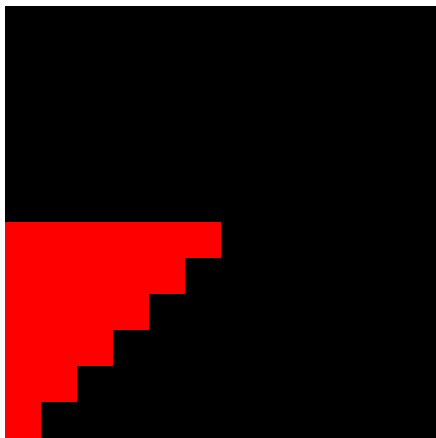
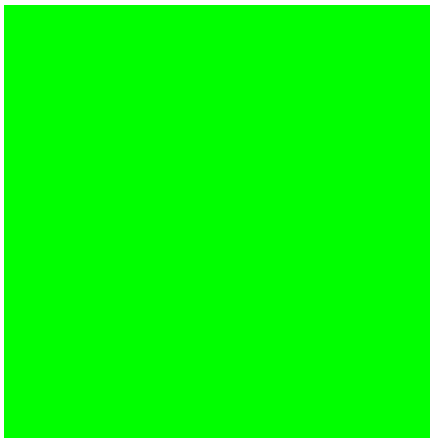
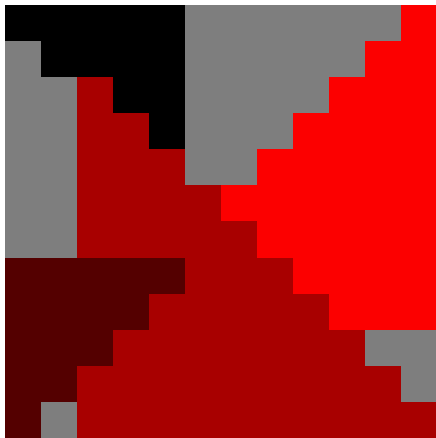
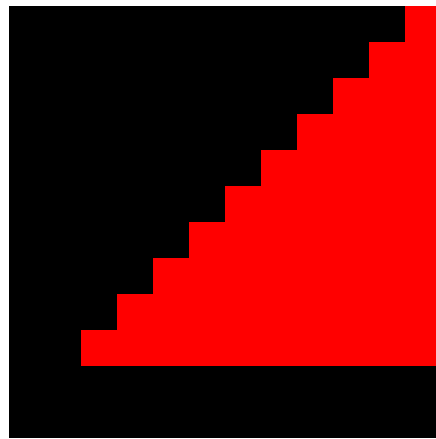
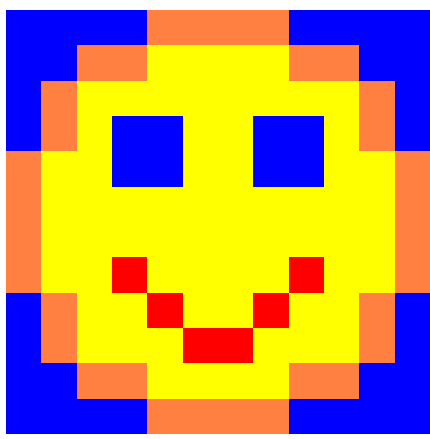


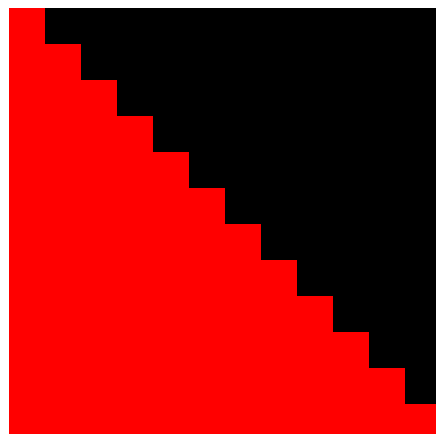
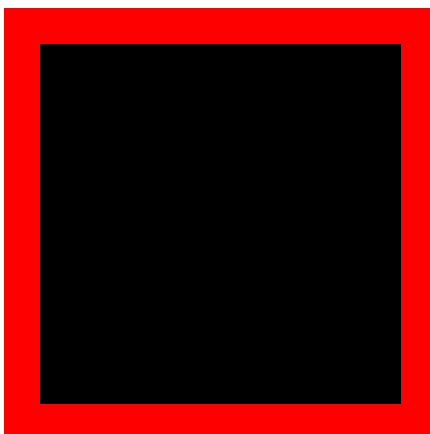
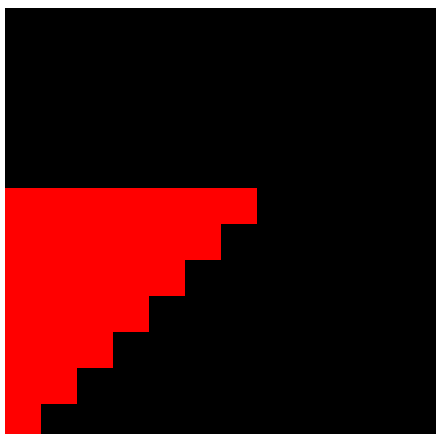
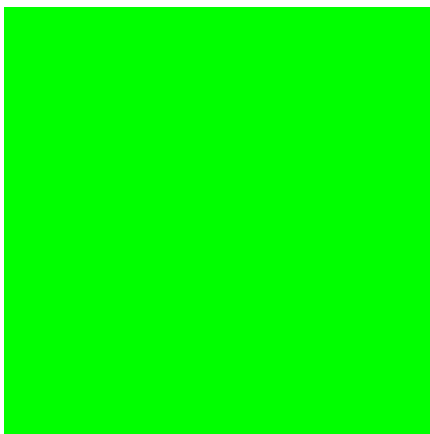
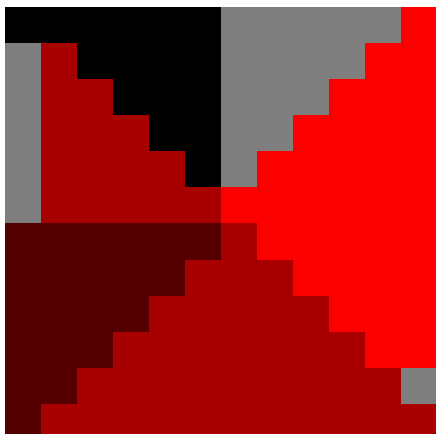
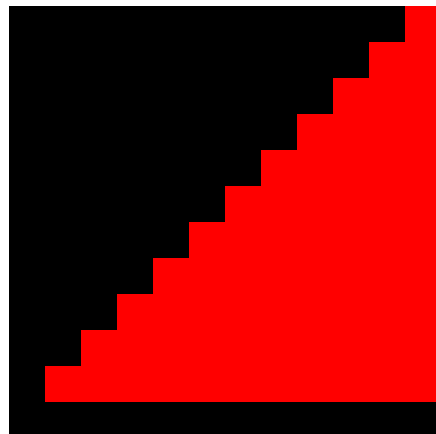
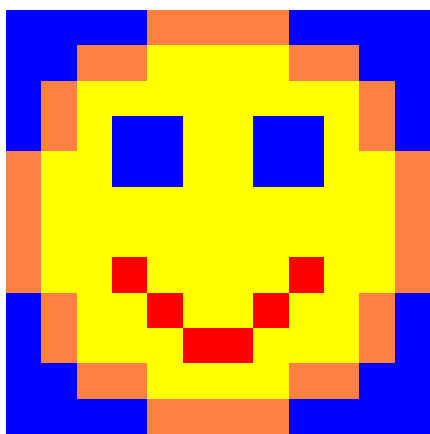


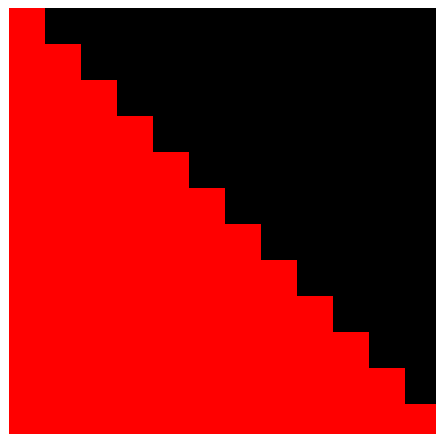
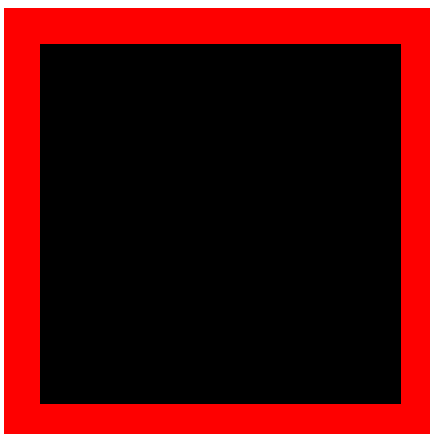
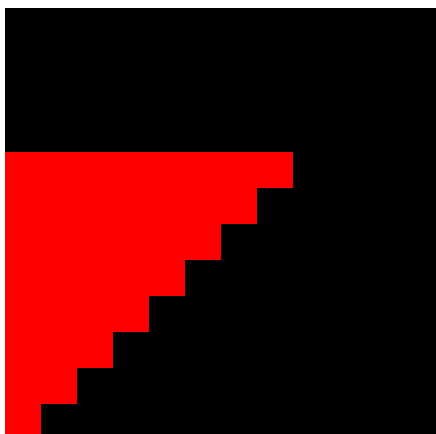
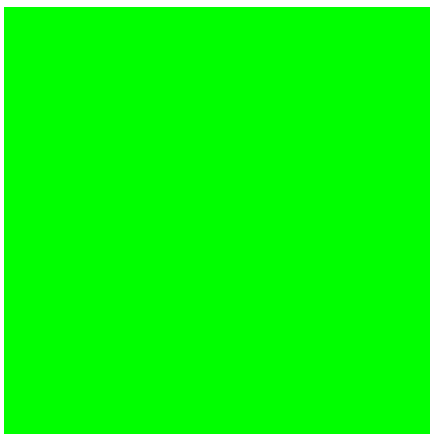
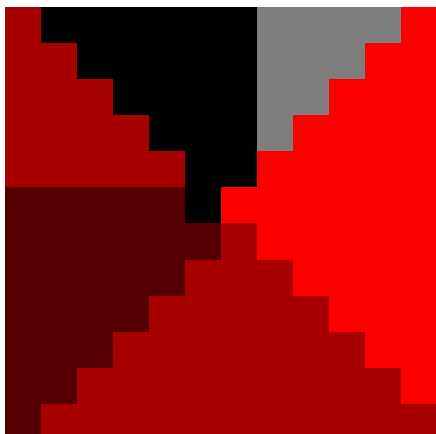
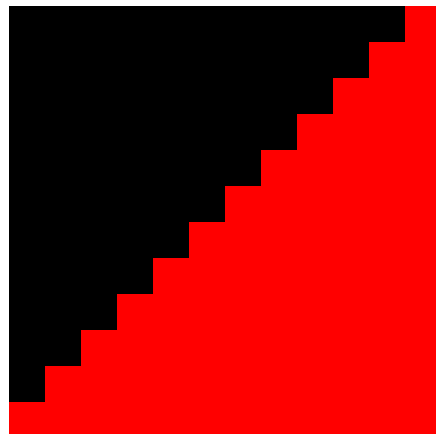
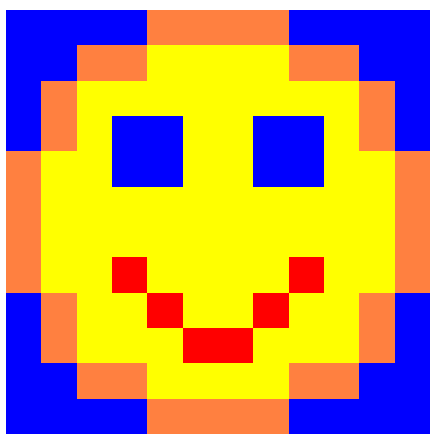
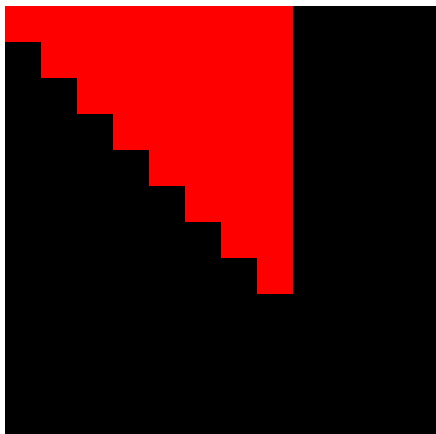


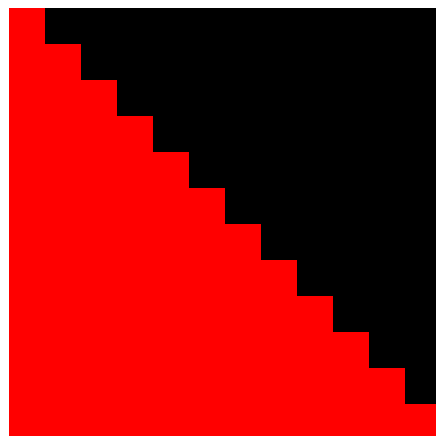
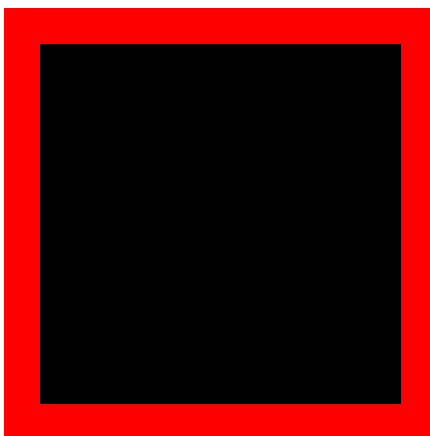
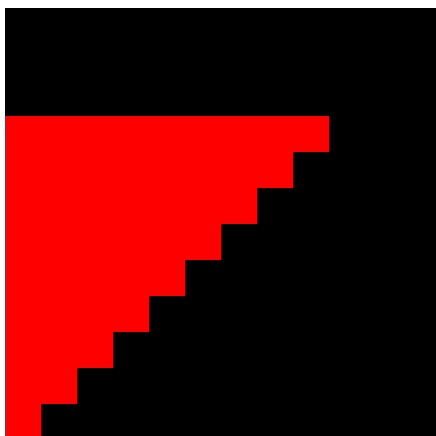
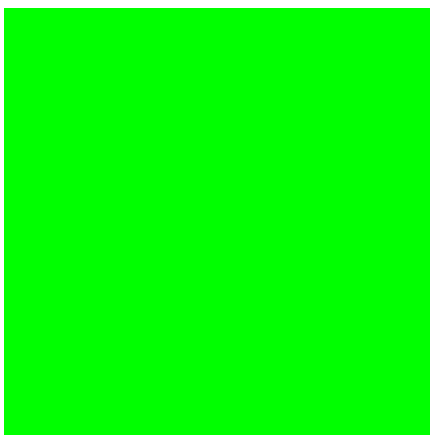
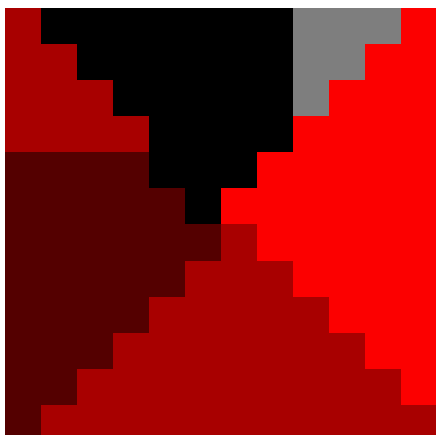
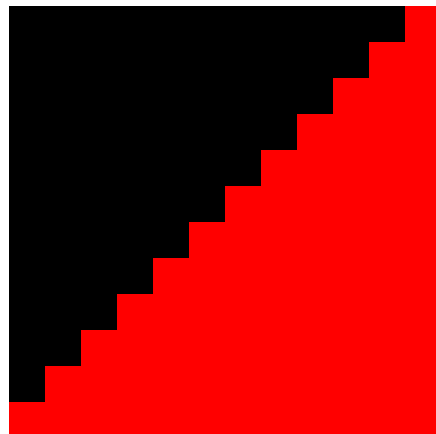
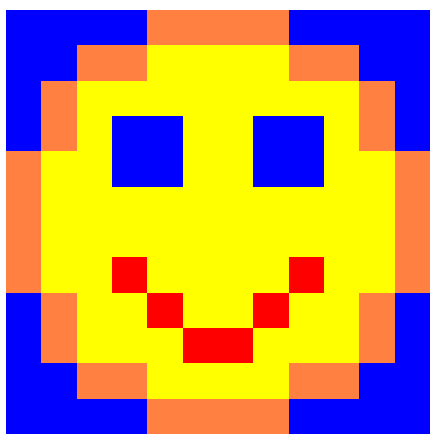


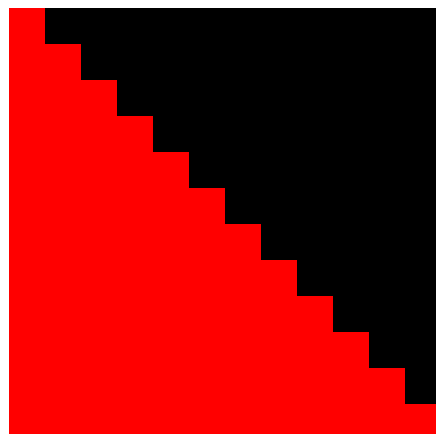
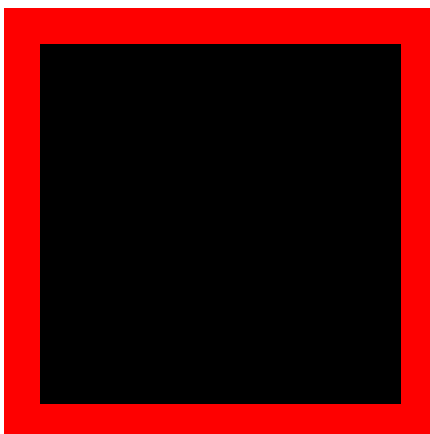
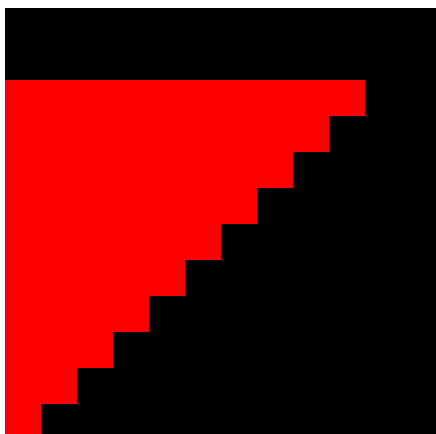
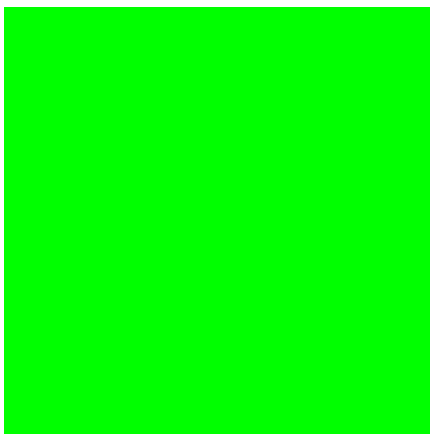
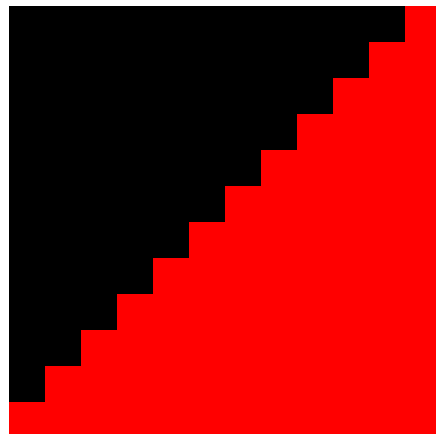
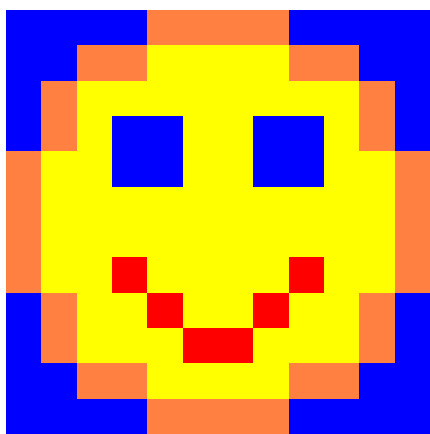
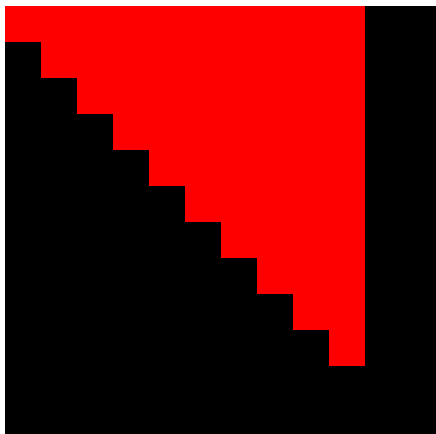


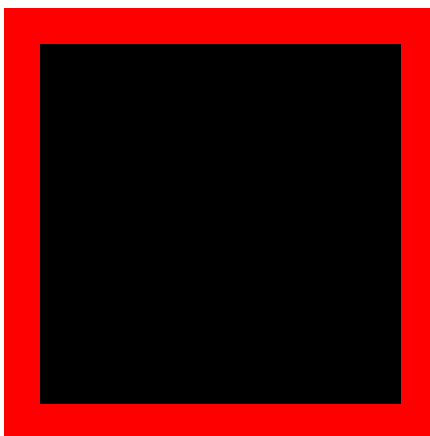
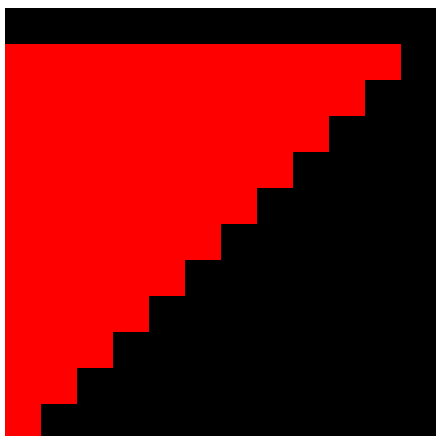
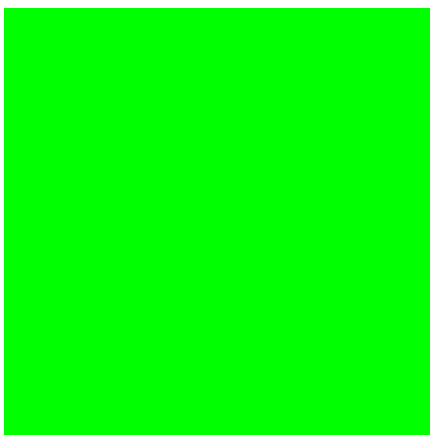
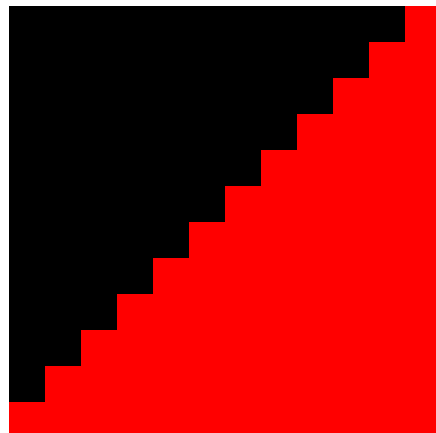
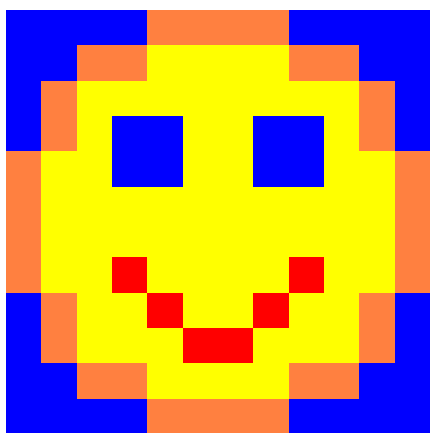
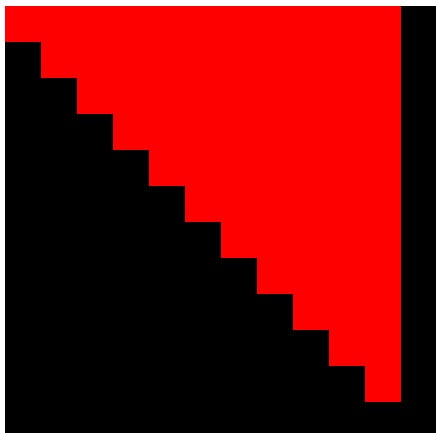


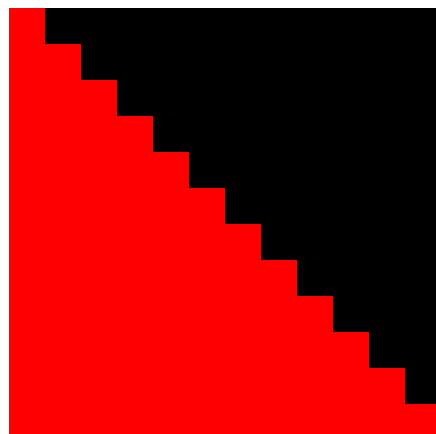
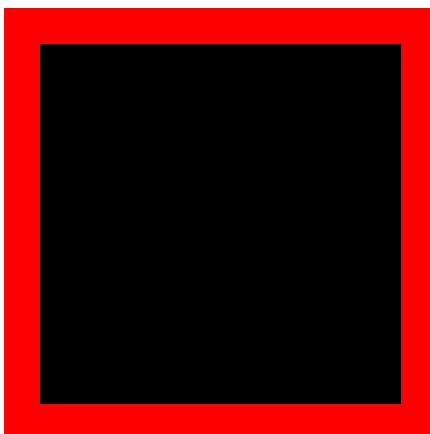
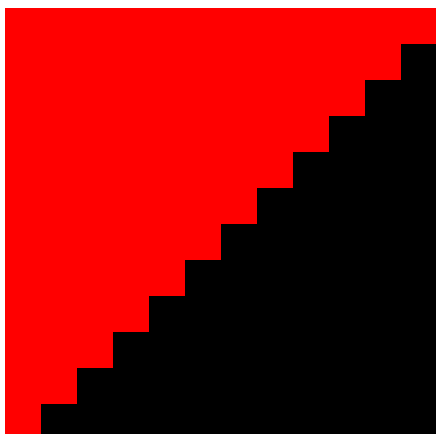
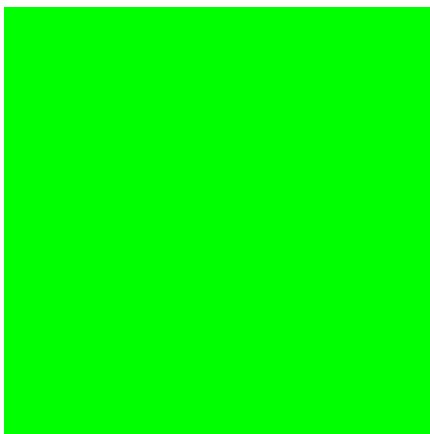
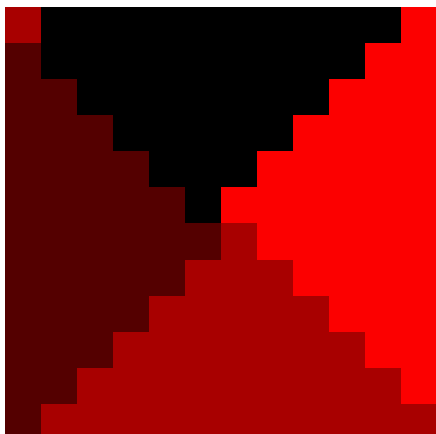
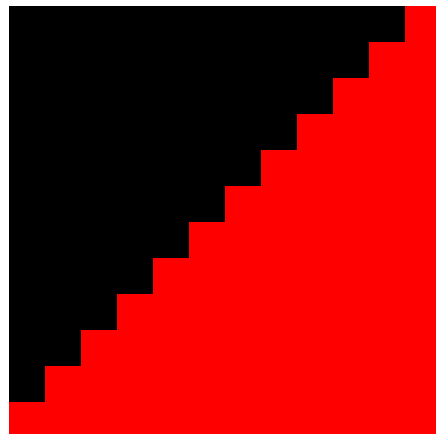
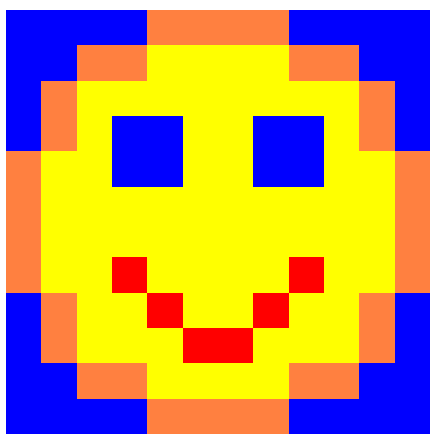
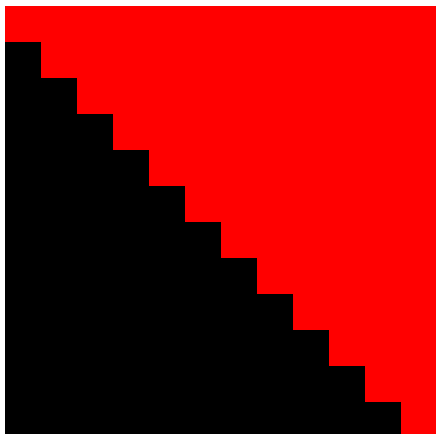


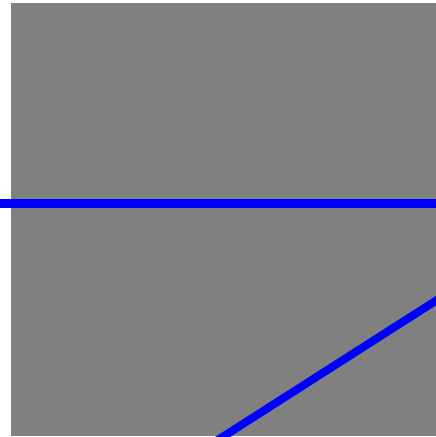
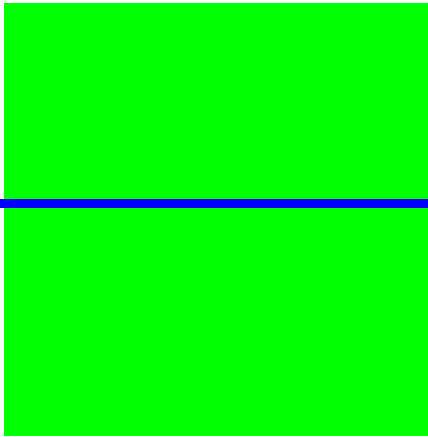
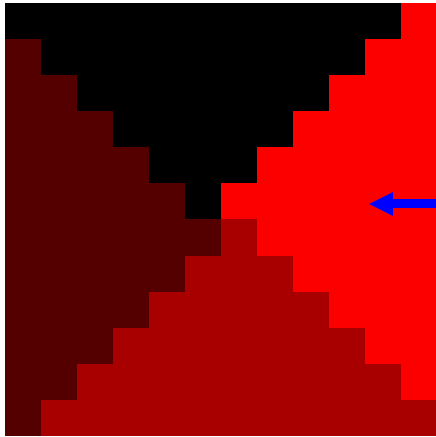
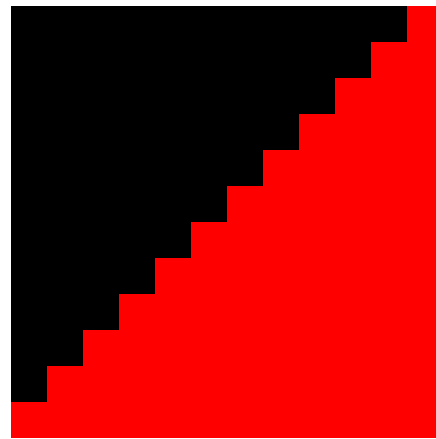
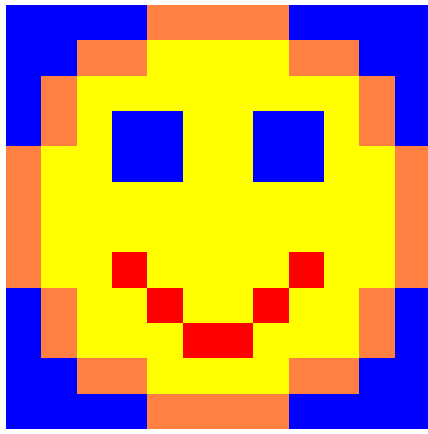
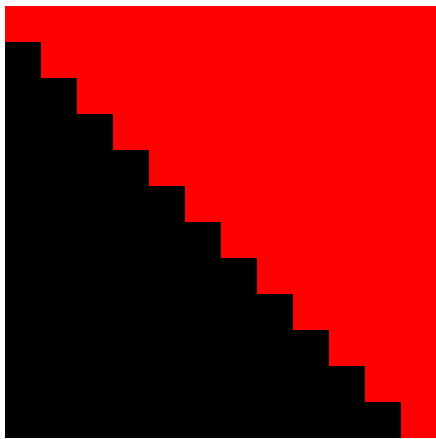




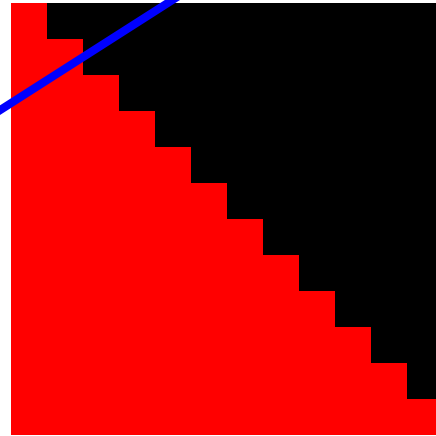
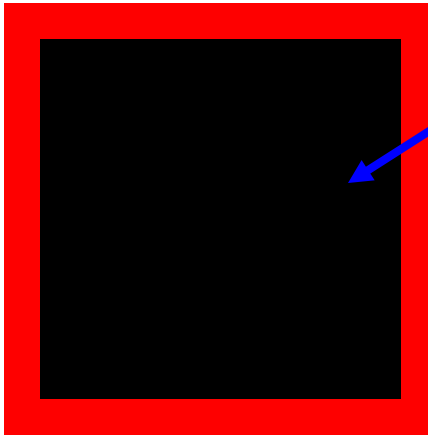
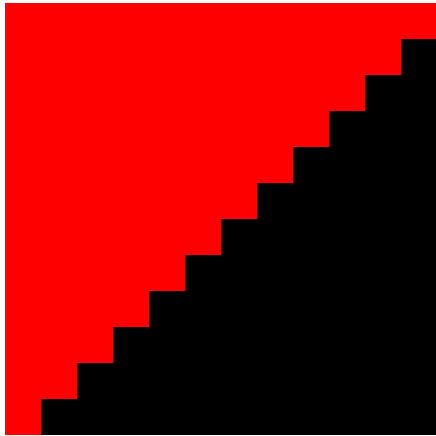


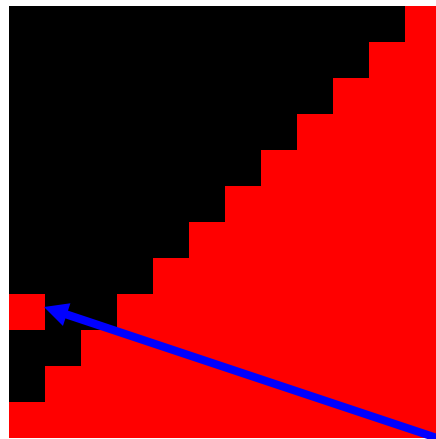
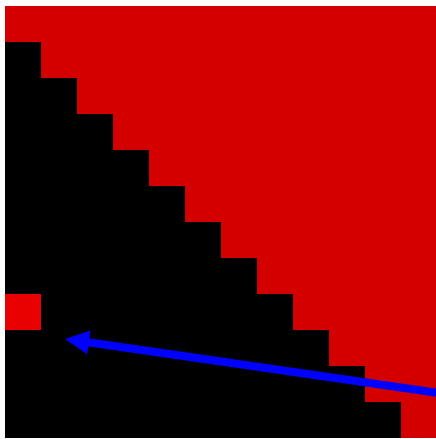




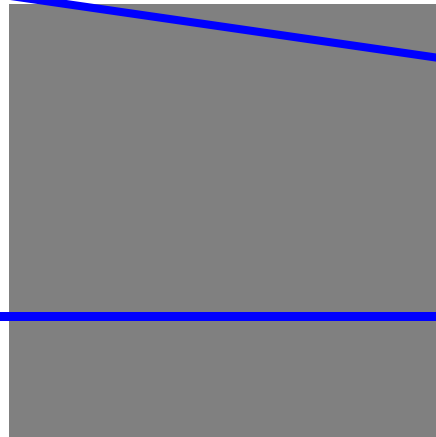
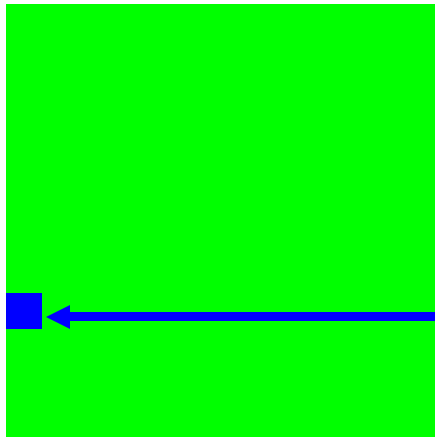
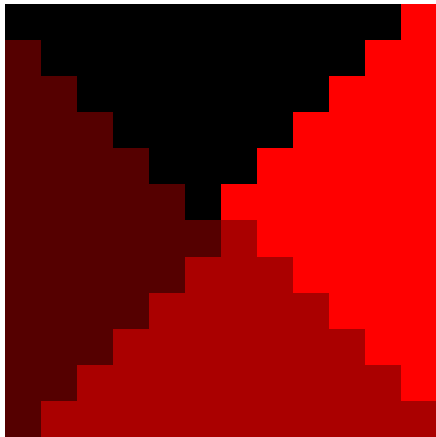


La phase de différenciation est achevée car c'est la bonne configuration

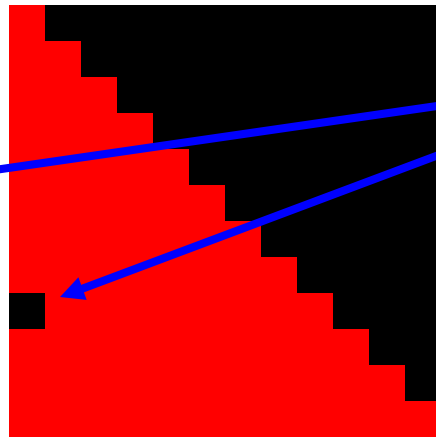
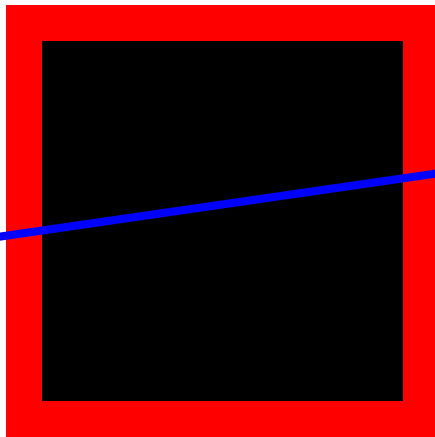
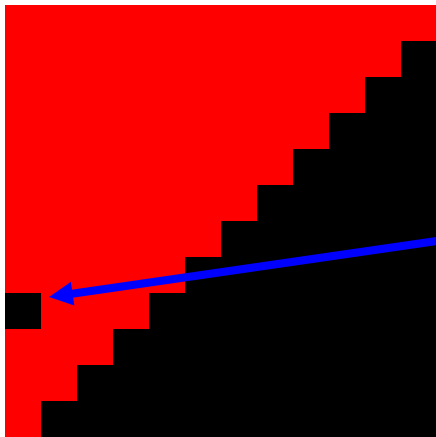




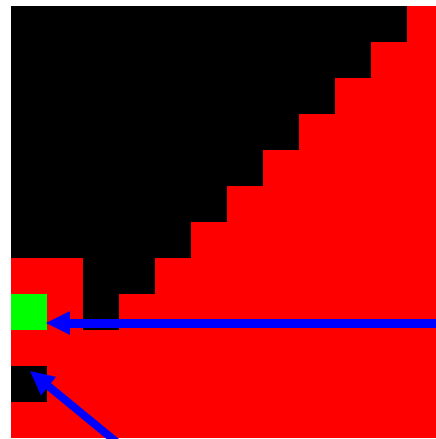
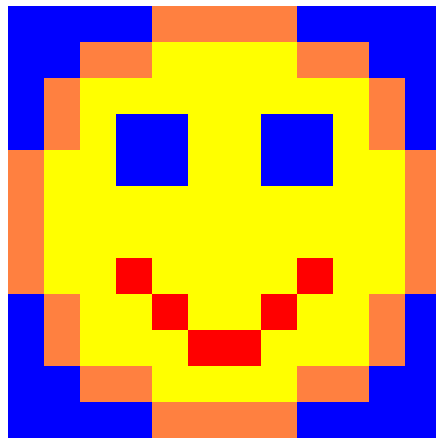
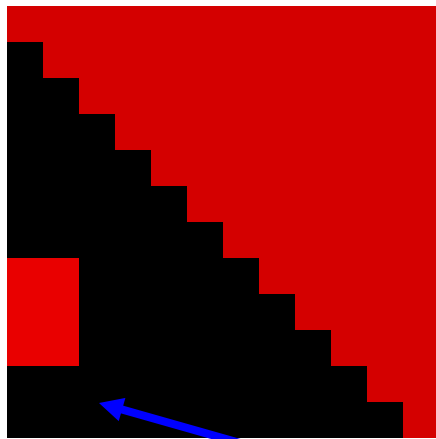
Le pipeline et le compte sont déclenchés



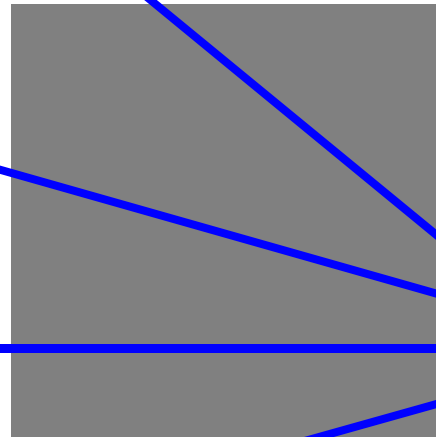
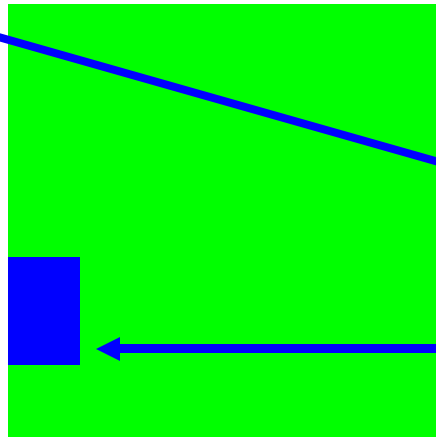
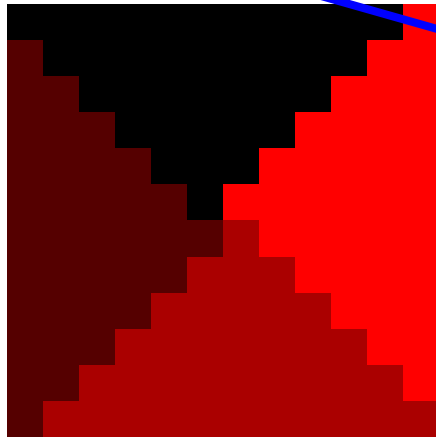
Une cellule est placée en phase d'exécution



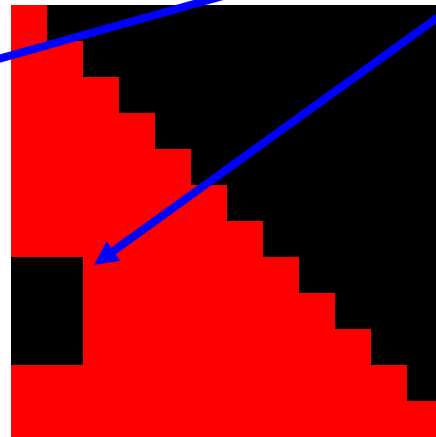
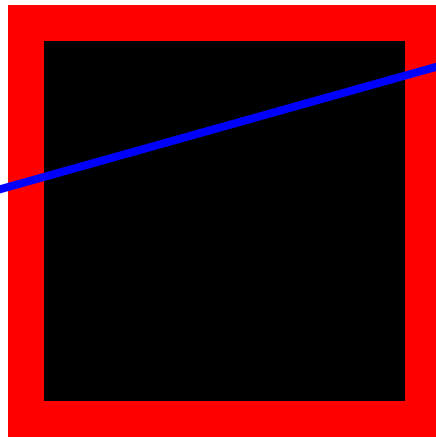
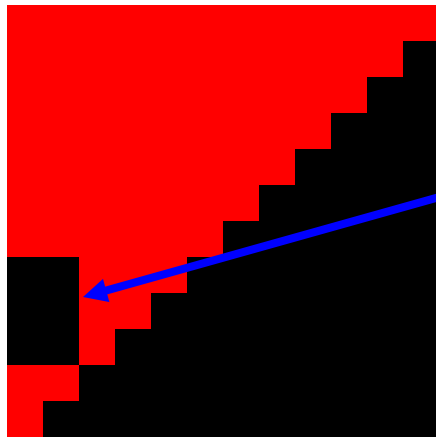
Futur occupé et parité initialisés

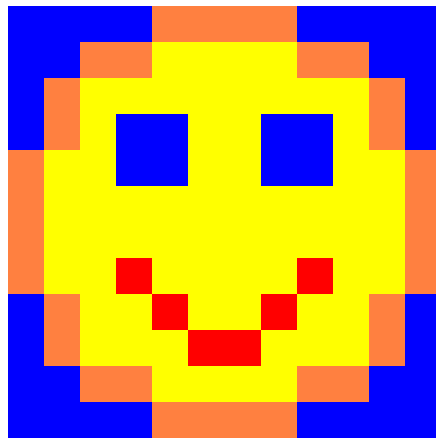
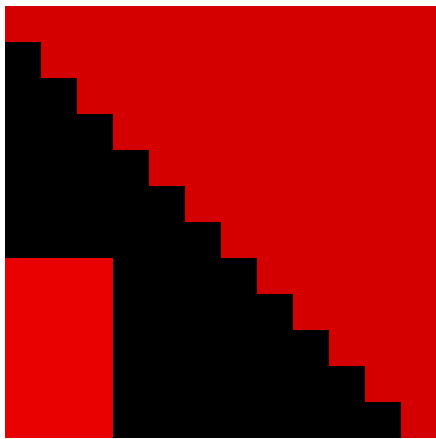


Le pipeline est vert :
il calcule les
variables futures

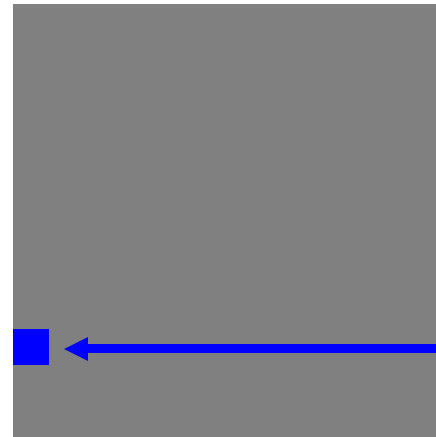
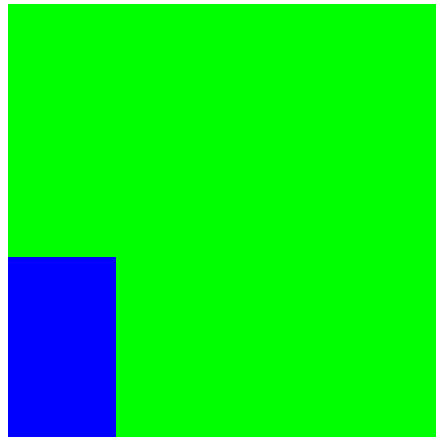
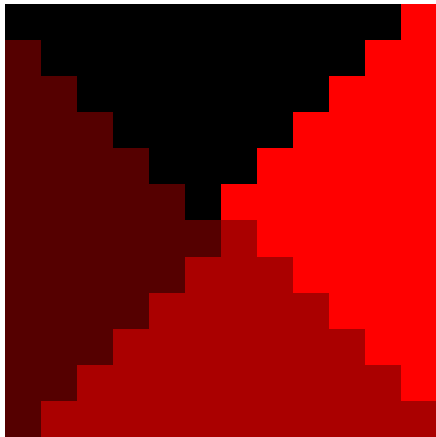


Et propage,
l'information à ces
voisines

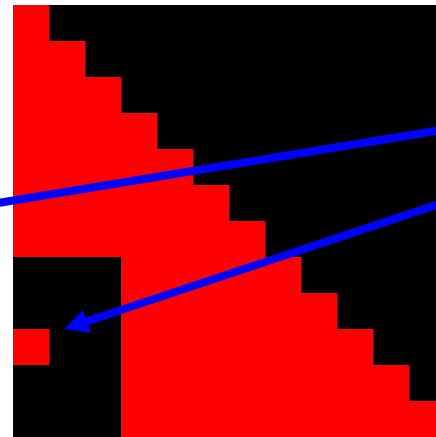
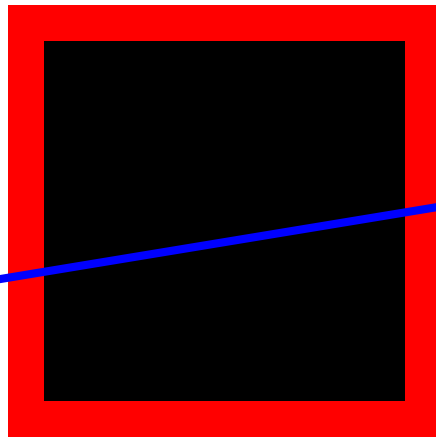
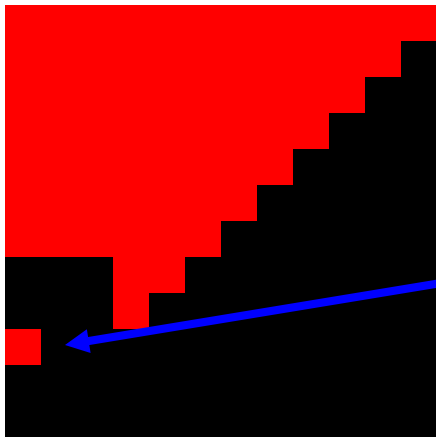




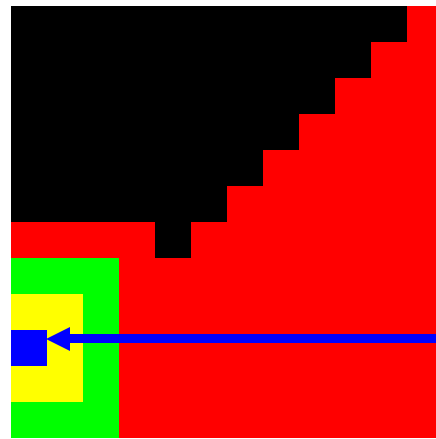
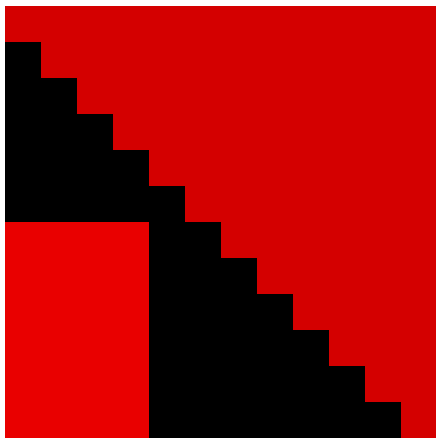
Pipeline=vert
= calcul variables futures



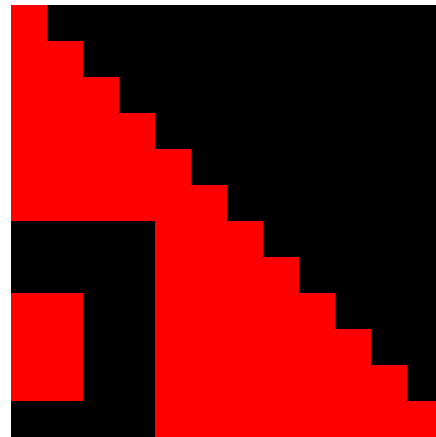
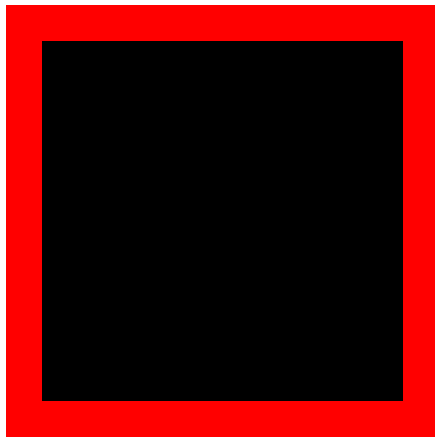
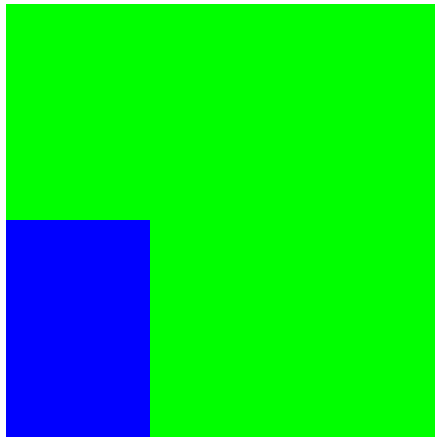
La couleur futur apparaît.

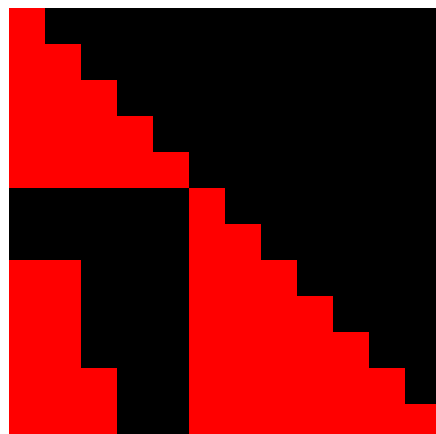
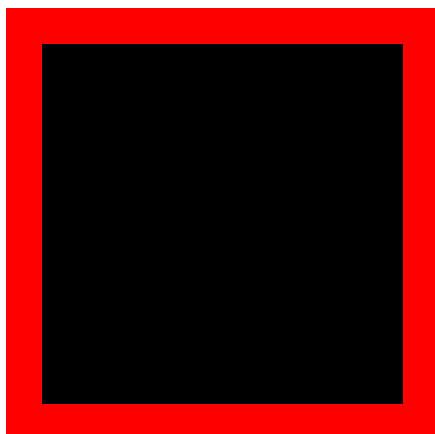
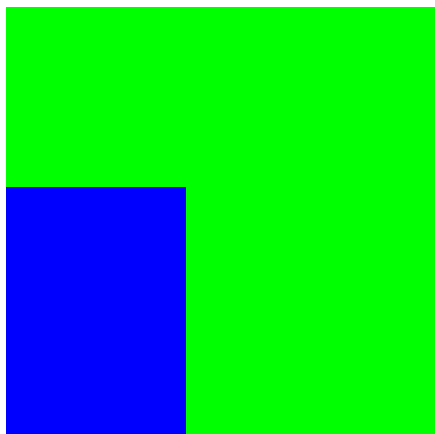
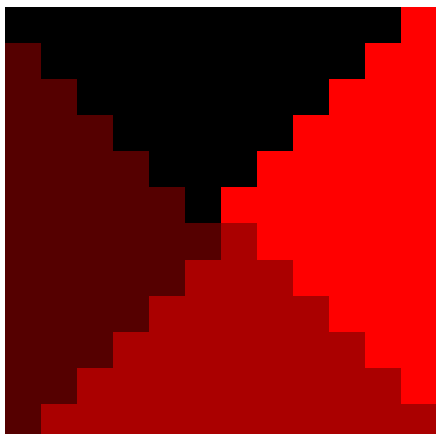
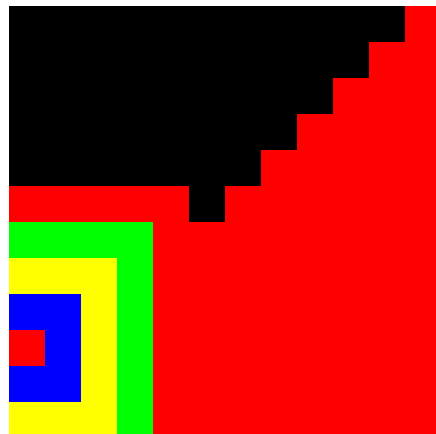
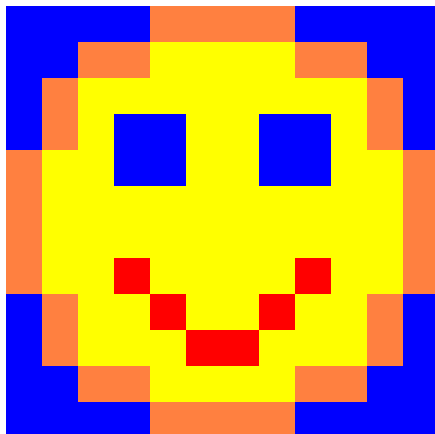


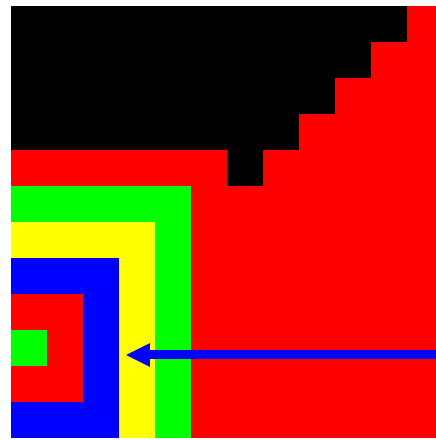
Et également occupé futur et parité



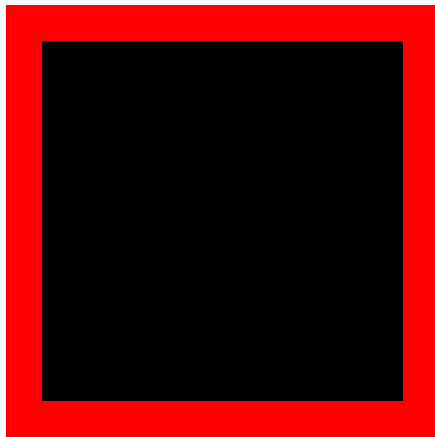
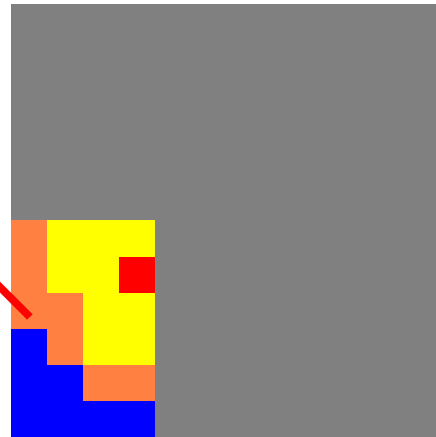
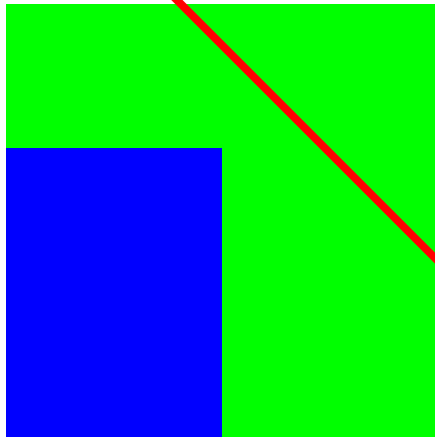
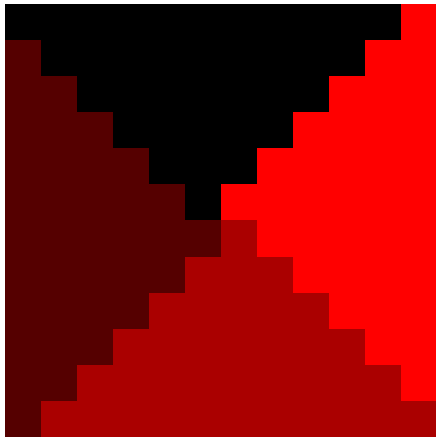
Le pipeline est bleu :
les variables futures
deviennent les
variables critiques

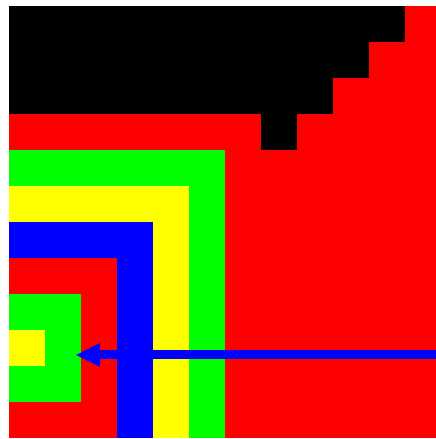






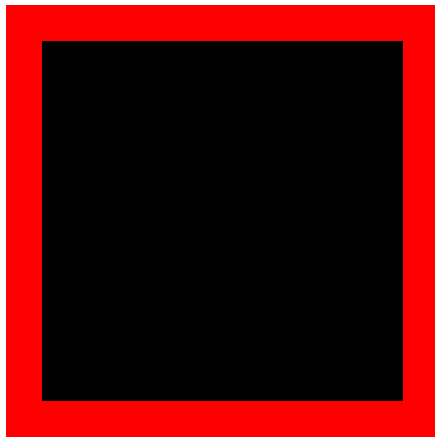
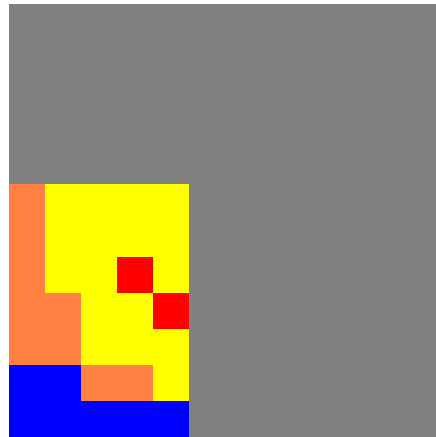
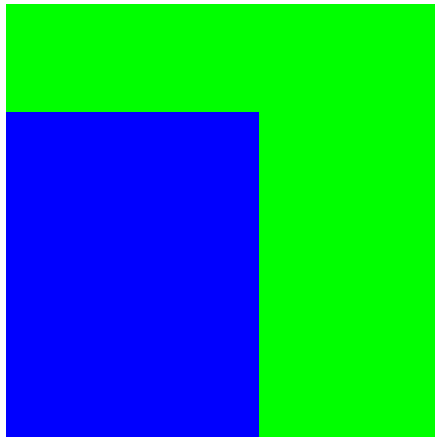
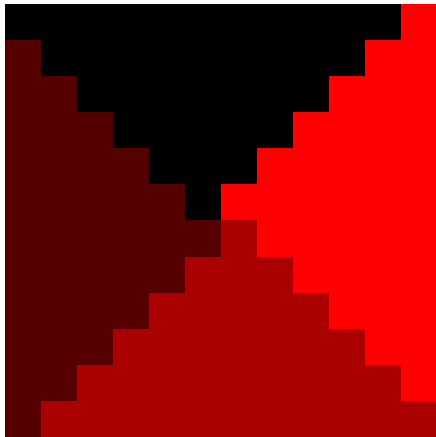
Pipeline=bleu
= Mise à jour des variables critiques

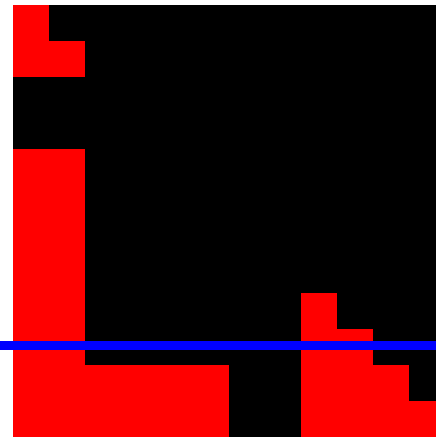
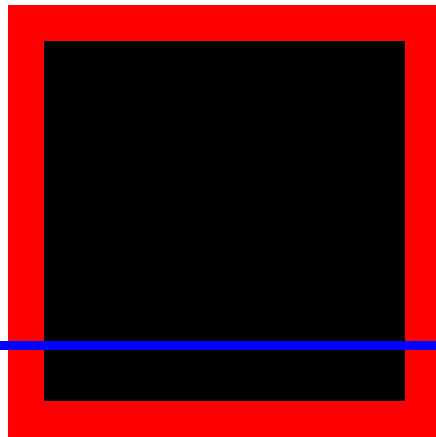
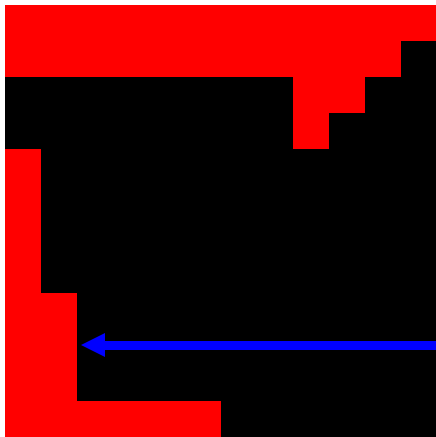
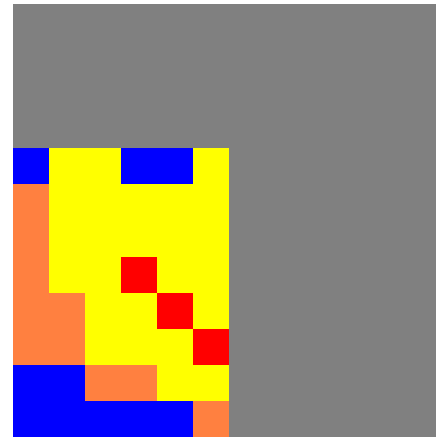
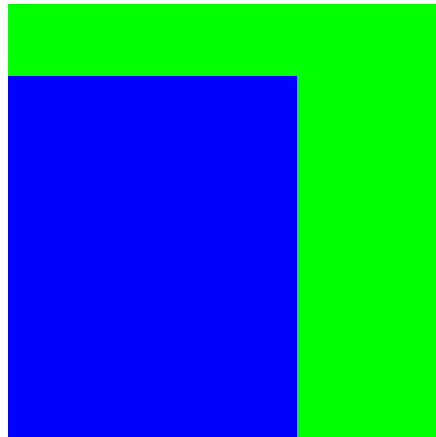
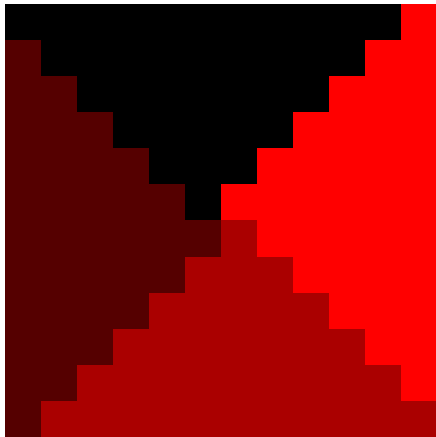
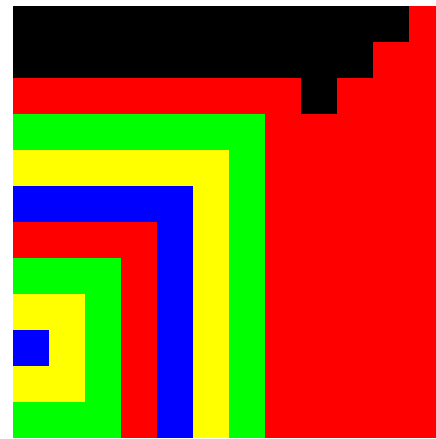
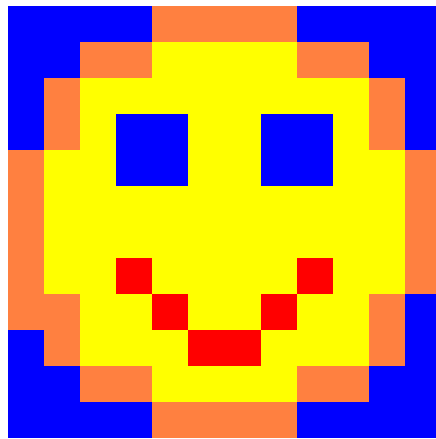




Pour mieux voir

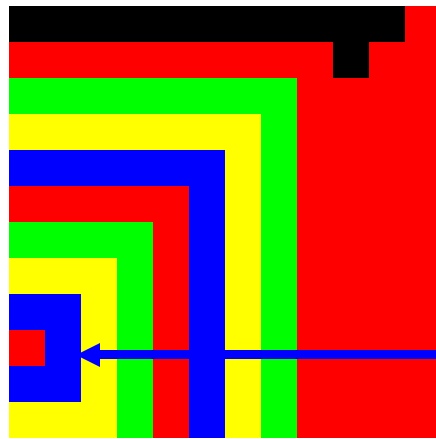
Pipeline vert



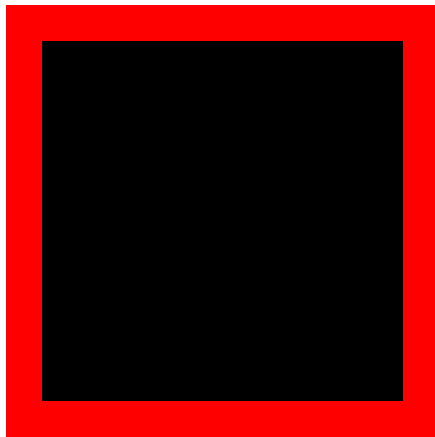
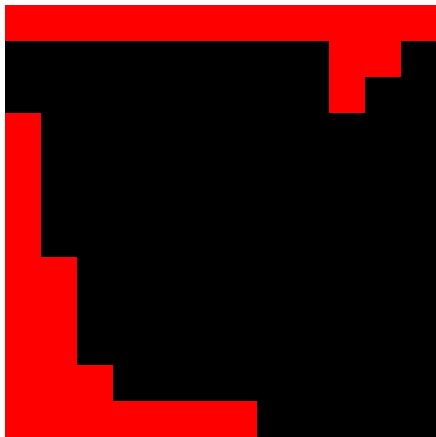
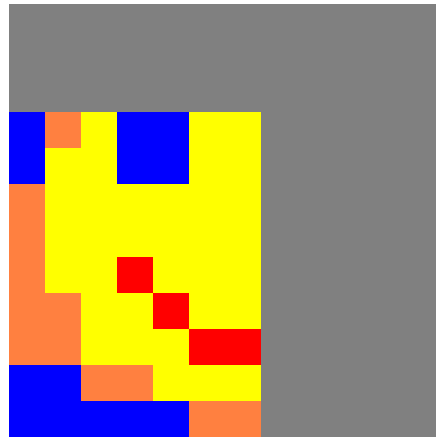
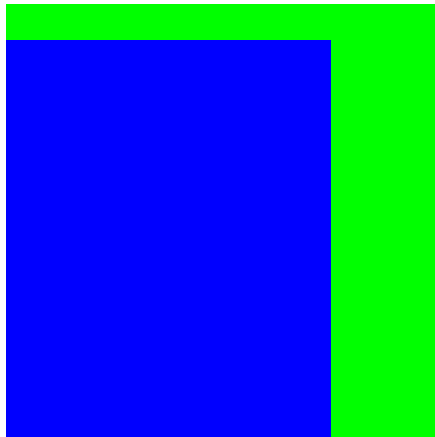
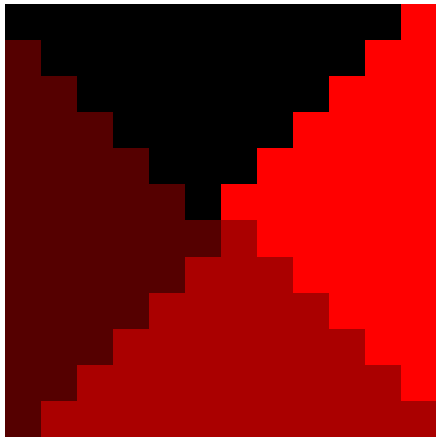


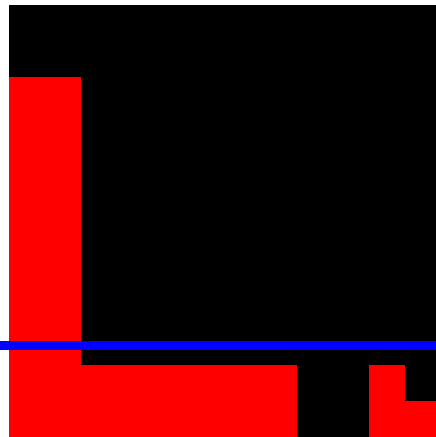
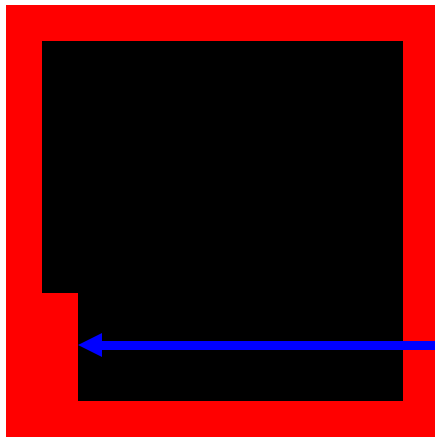
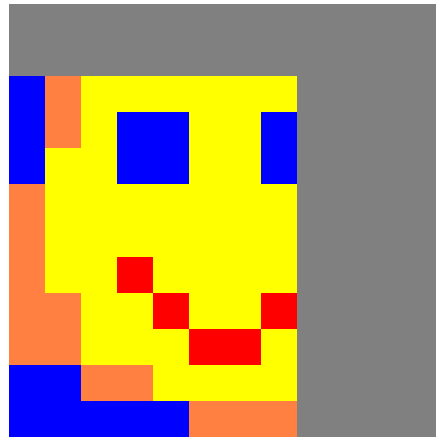
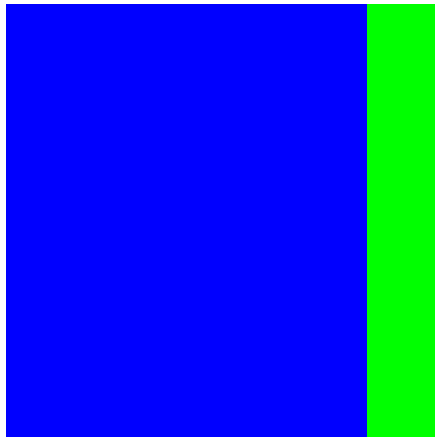
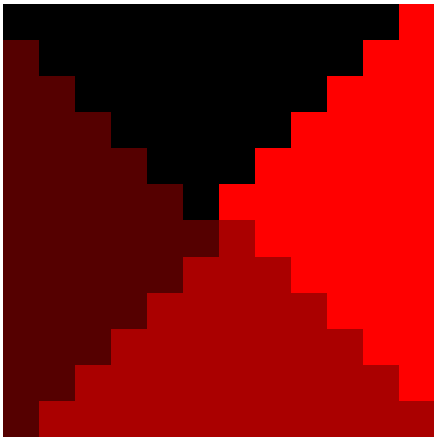
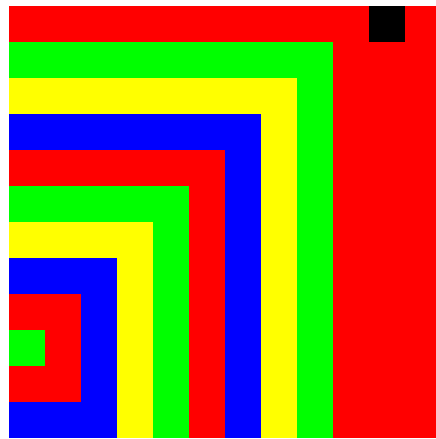
Pipeline était vert
= Mise à jour des
variables critiques





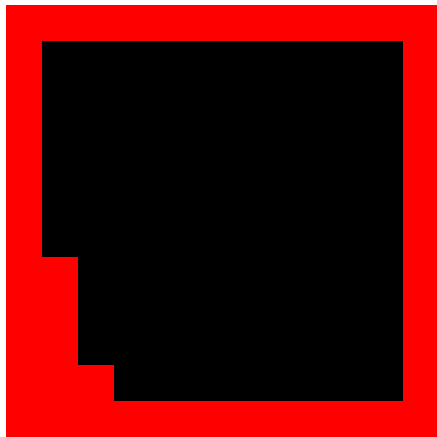
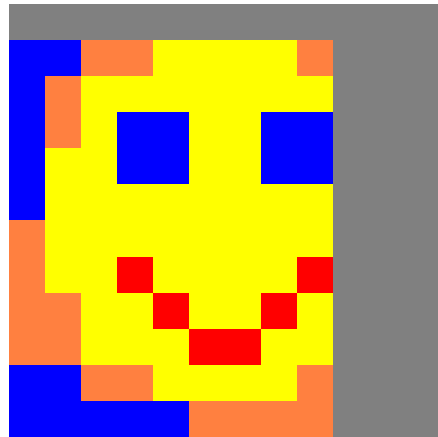
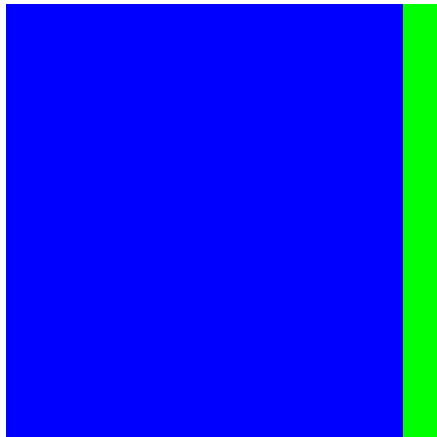
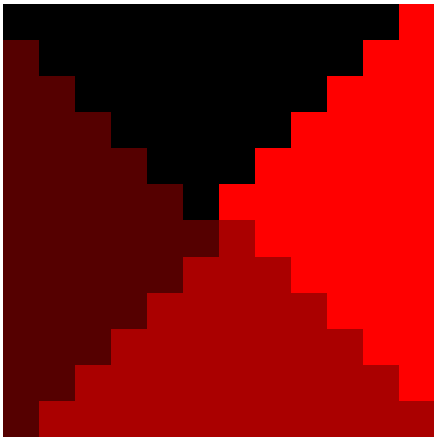
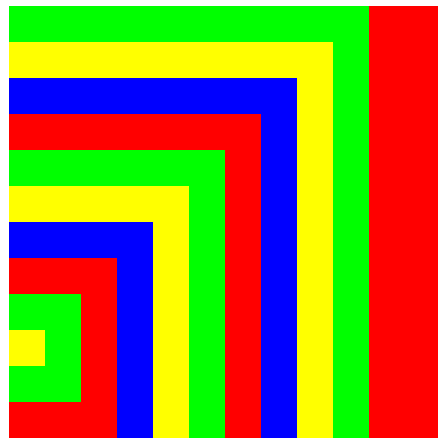
Pipeline bleu

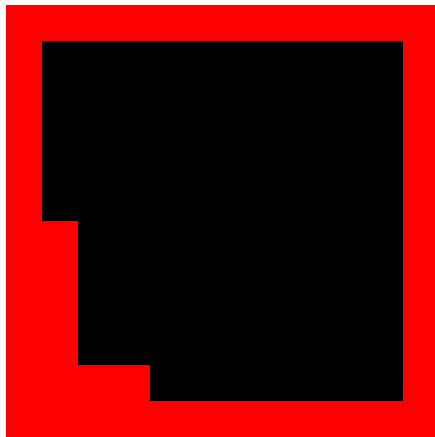
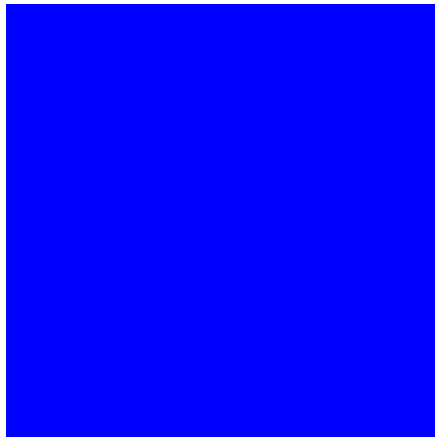
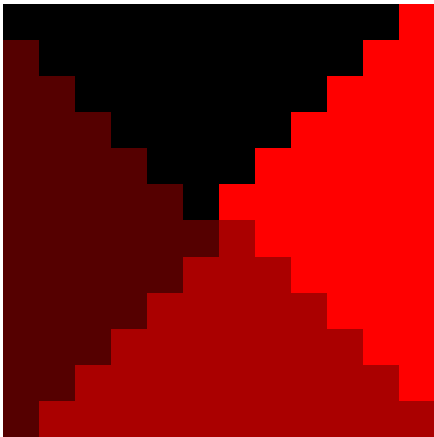
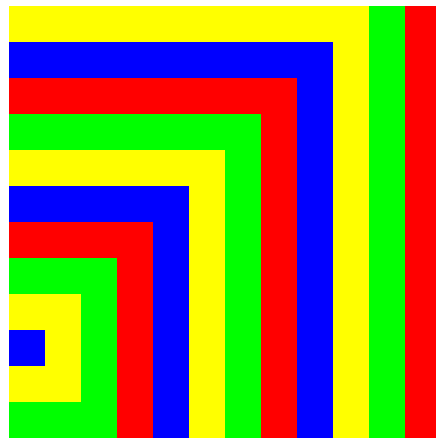
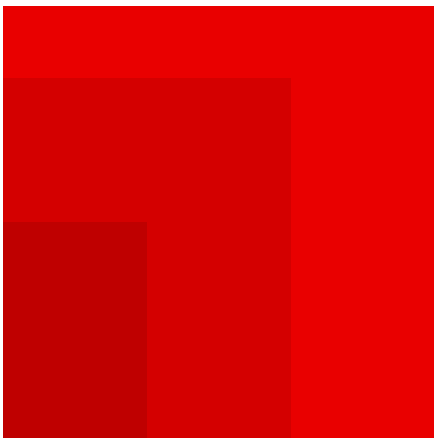


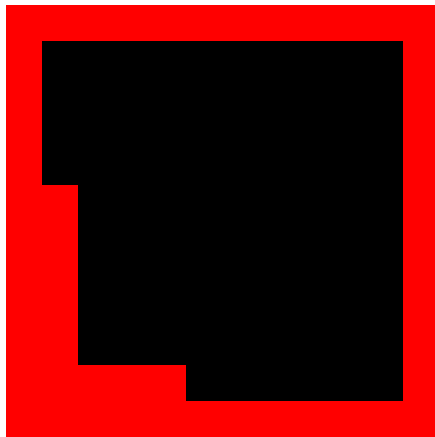
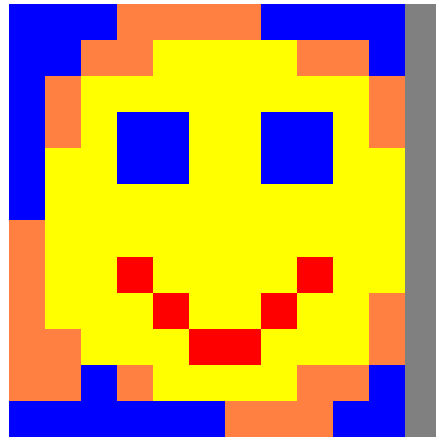
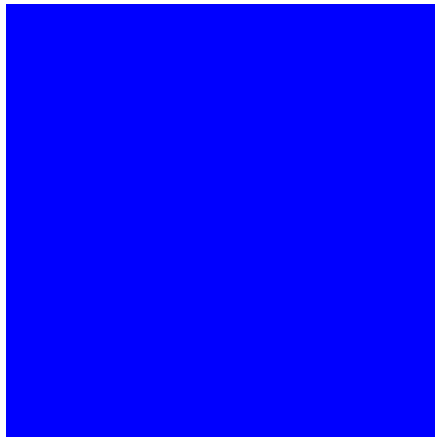
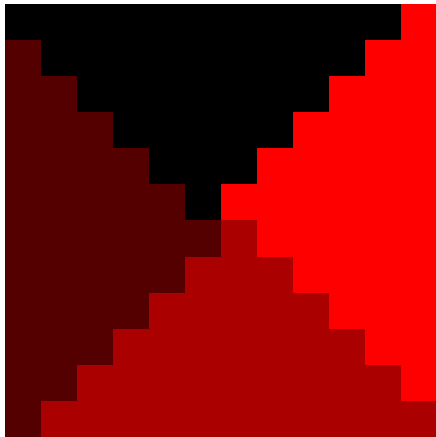
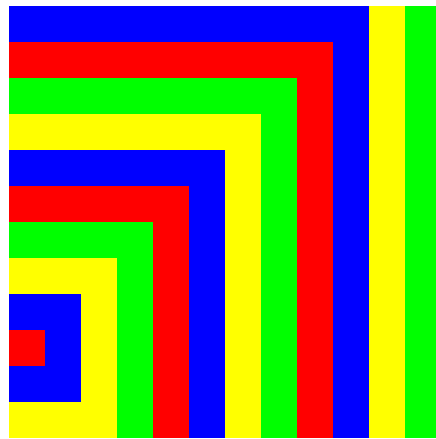


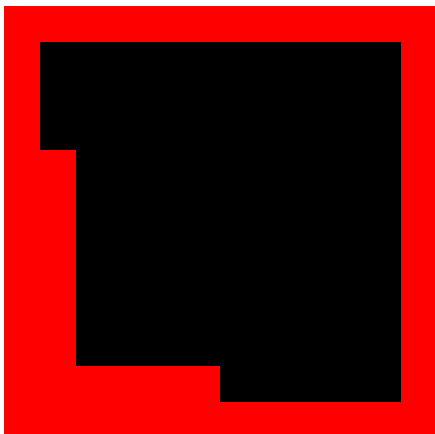
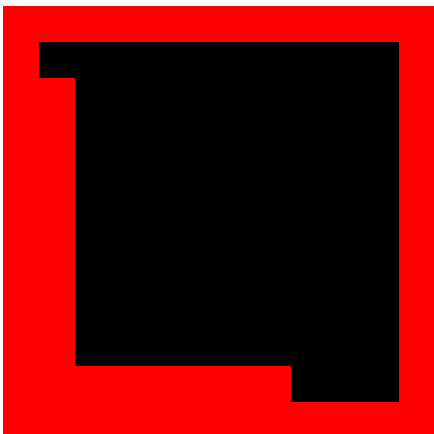
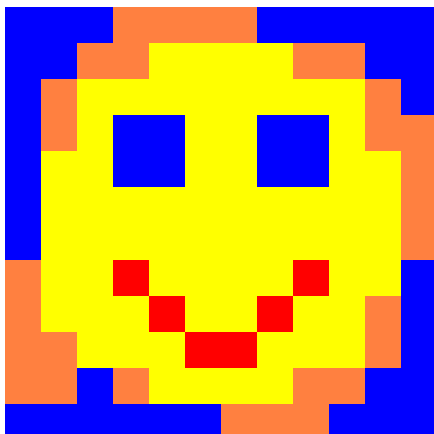
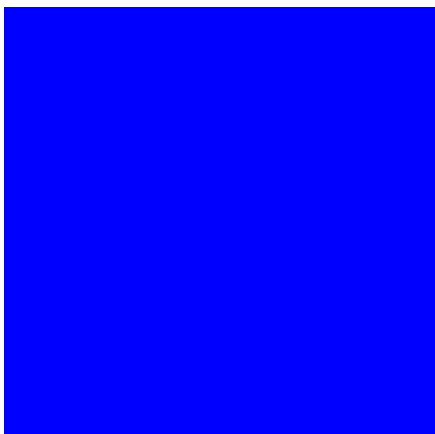
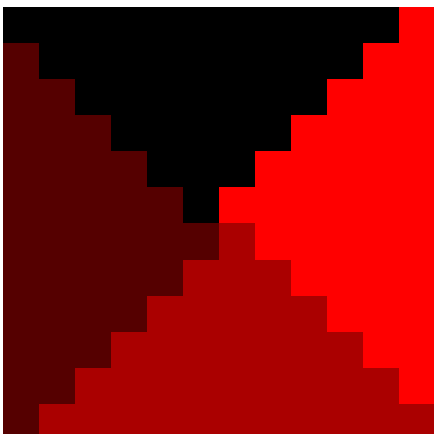
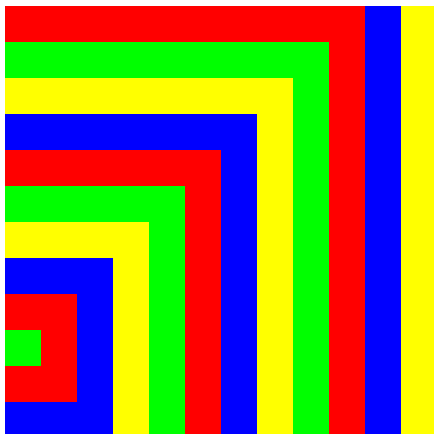
Pipeline était bleu
= Mise à jour de
états futurs

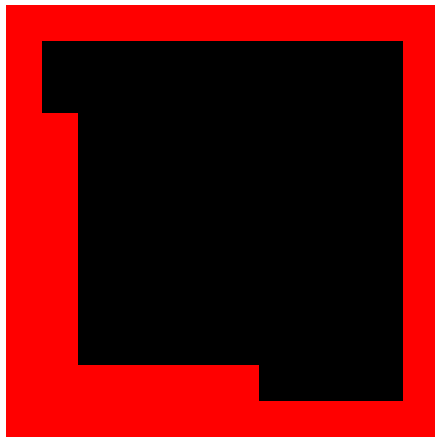
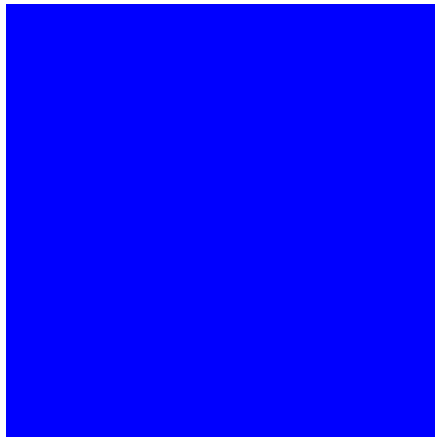
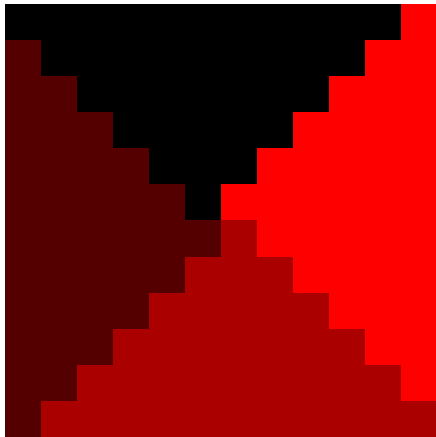
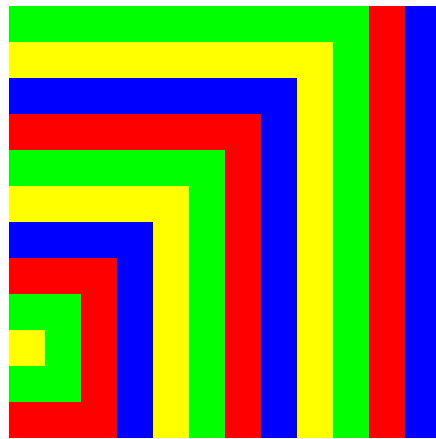


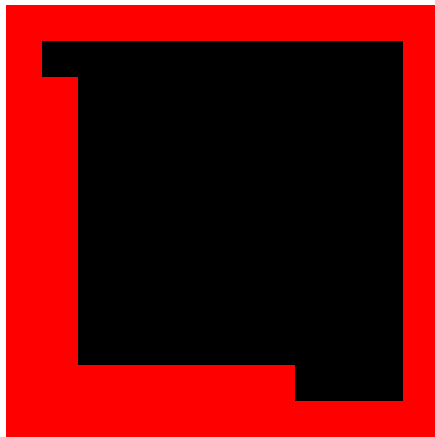
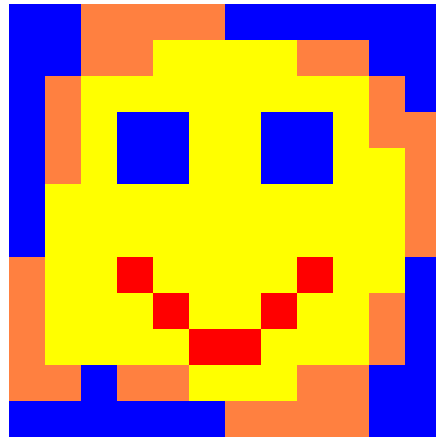
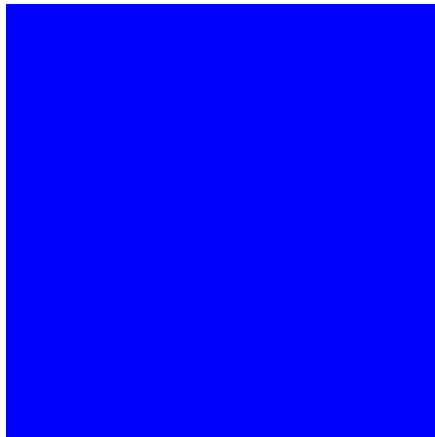
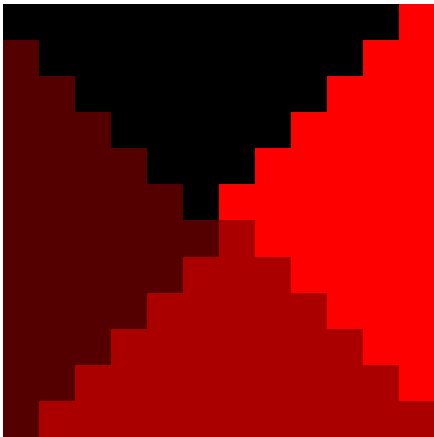
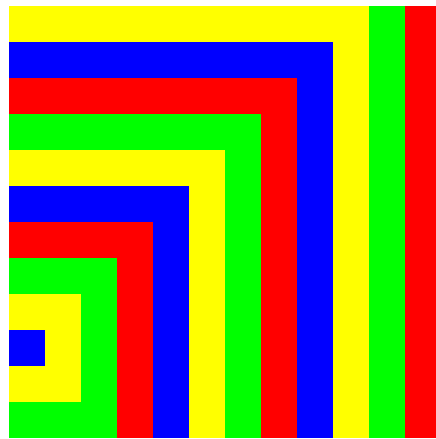


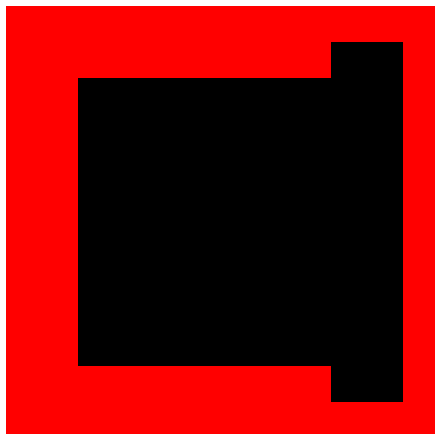
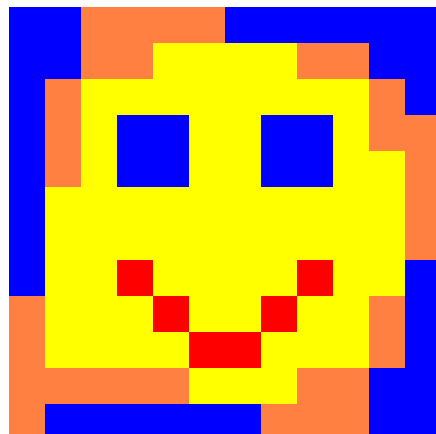
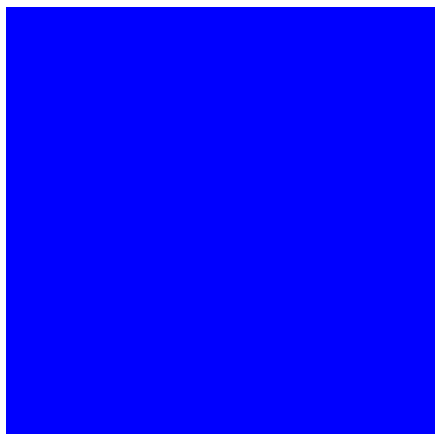
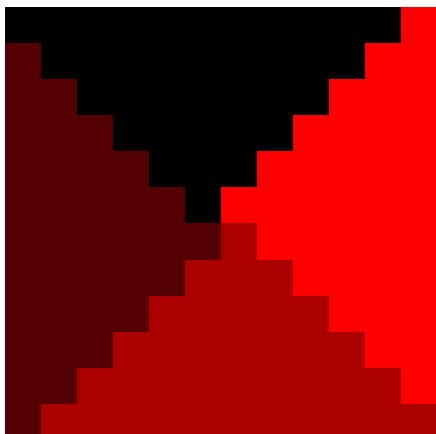
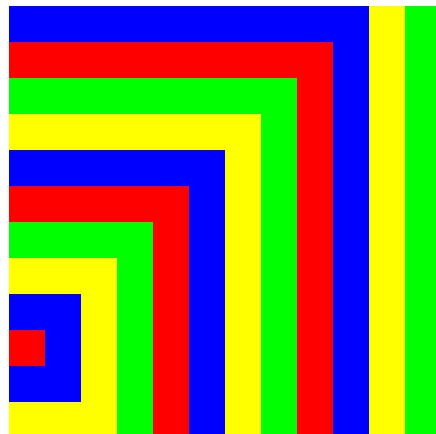


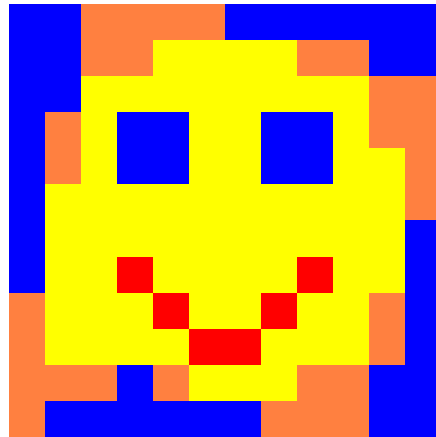
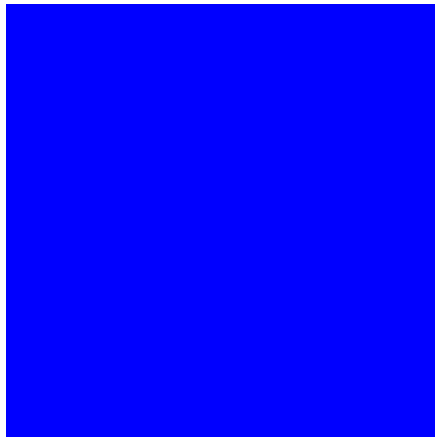
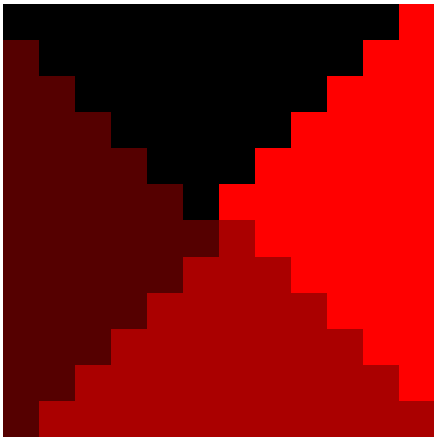
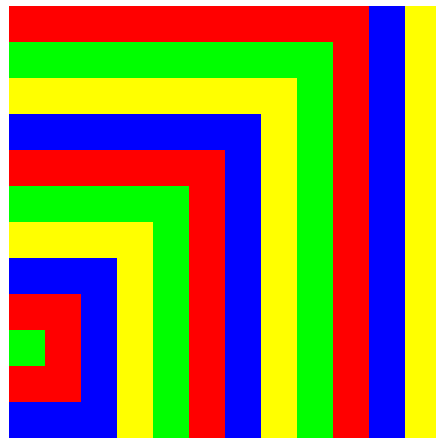
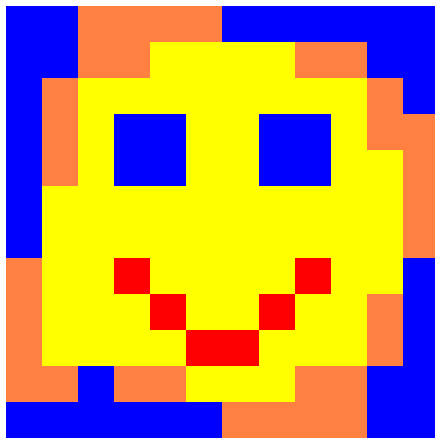


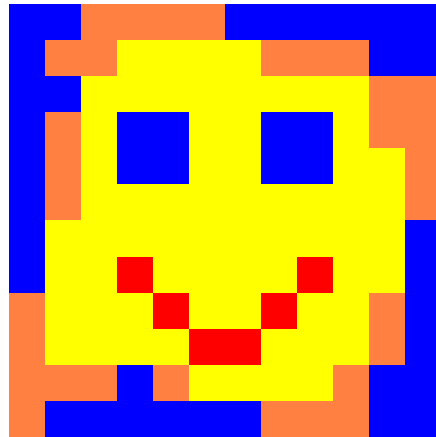
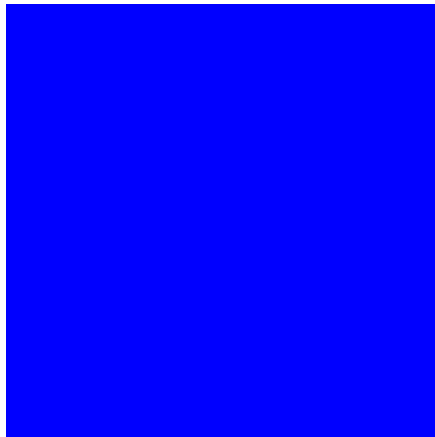
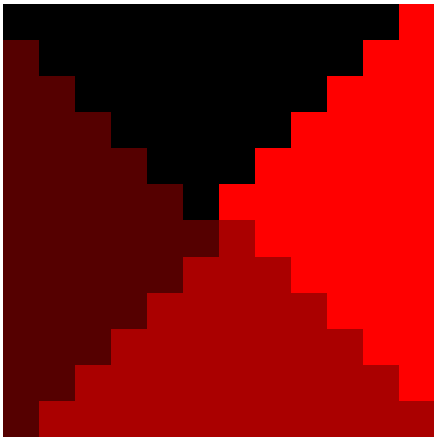
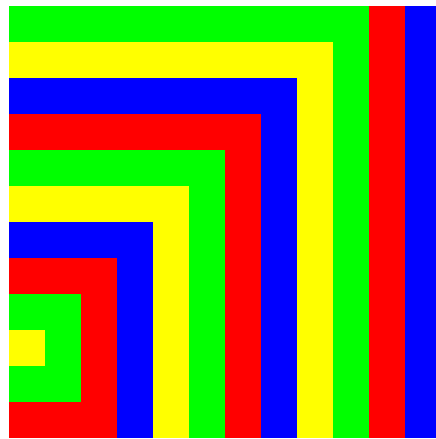
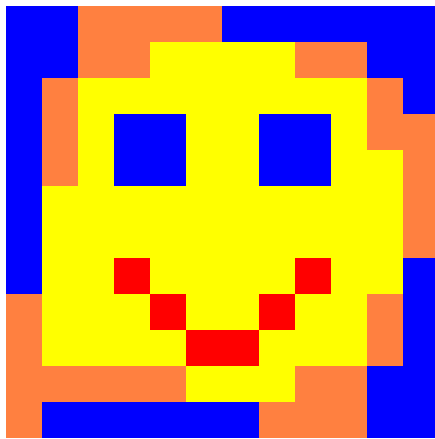


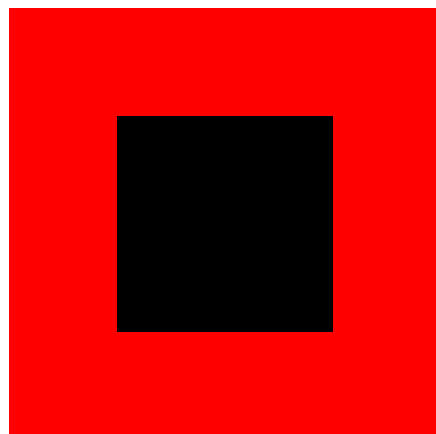
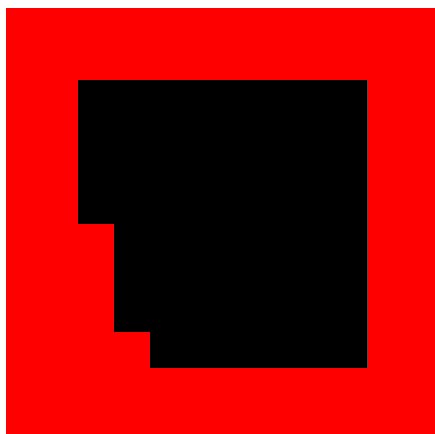
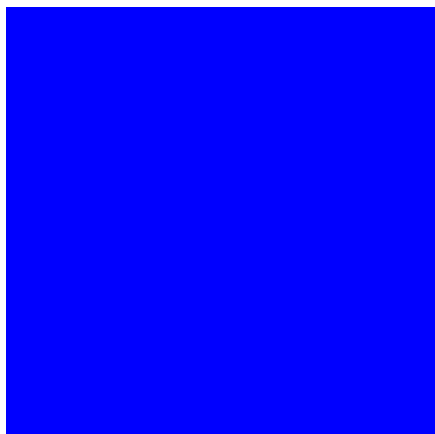
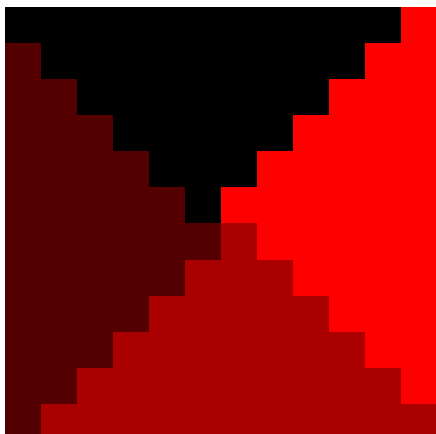
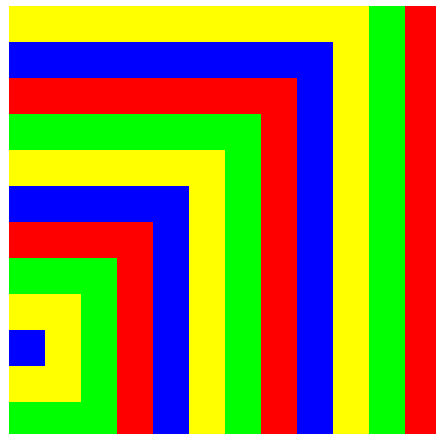
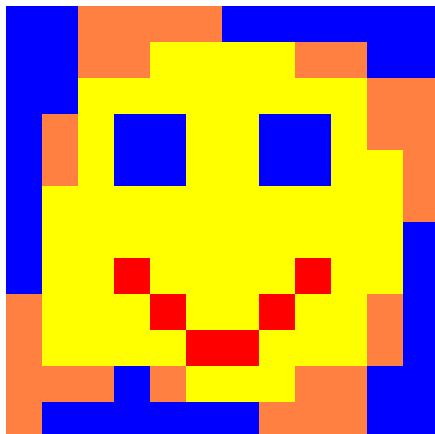


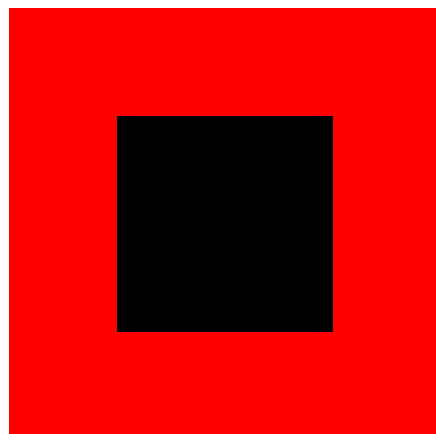
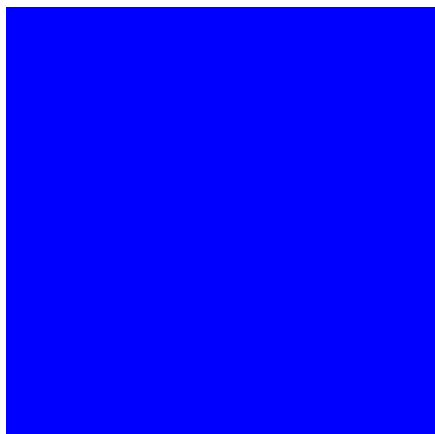
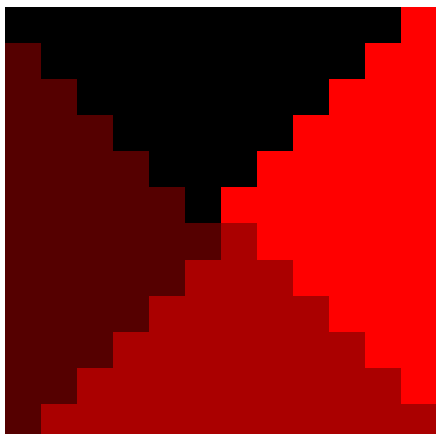
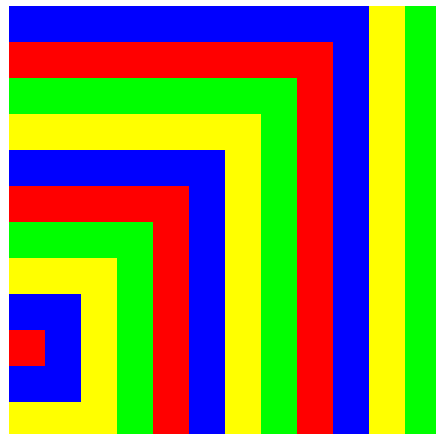


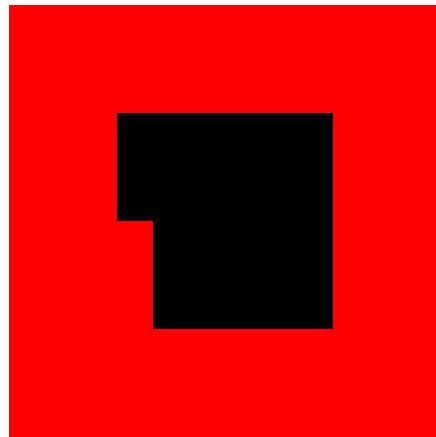
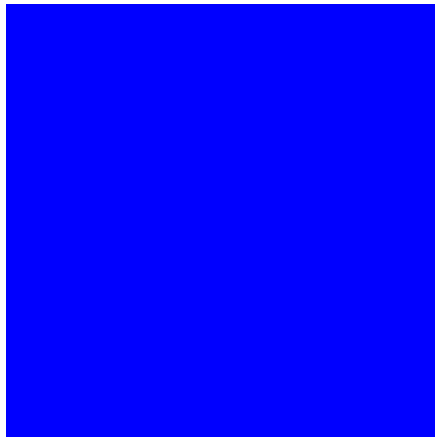
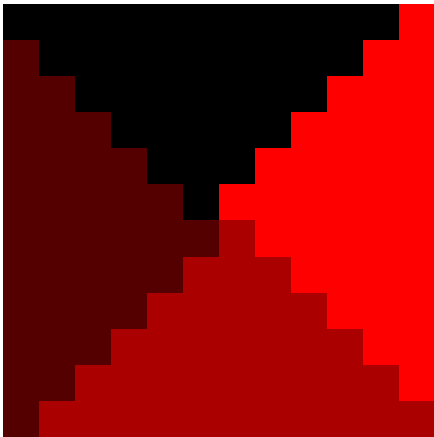
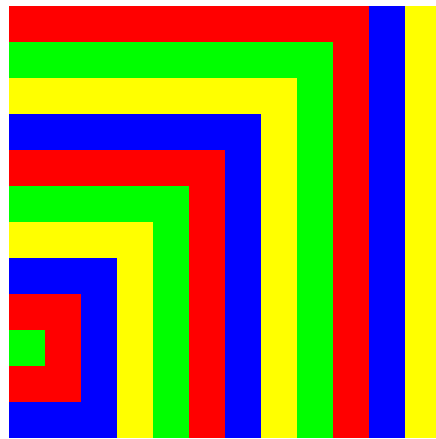


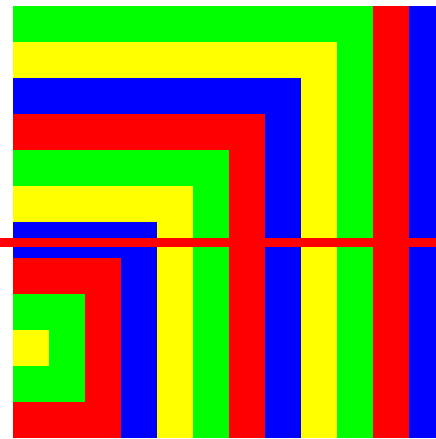
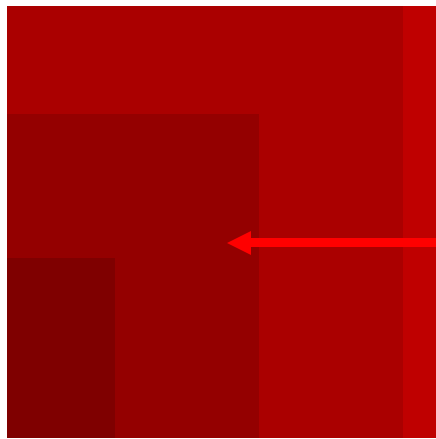




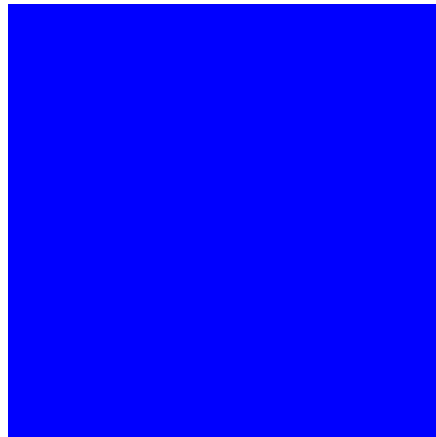
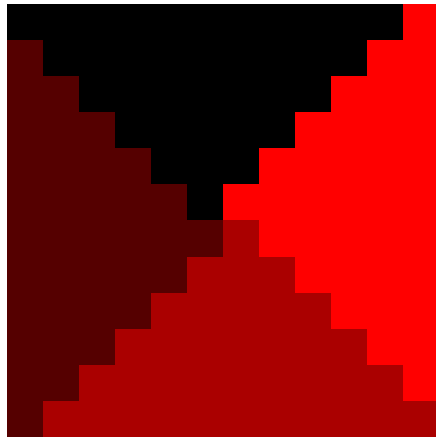


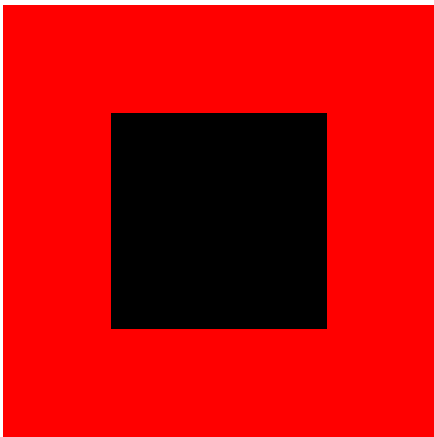
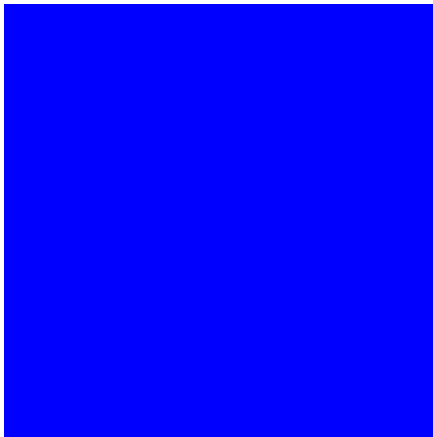
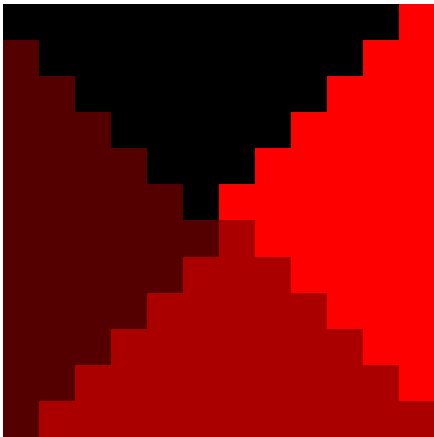
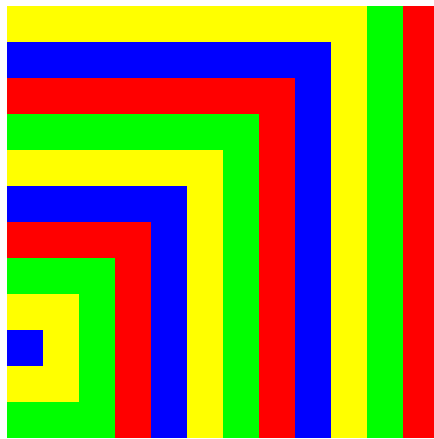


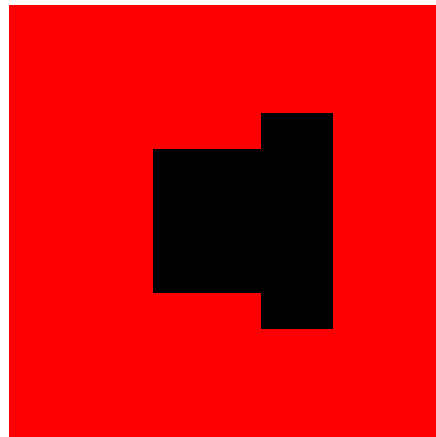
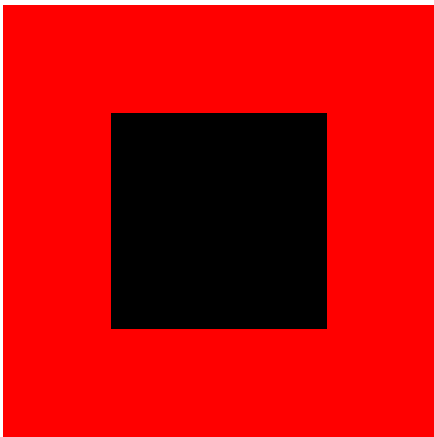
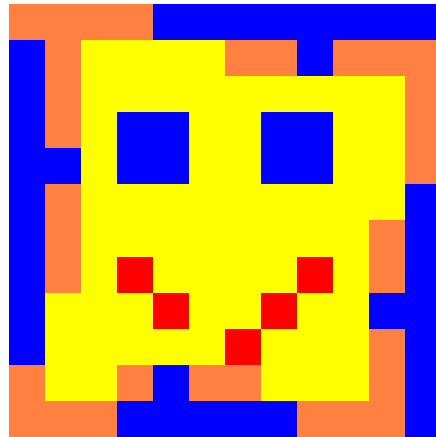
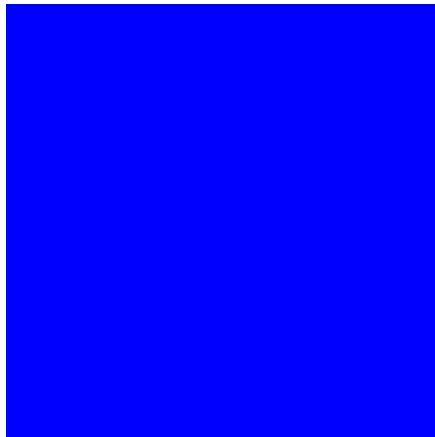
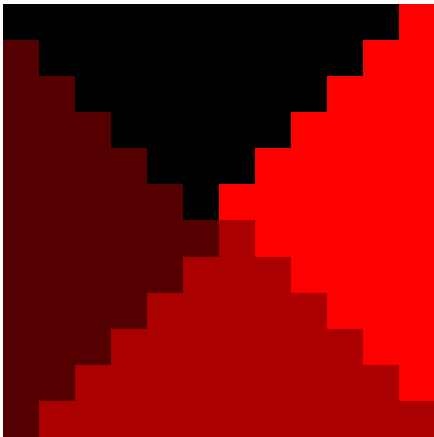
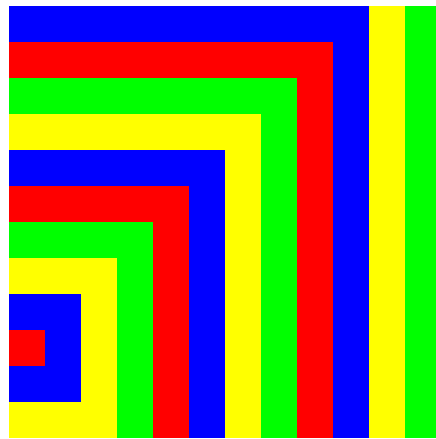


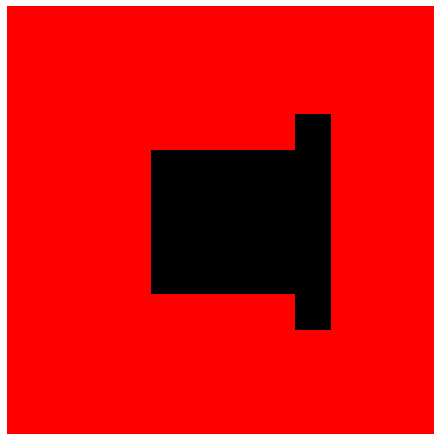
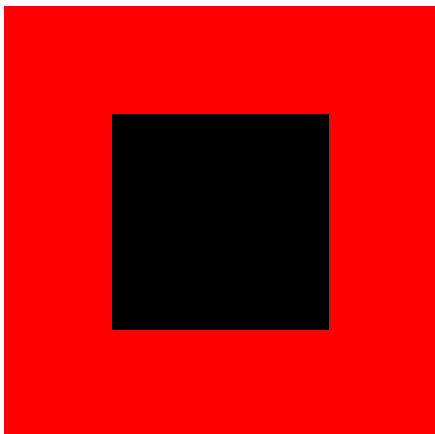
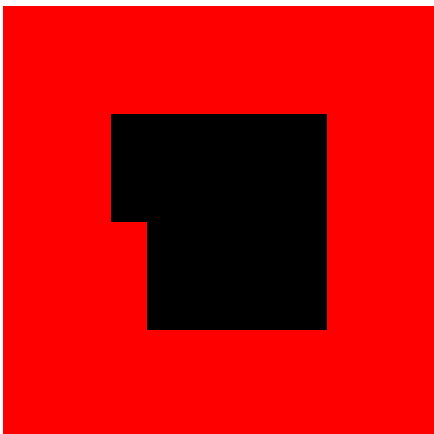
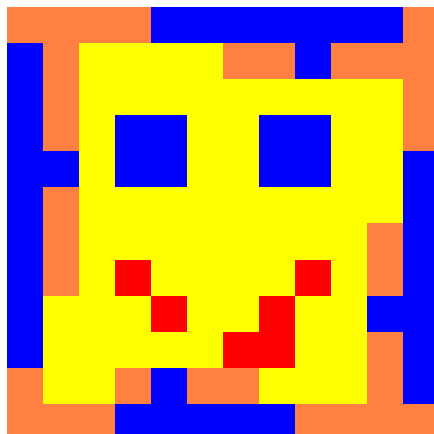
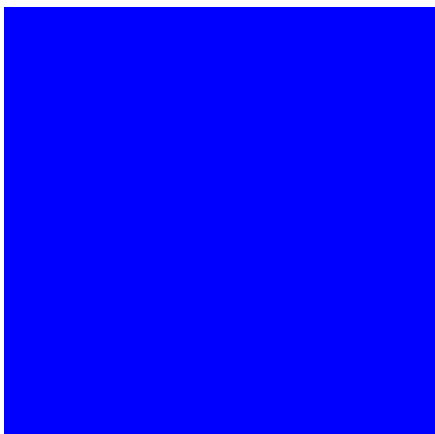
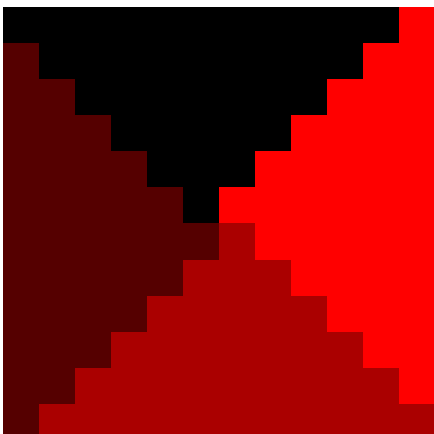
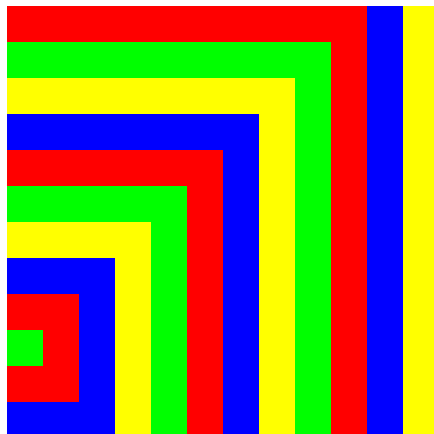


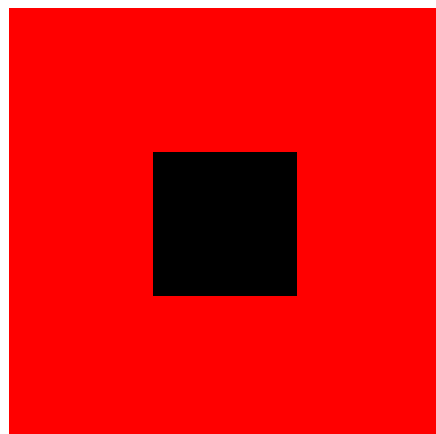
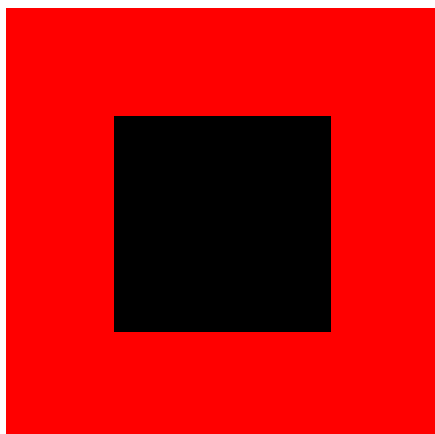
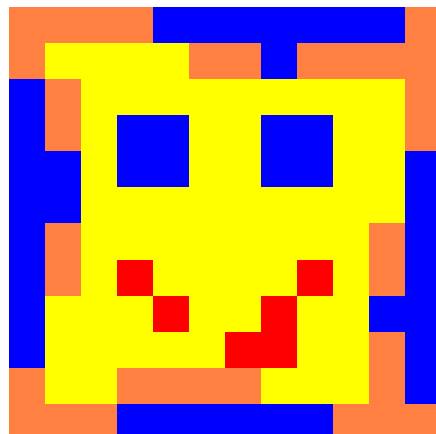
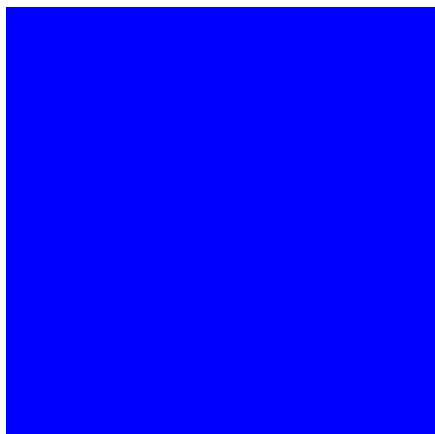
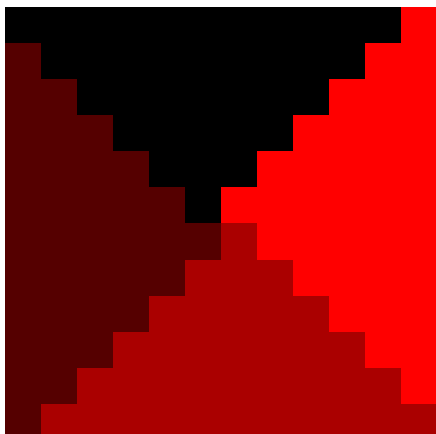
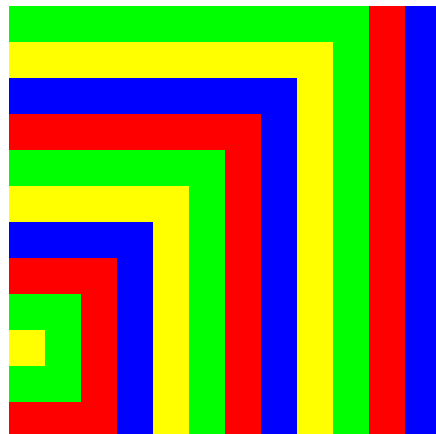
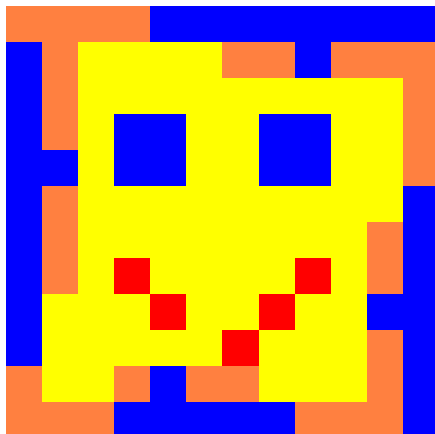
Le compte est
décrémentée. Chaque
cellule n'est pas au
même cycle

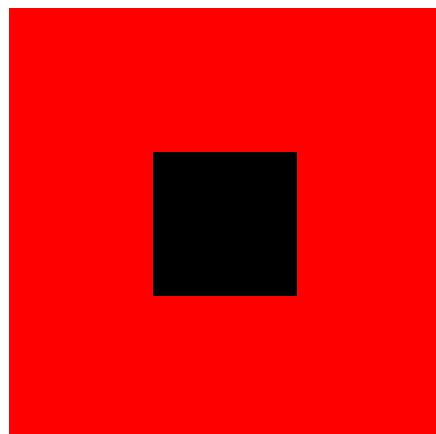
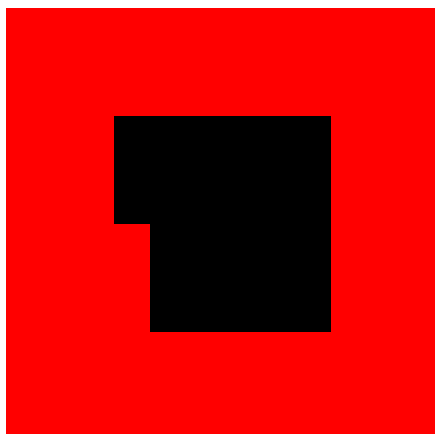
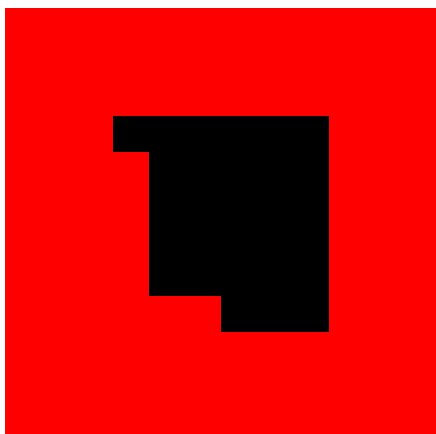
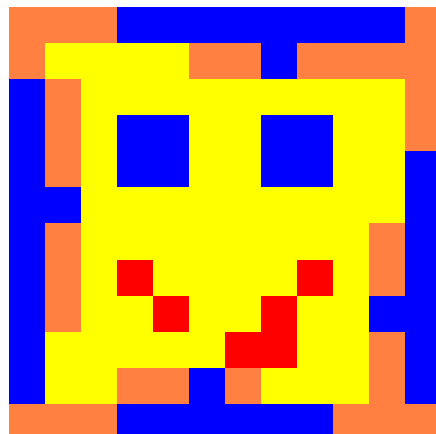
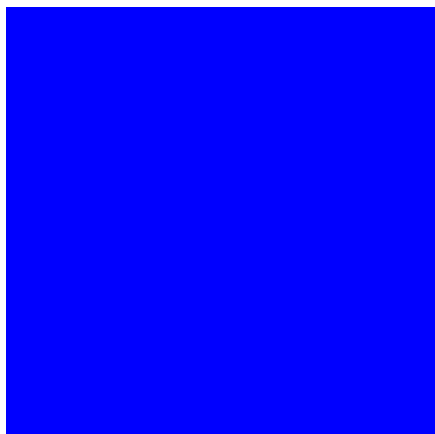
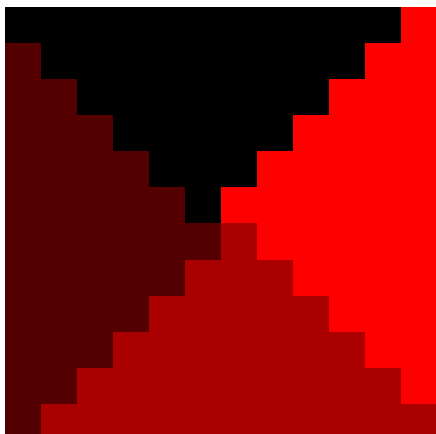
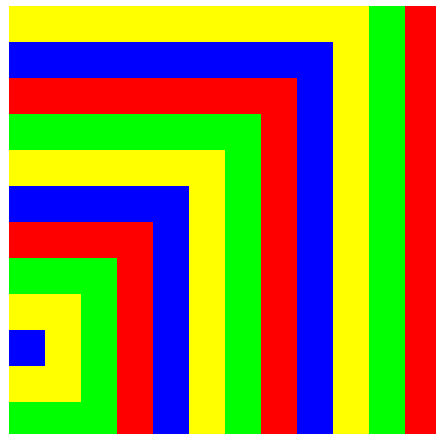
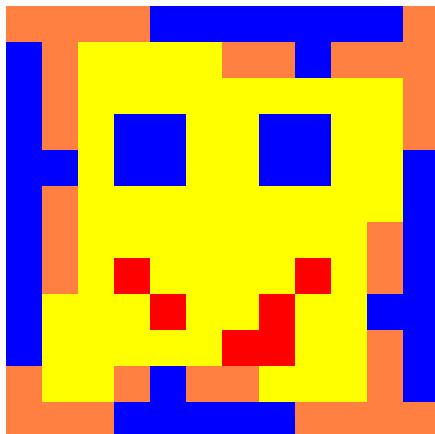


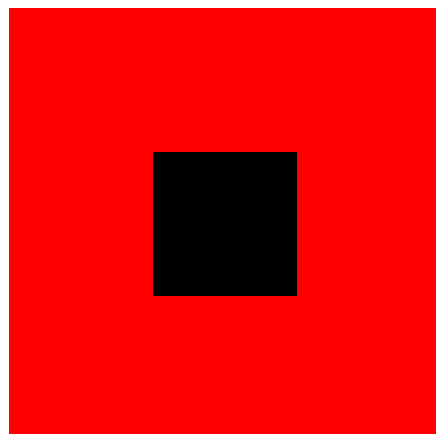
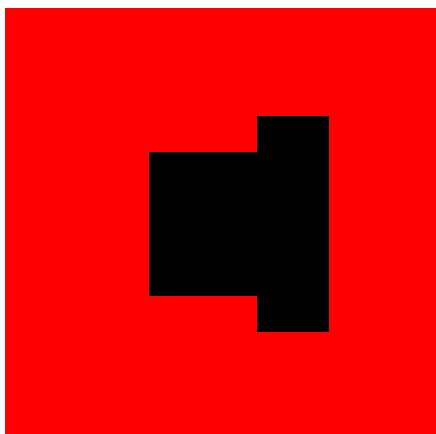
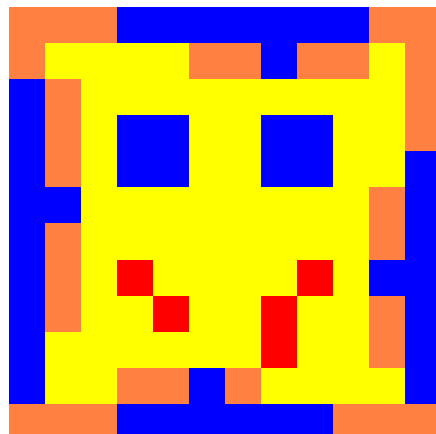
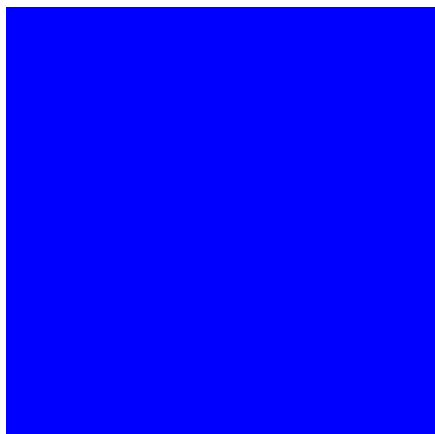
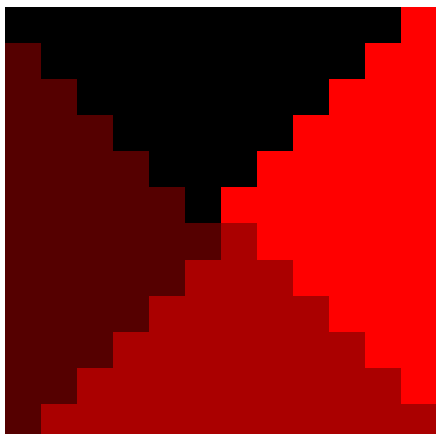
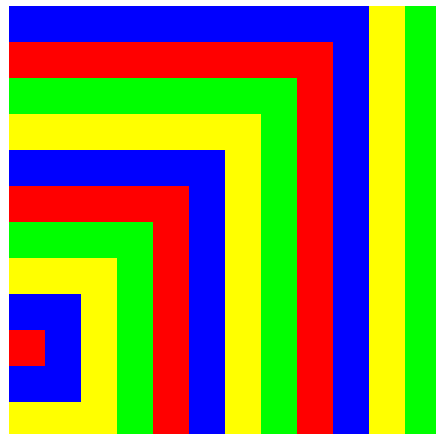


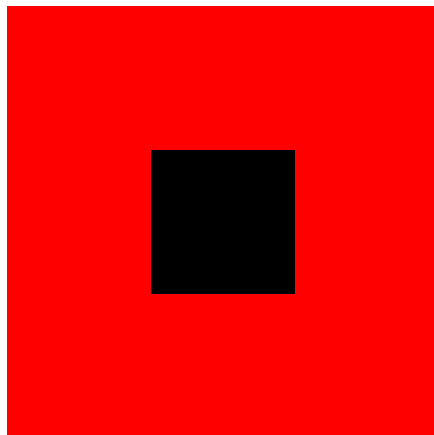
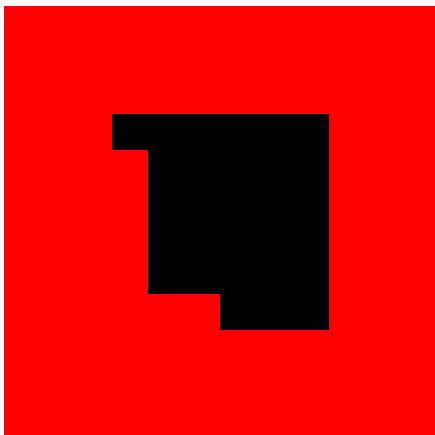
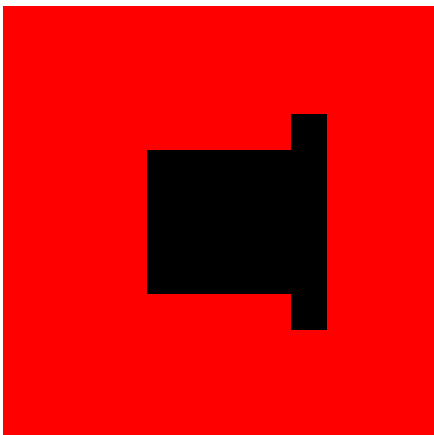
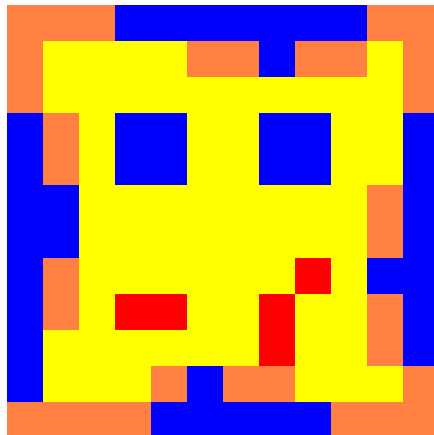
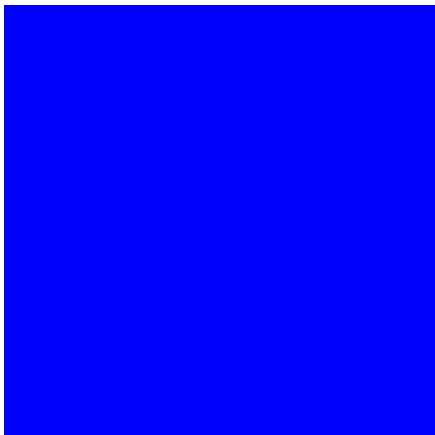
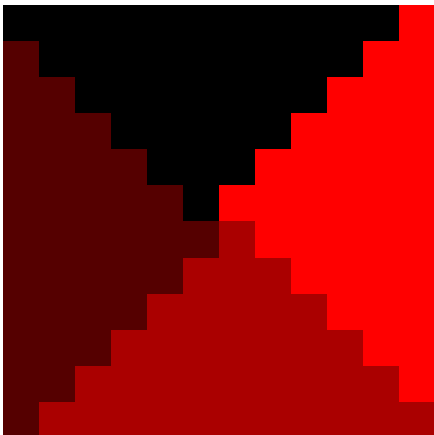
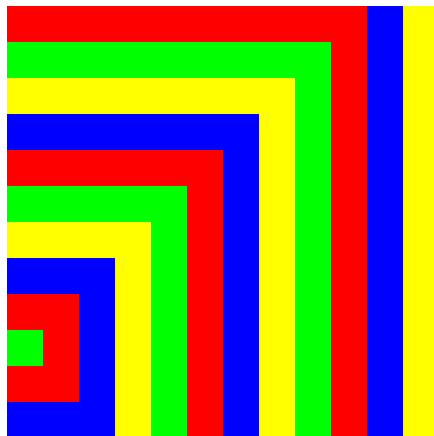


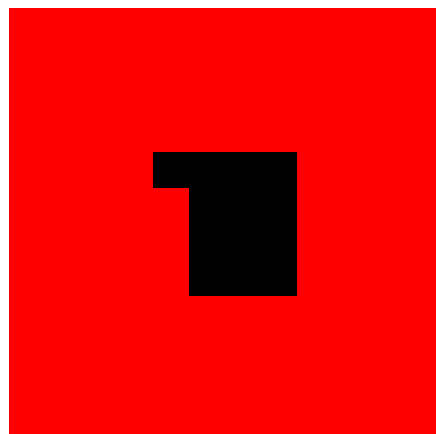
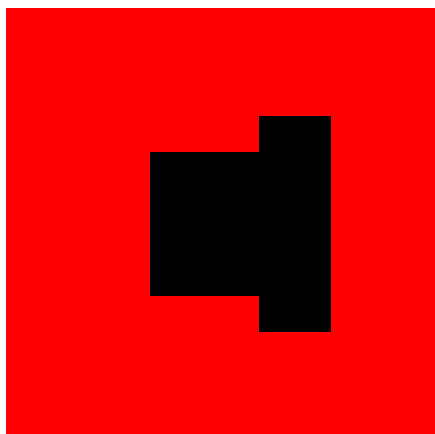
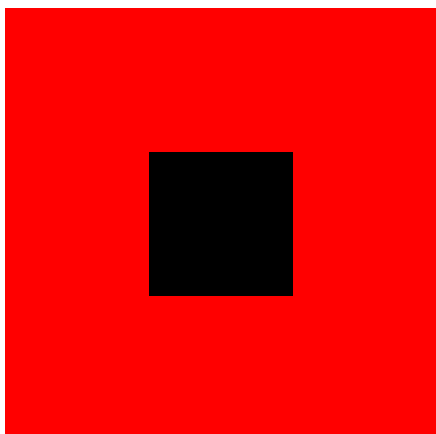
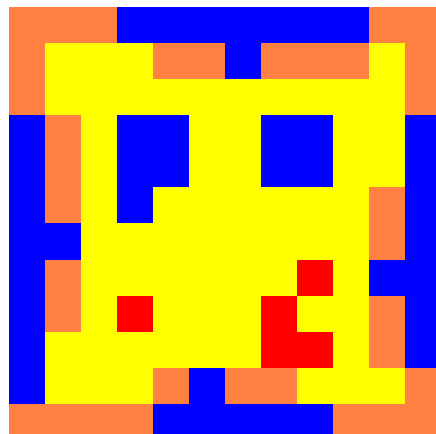
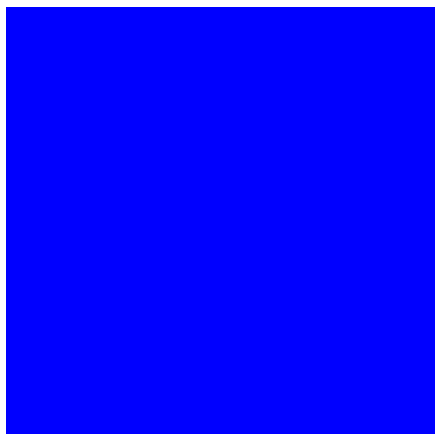
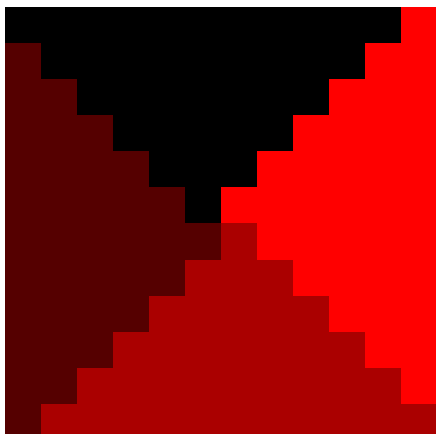
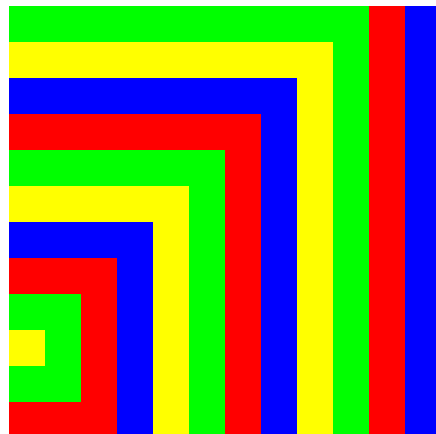
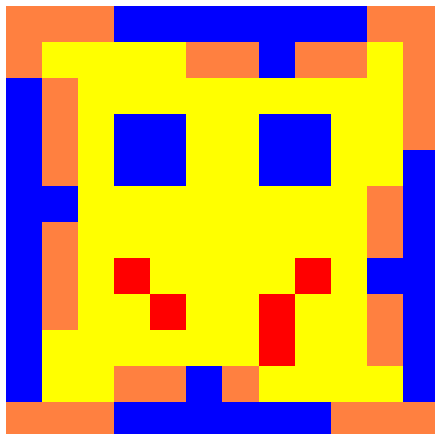


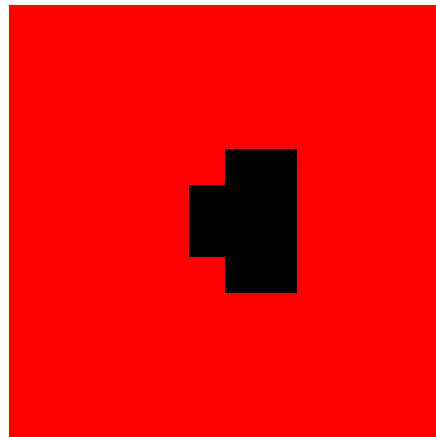
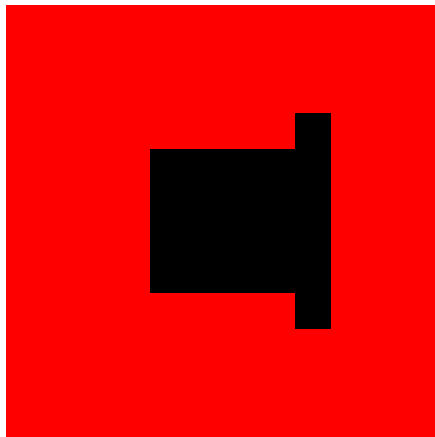
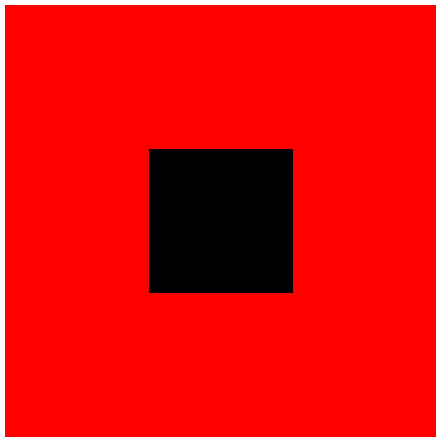
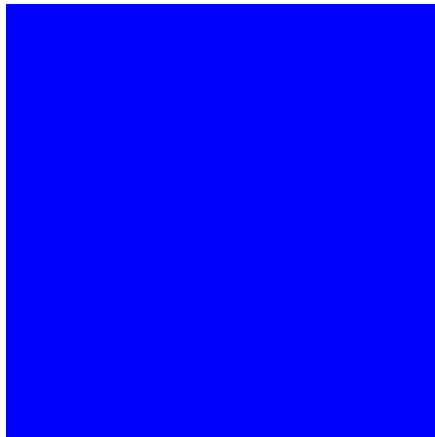
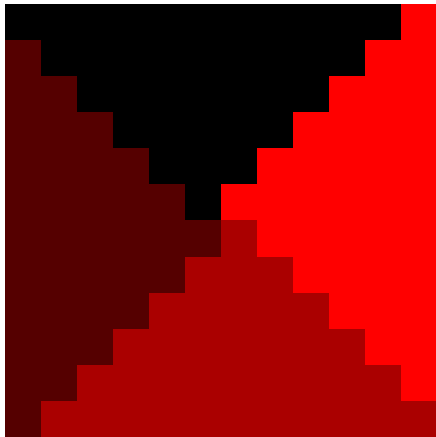
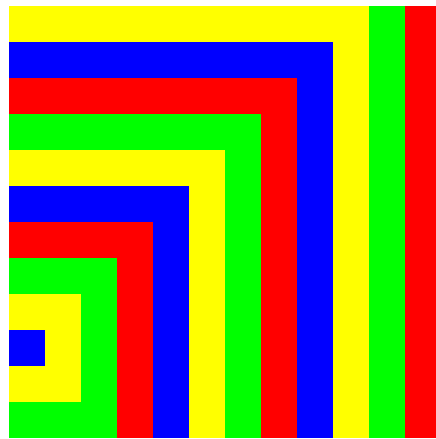
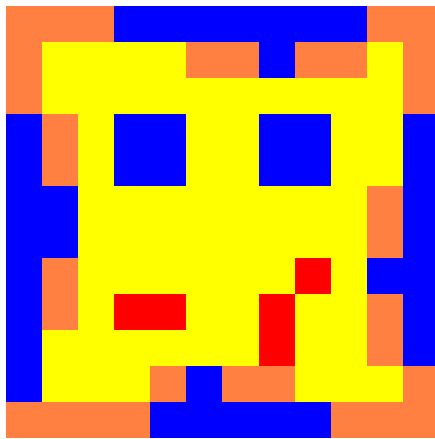
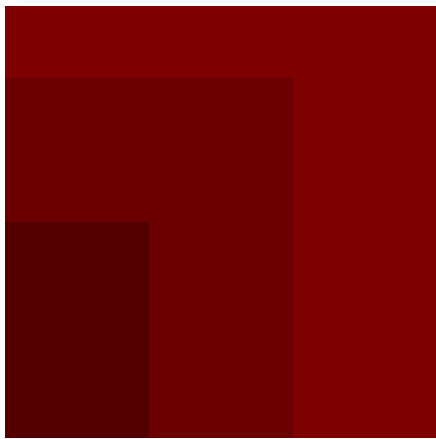


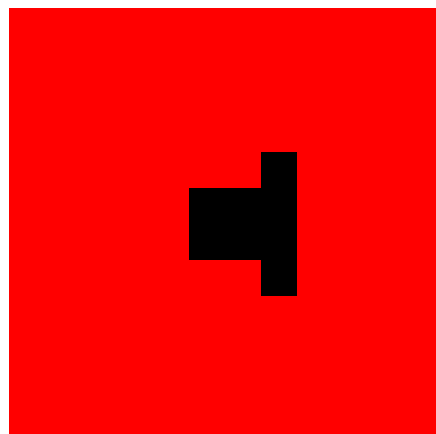
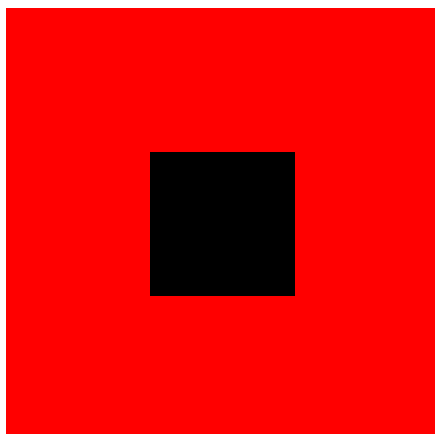
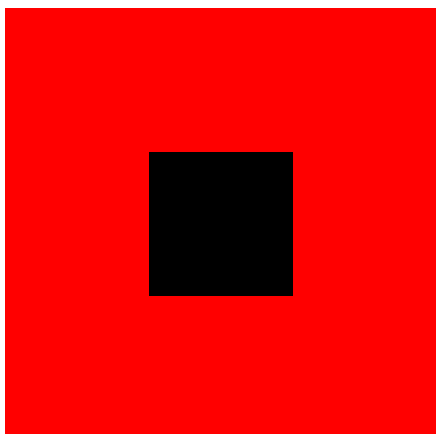
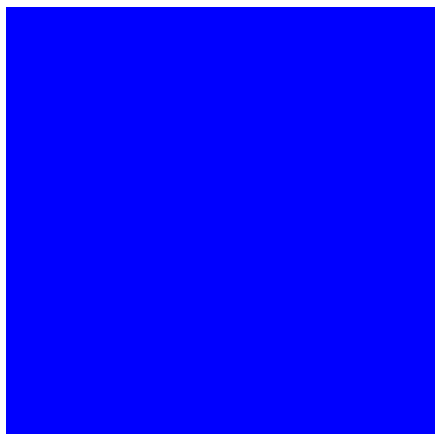
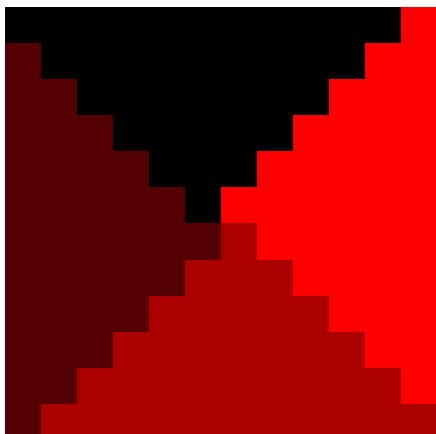
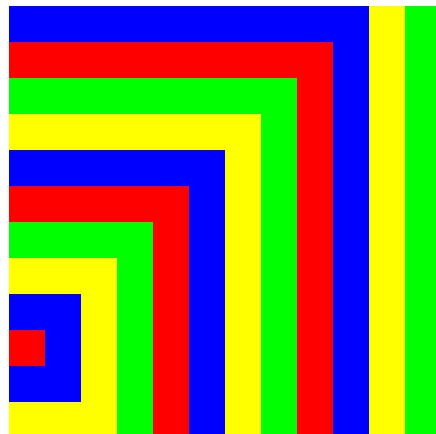
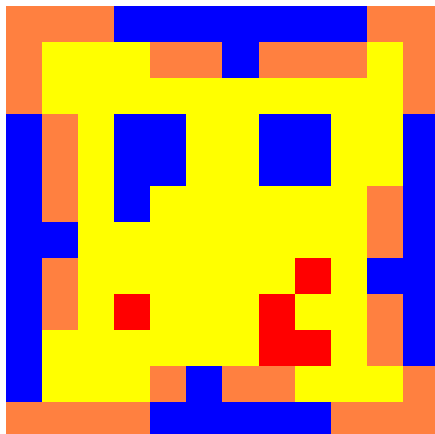


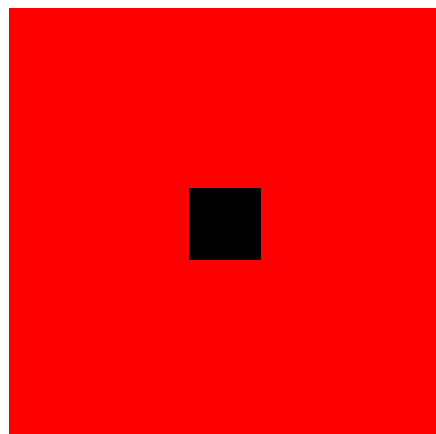
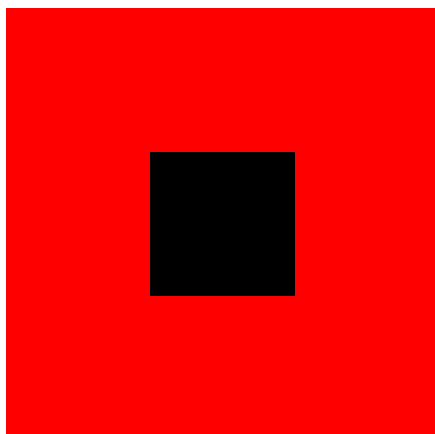
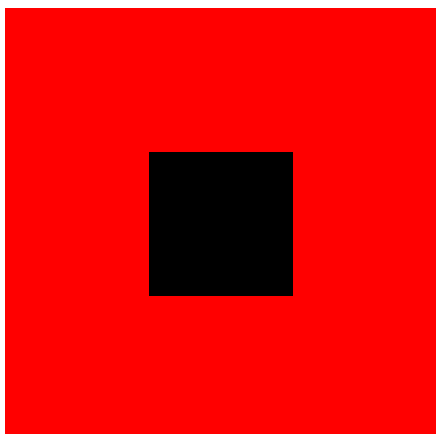
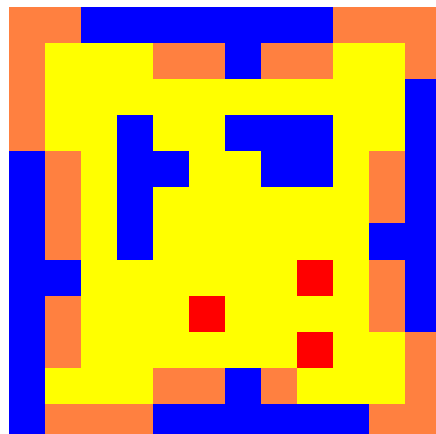
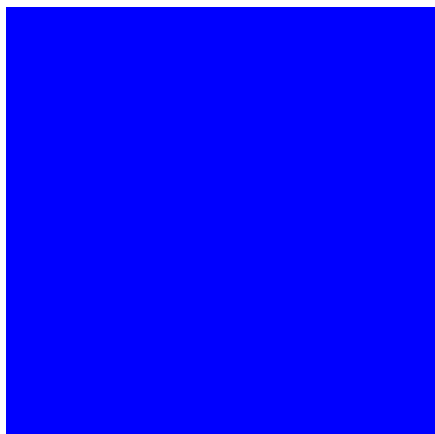
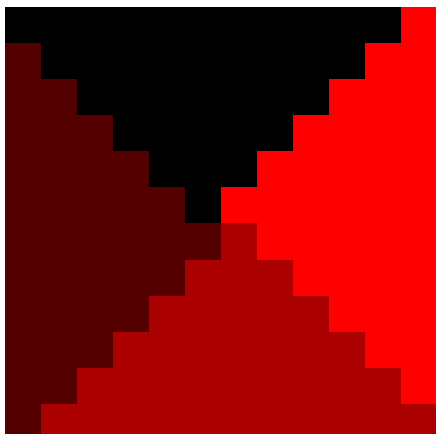
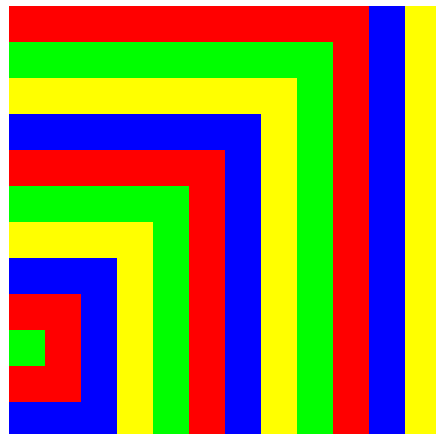


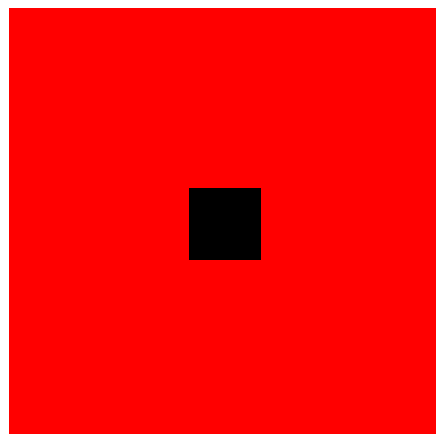
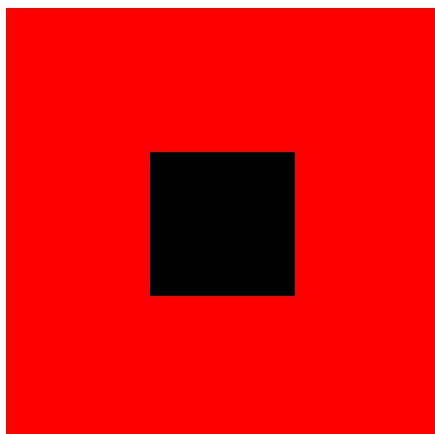
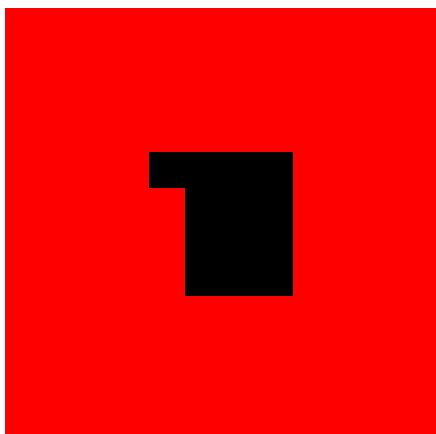
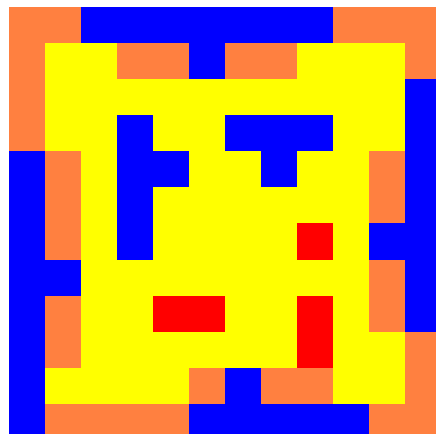
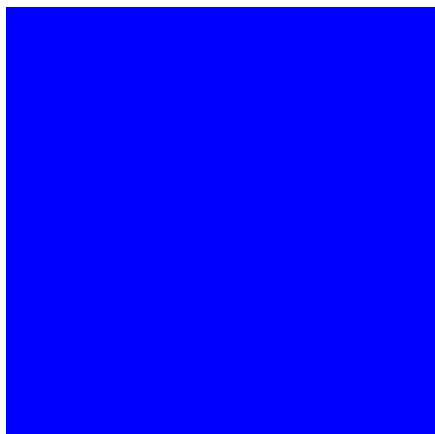
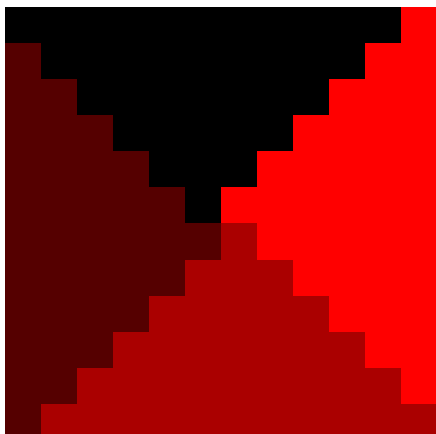
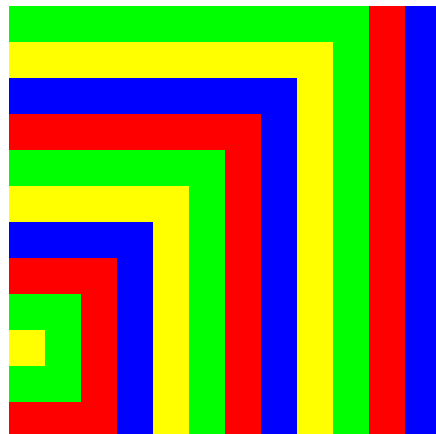


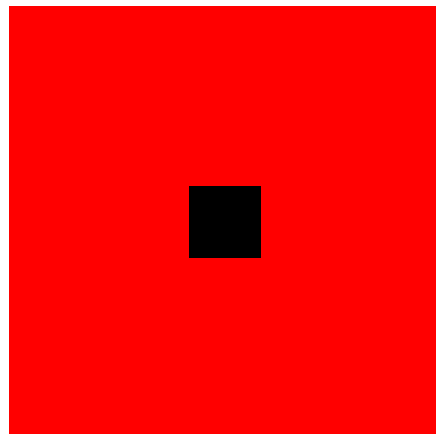
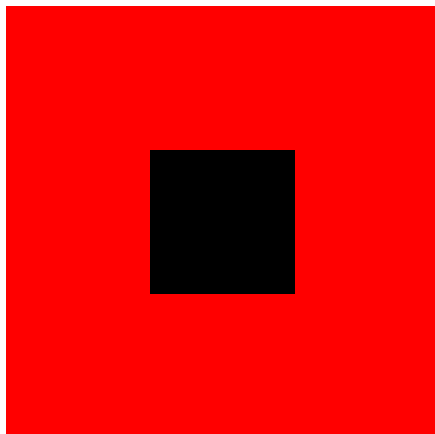
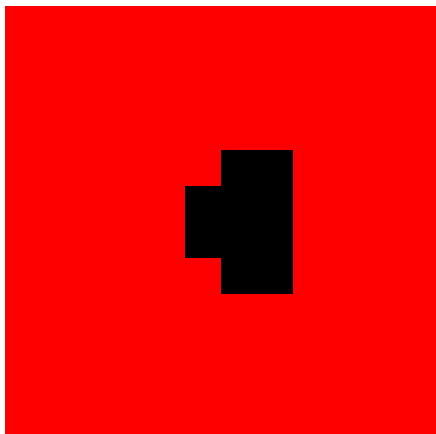
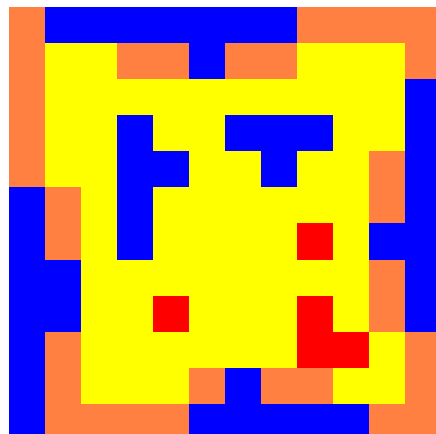
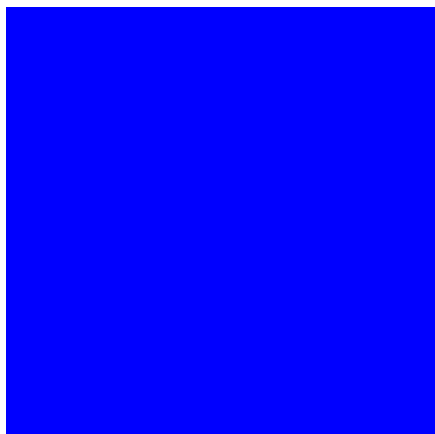
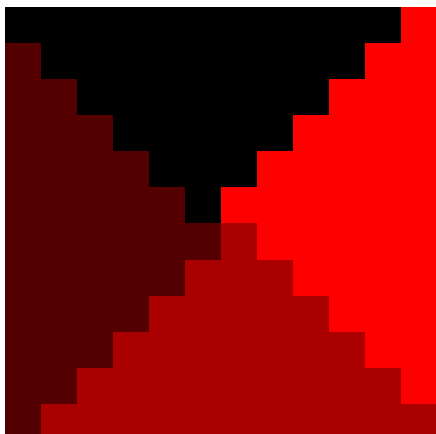
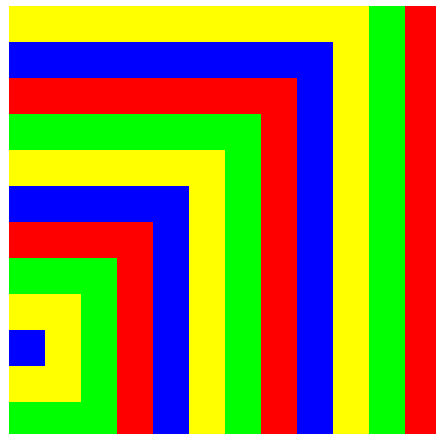


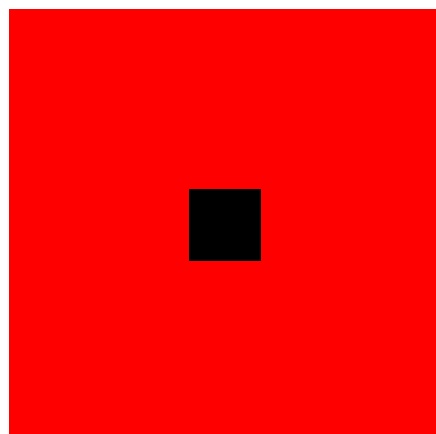
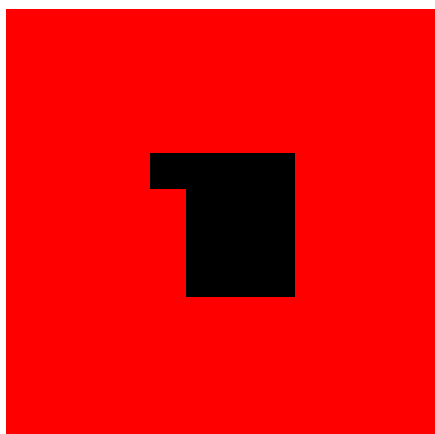
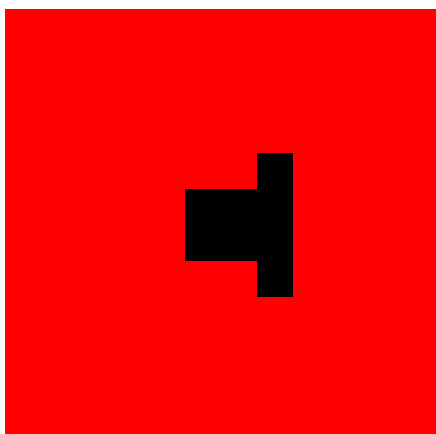
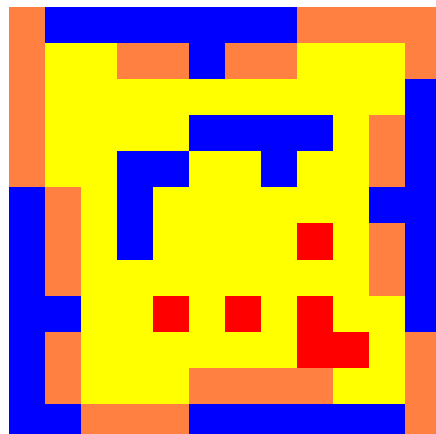
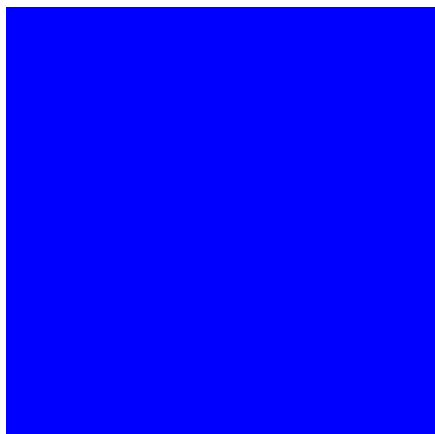
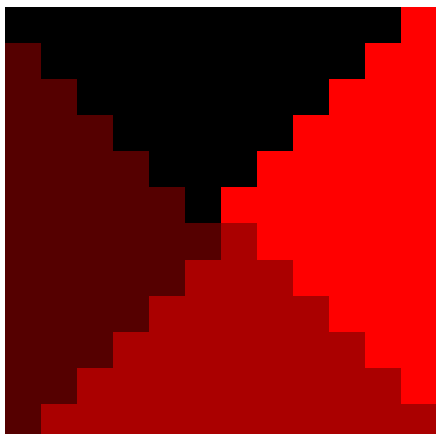
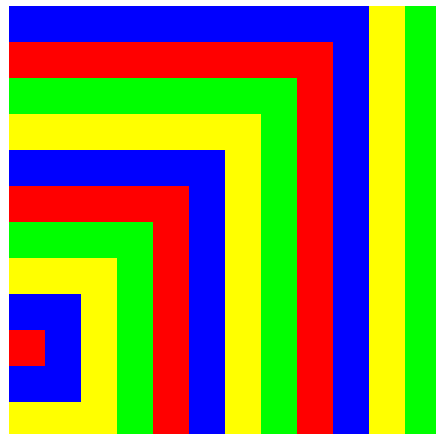


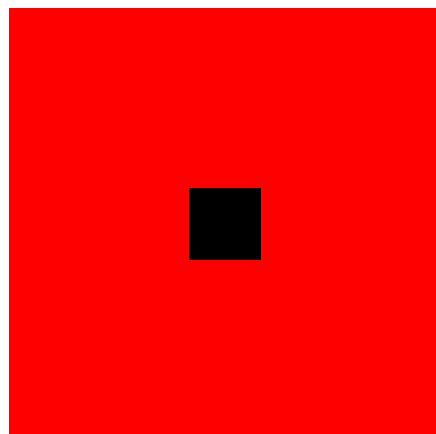
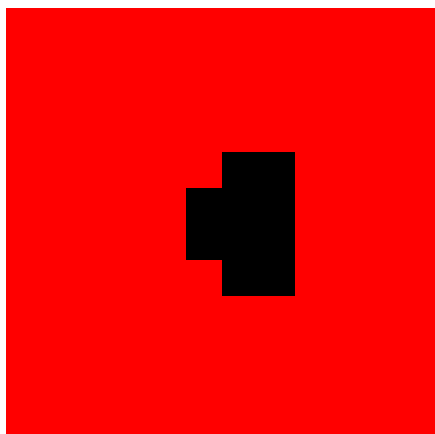
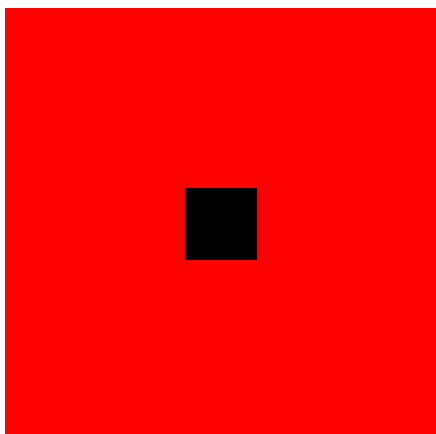
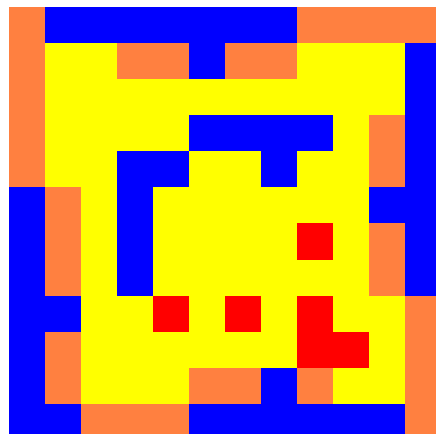
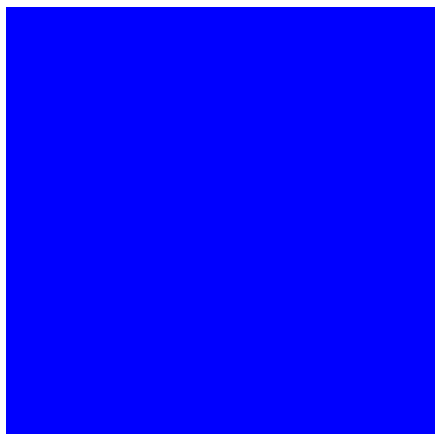
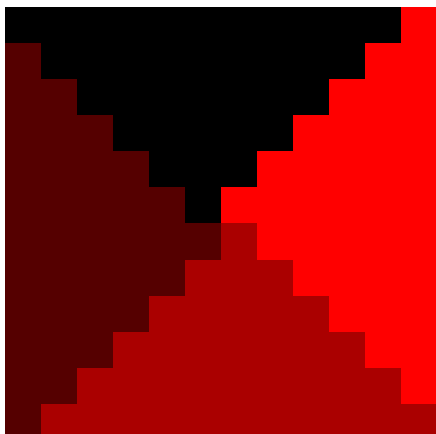
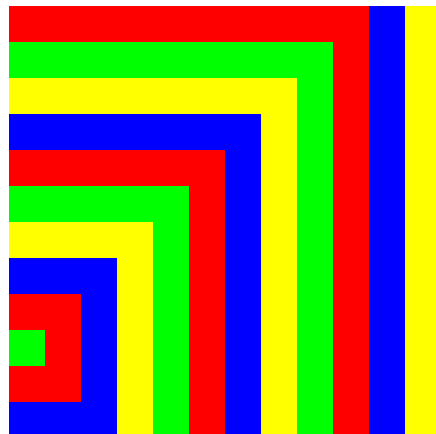
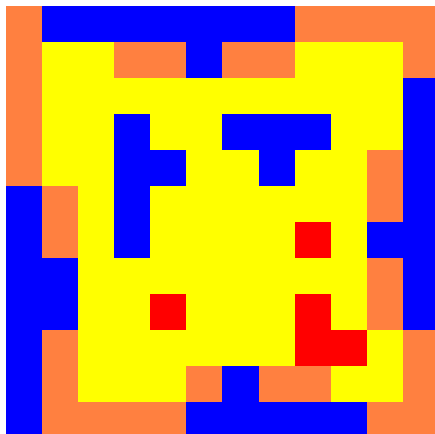


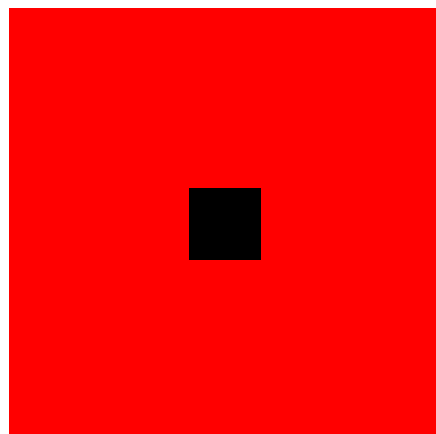
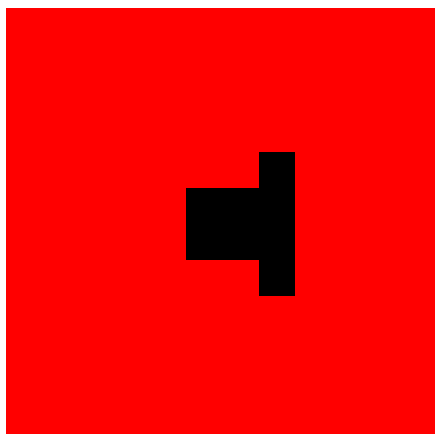
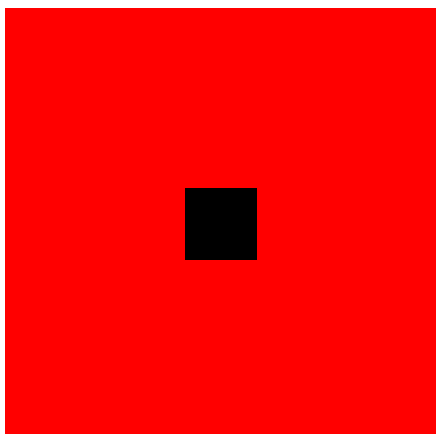
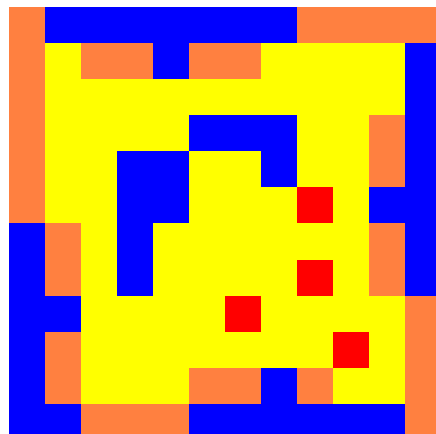
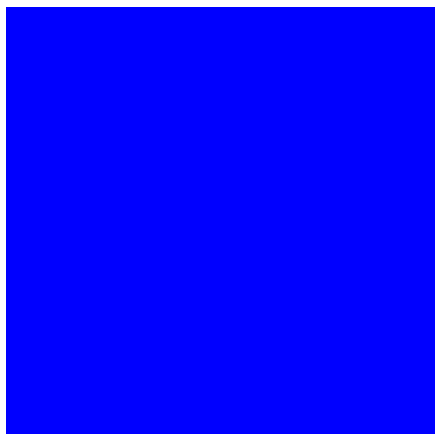
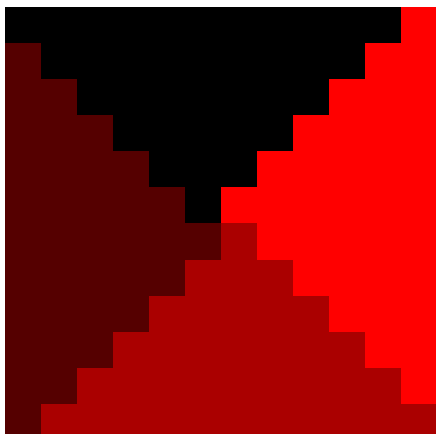
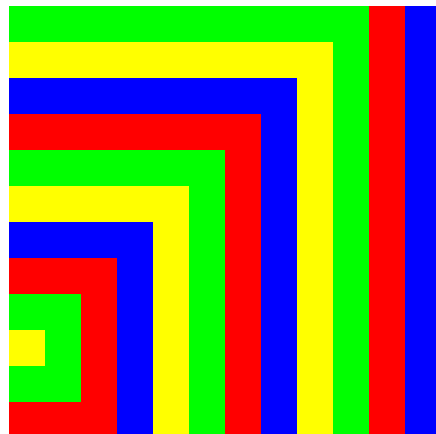
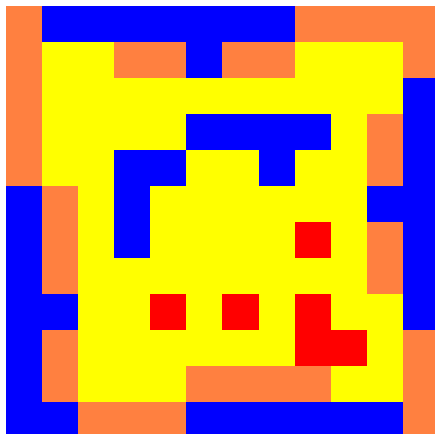


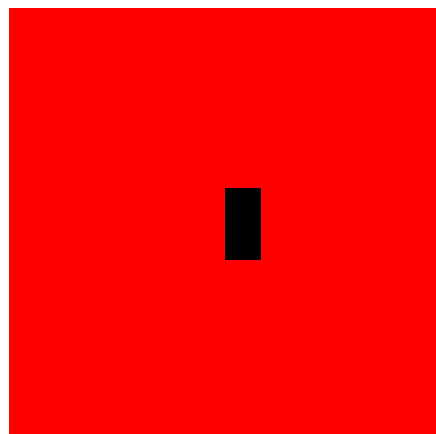
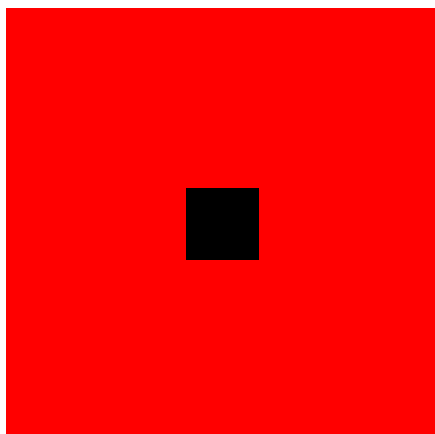
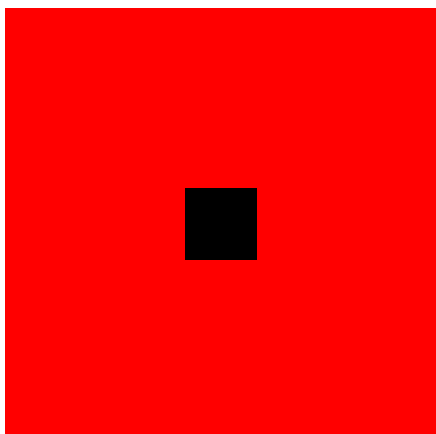
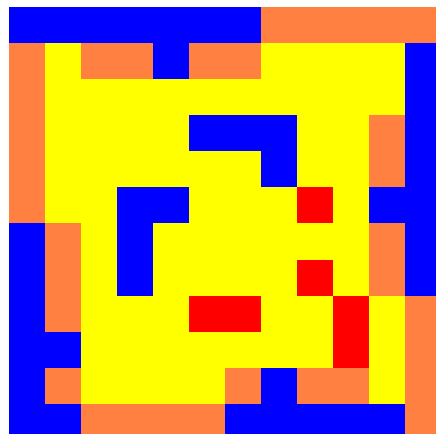
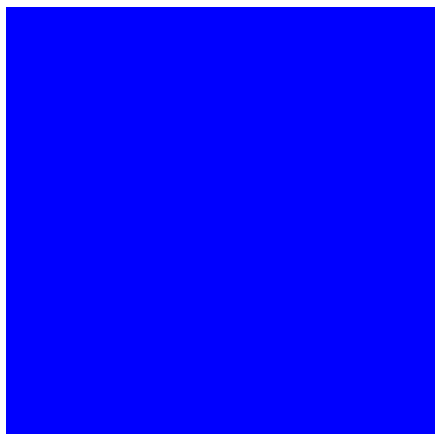
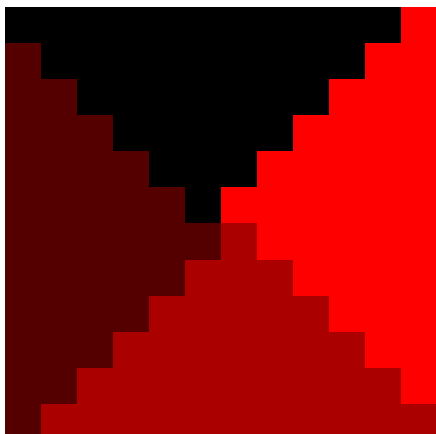
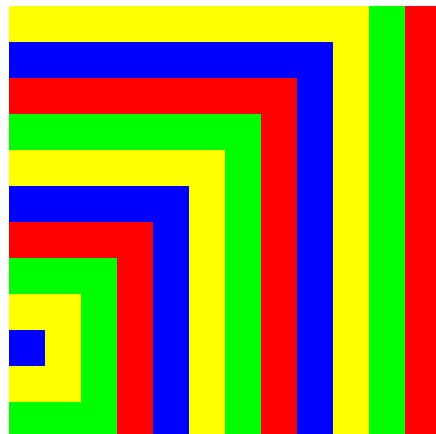
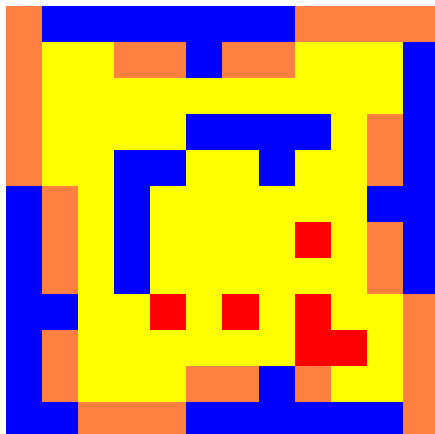


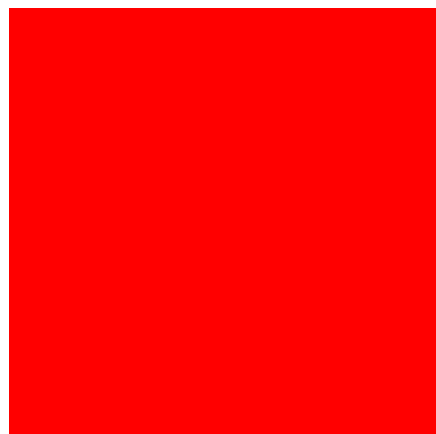
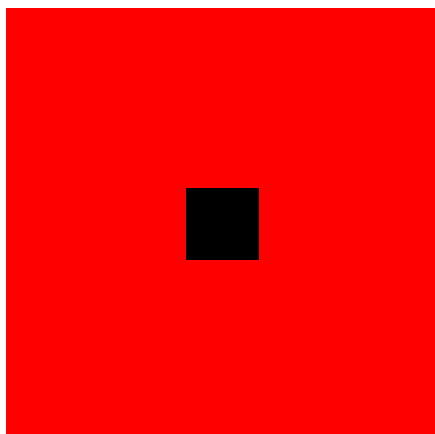
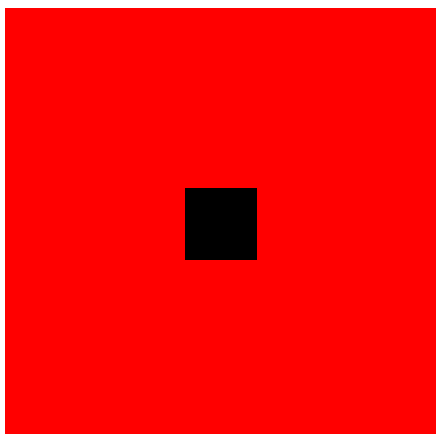
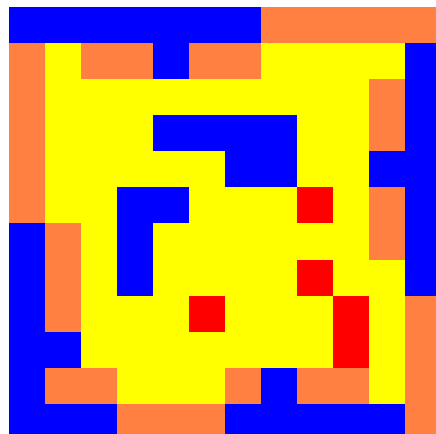
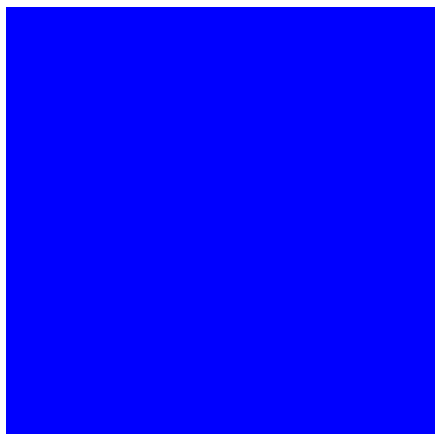
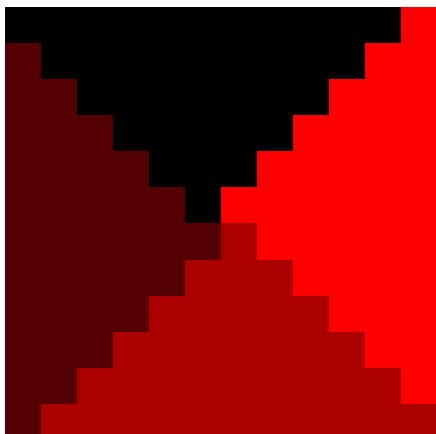
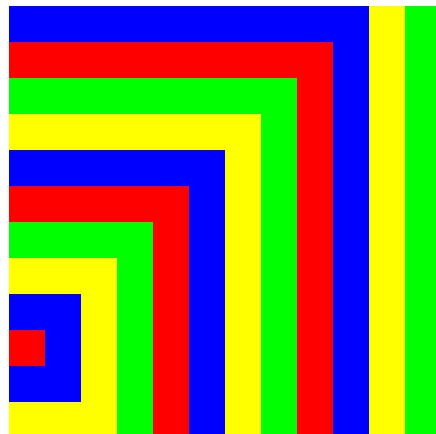
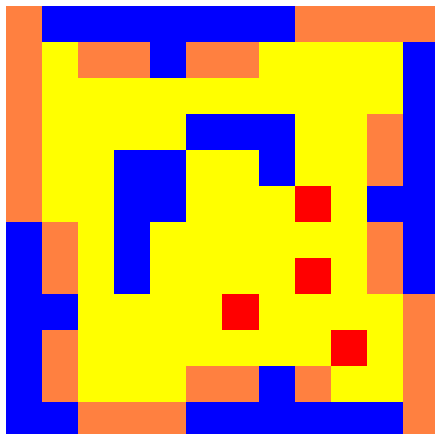
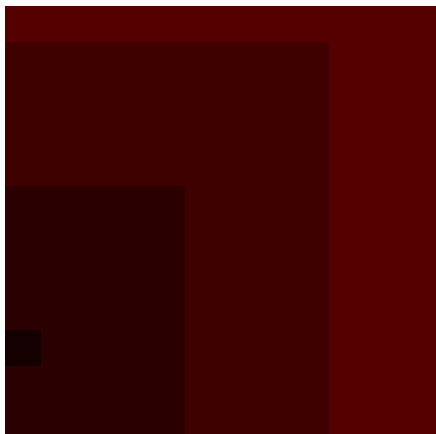


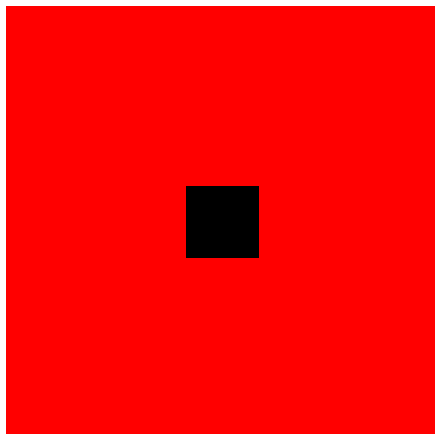
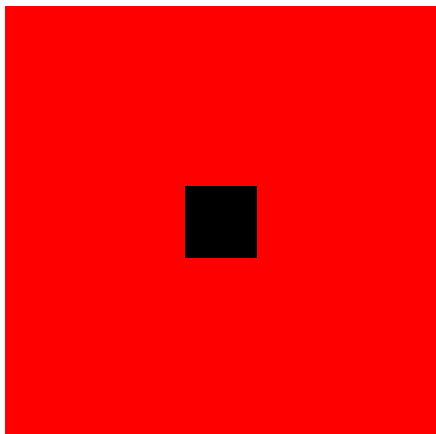
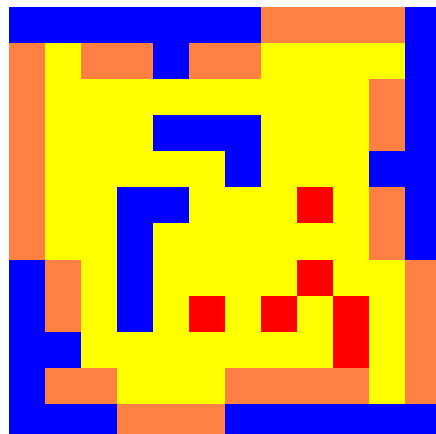
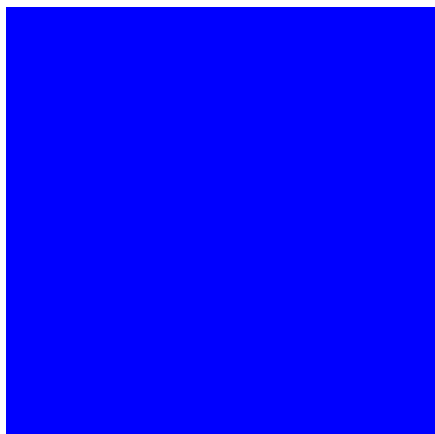
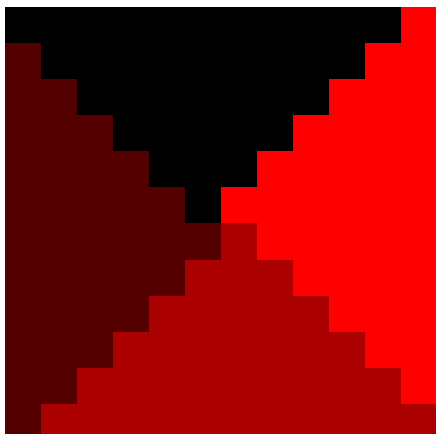
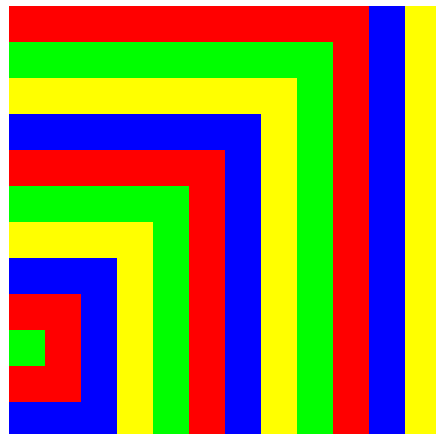
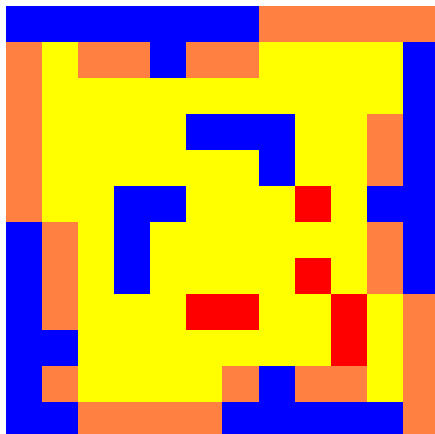
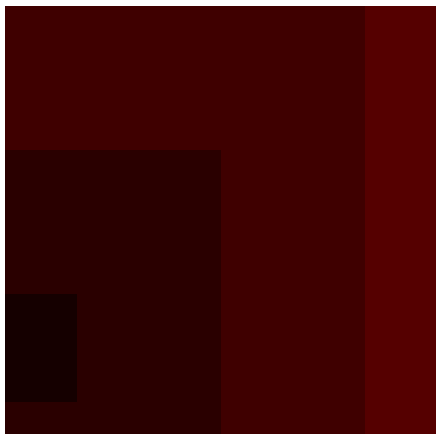


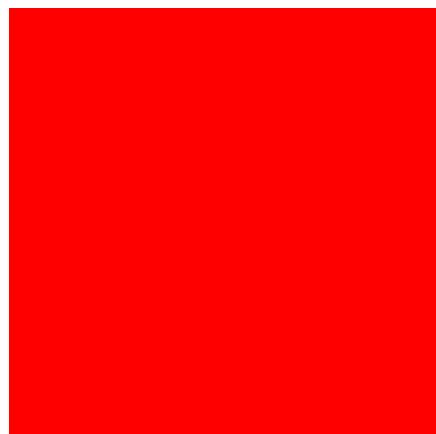
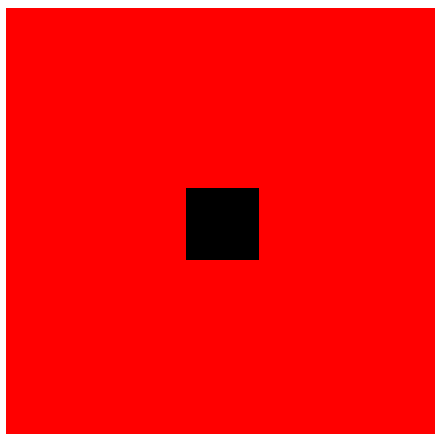
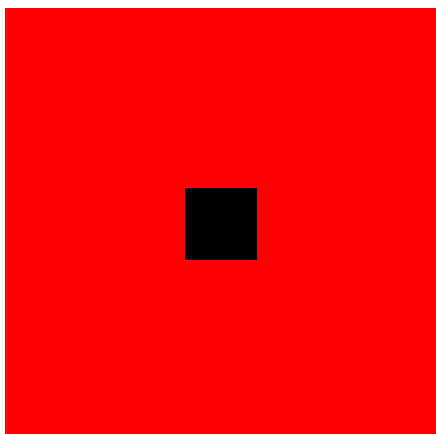
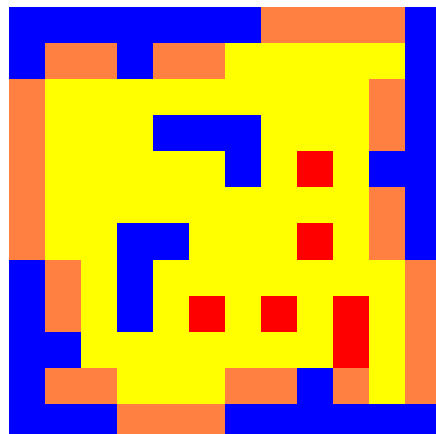
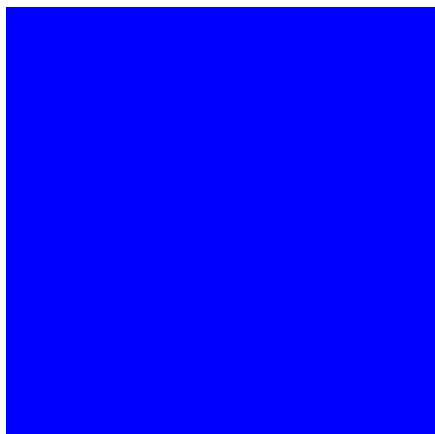
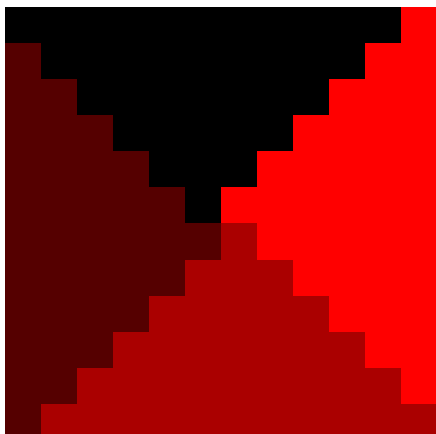
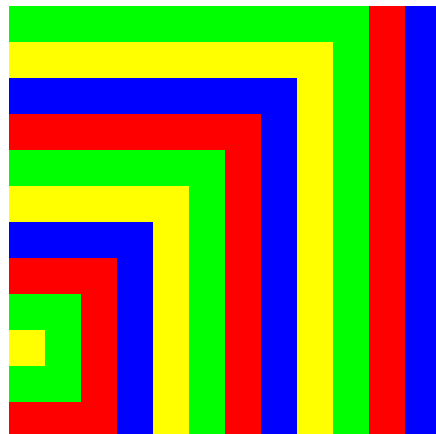
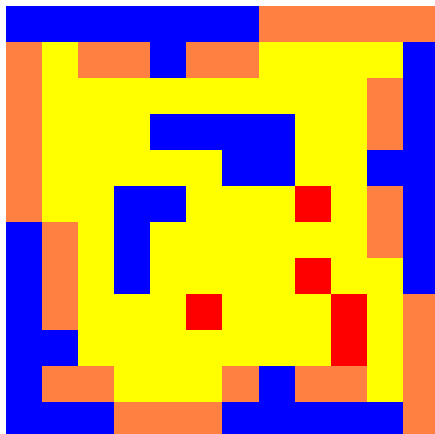


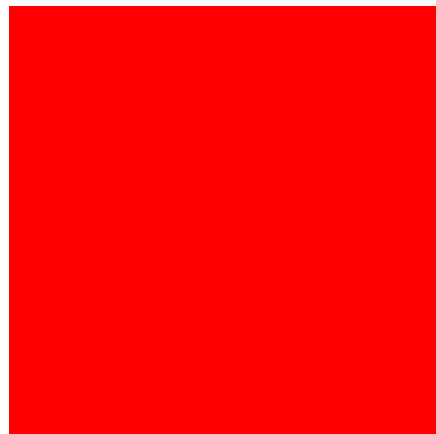
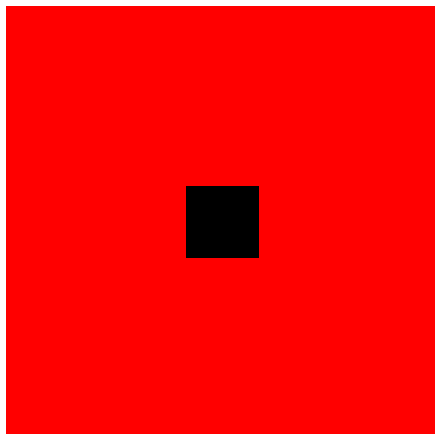
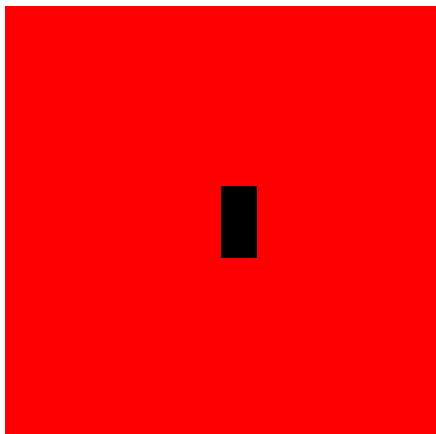
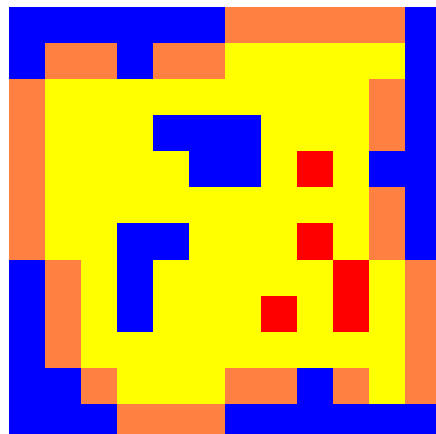
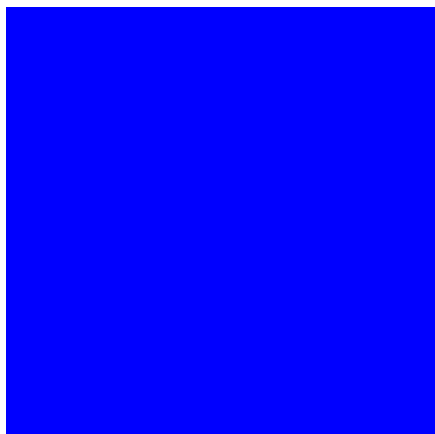
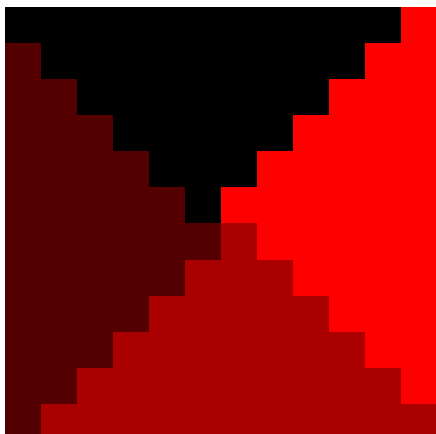
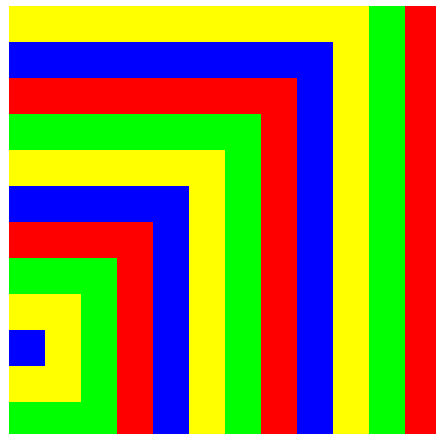
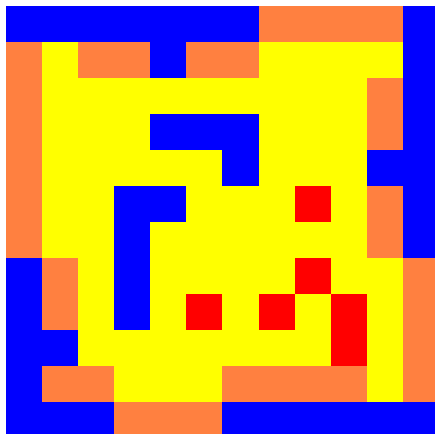
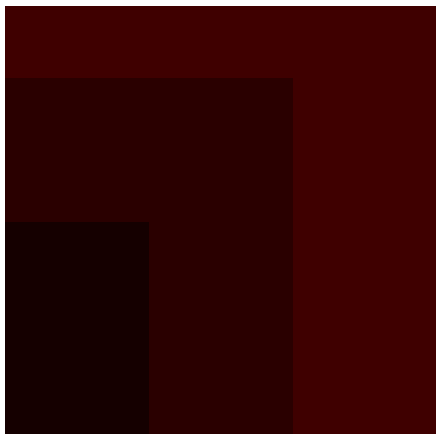


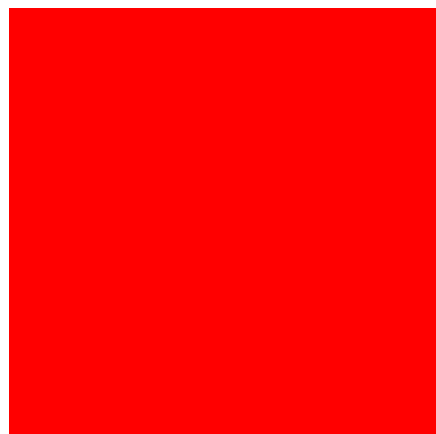
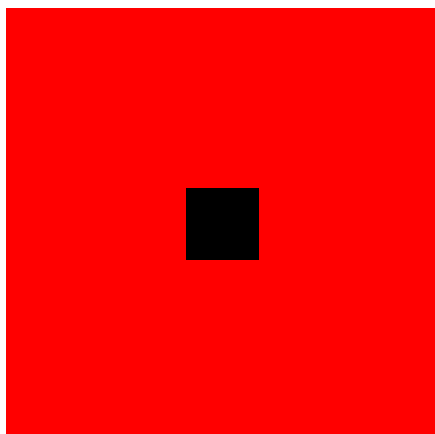
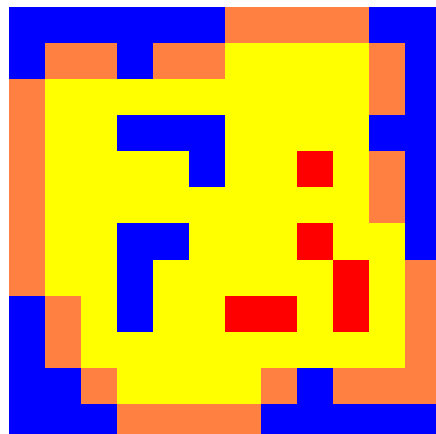
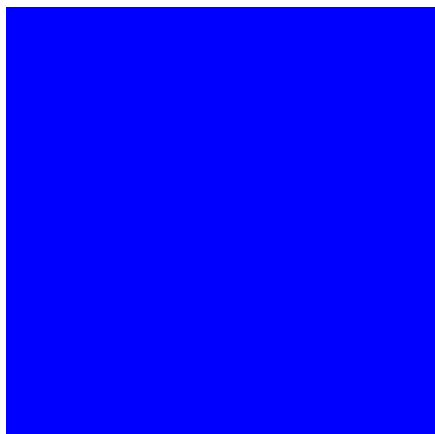
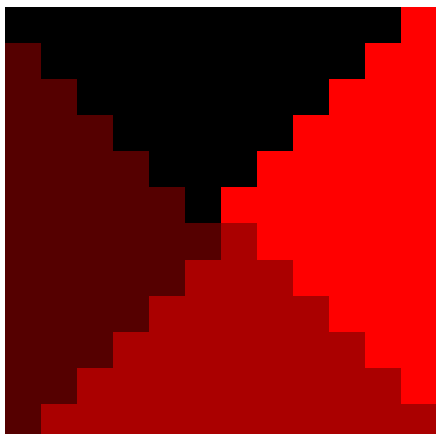
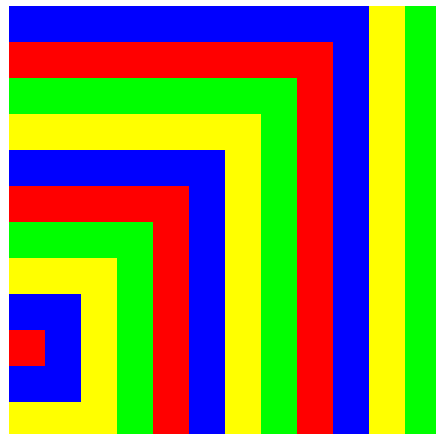
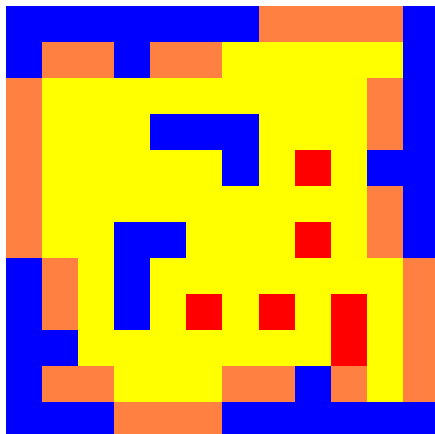
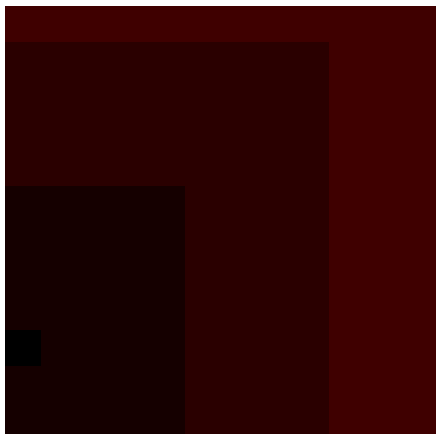


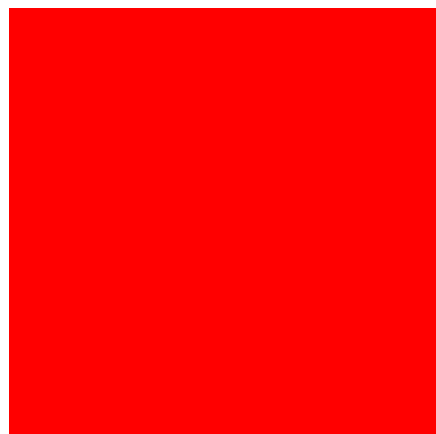
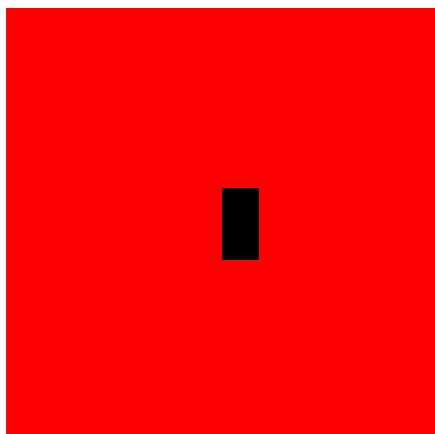
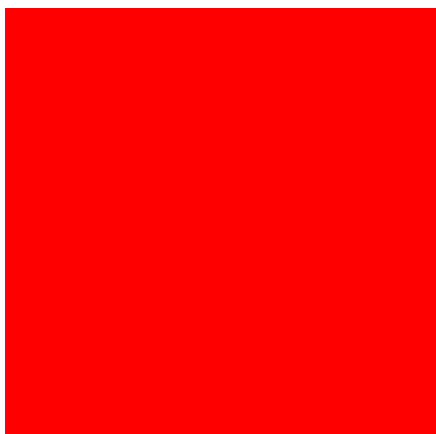
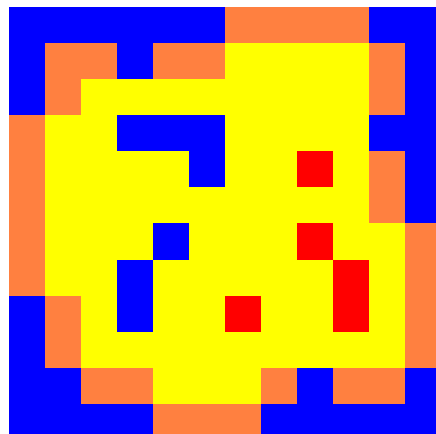
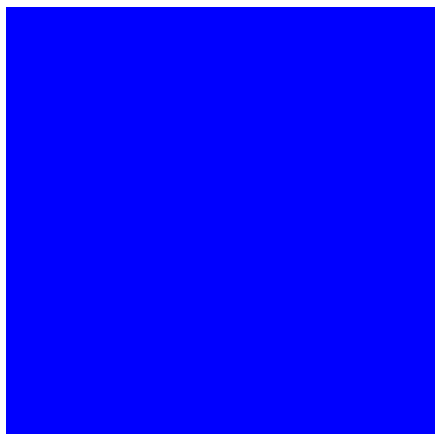
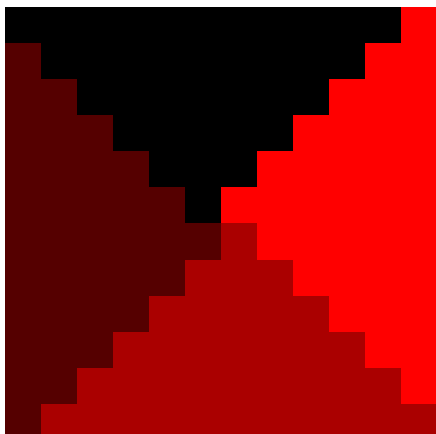
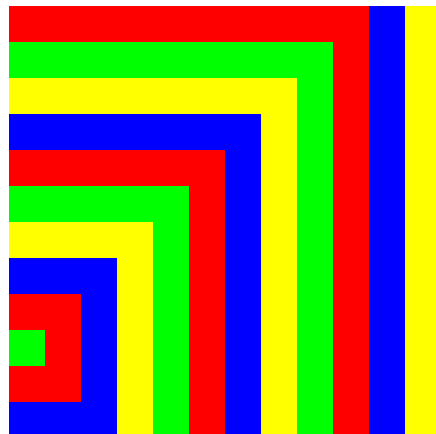
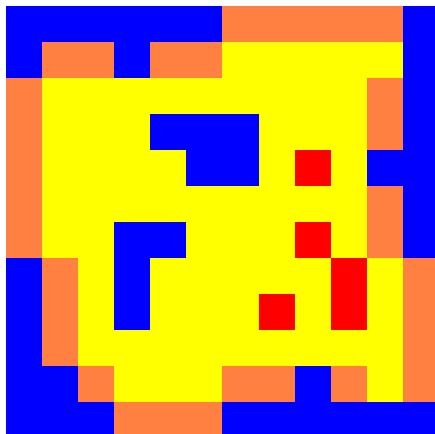
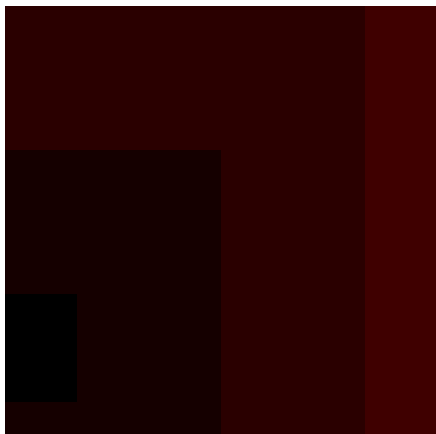


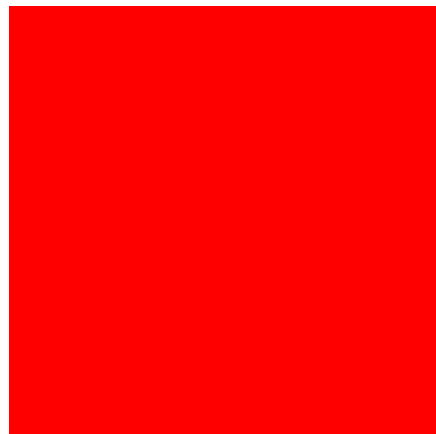
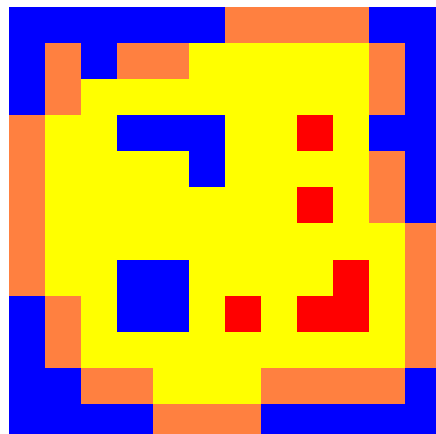
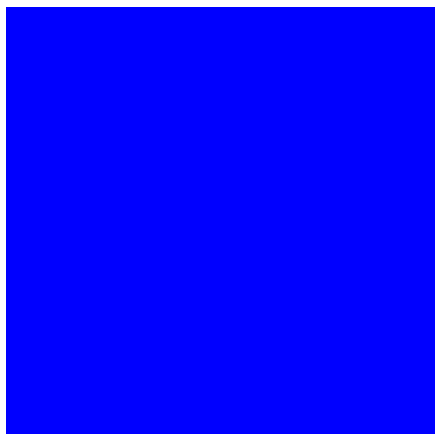
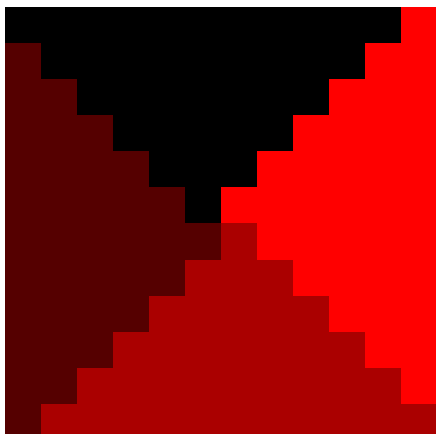
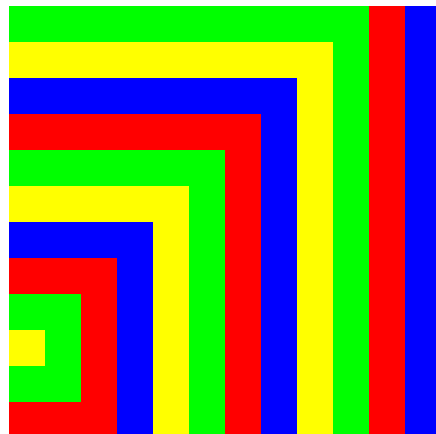
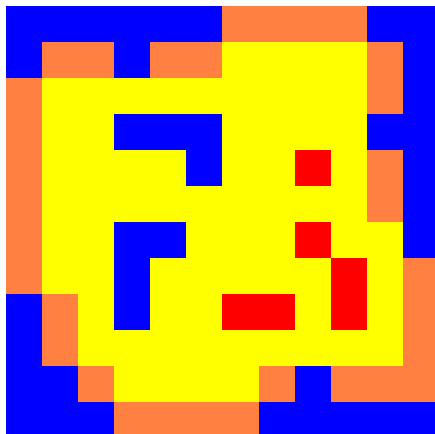
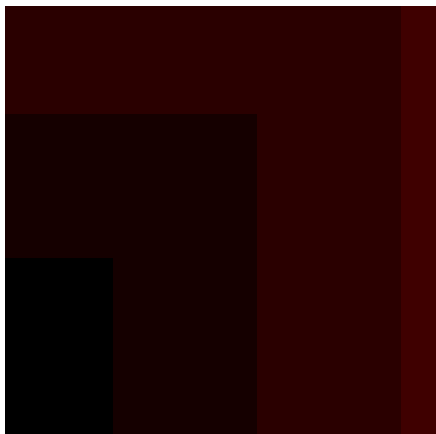


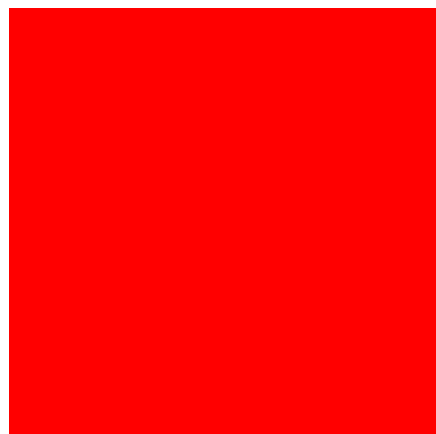
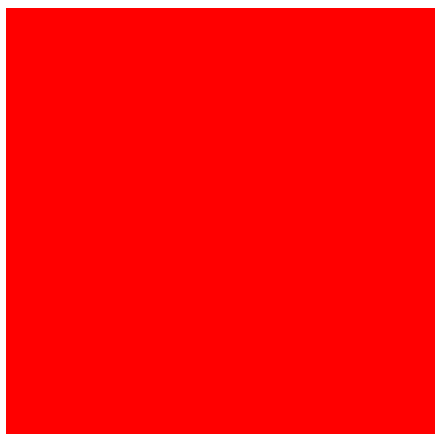
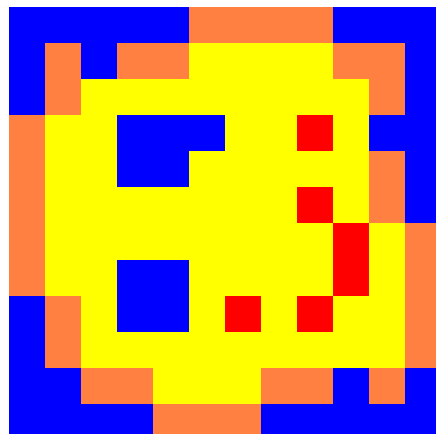
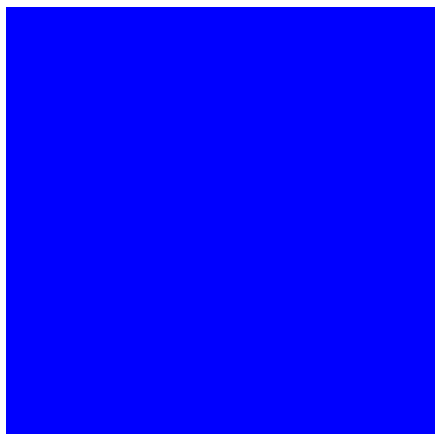
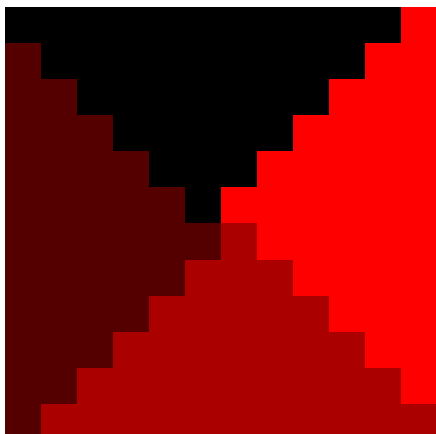
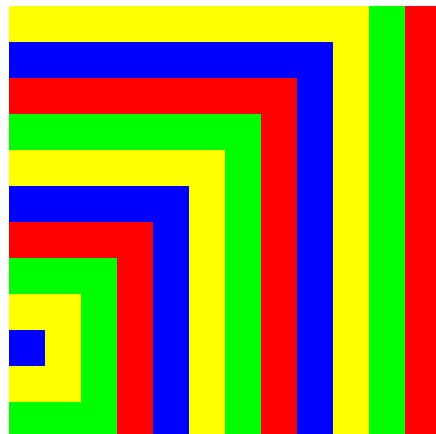
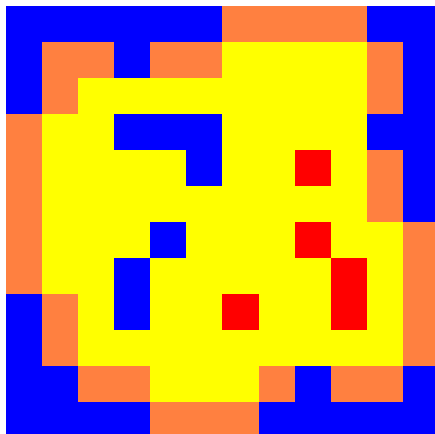
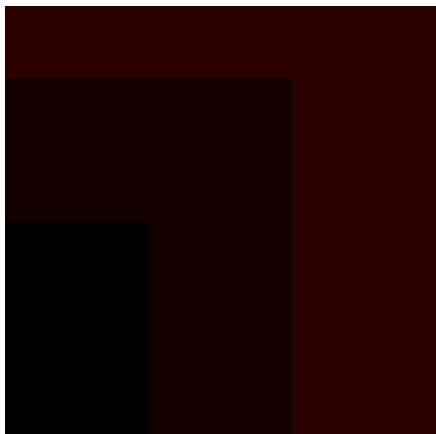


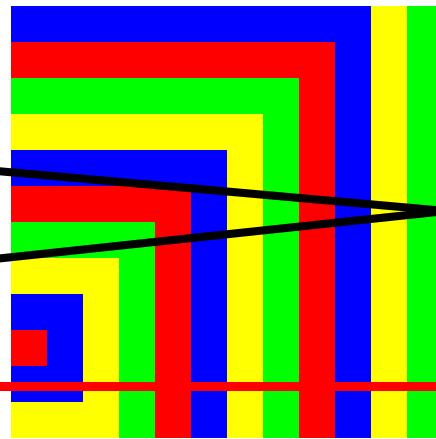
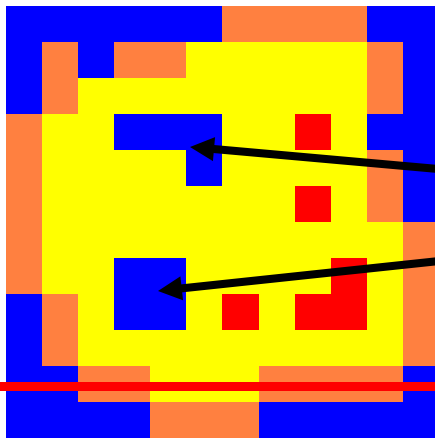
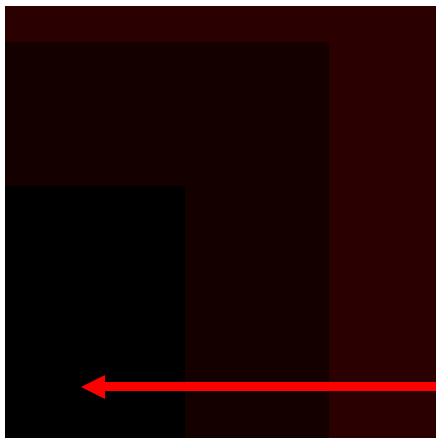






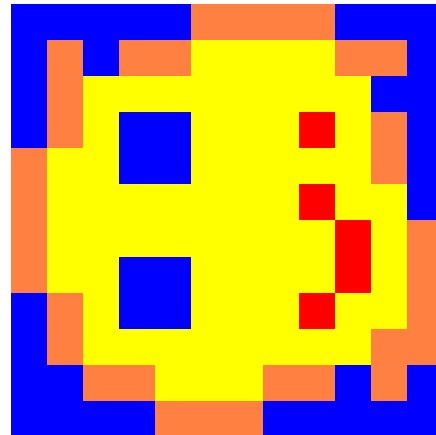
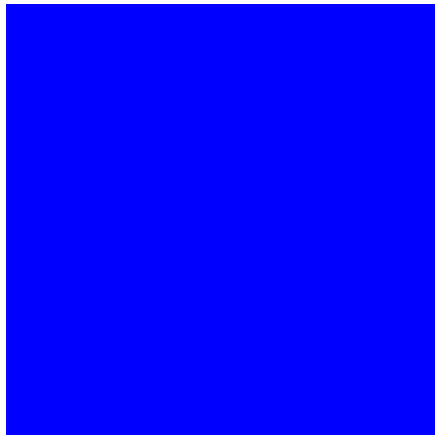
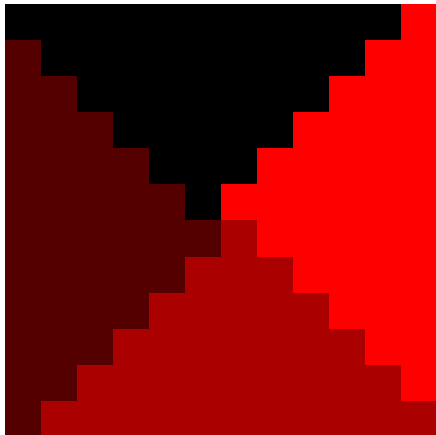


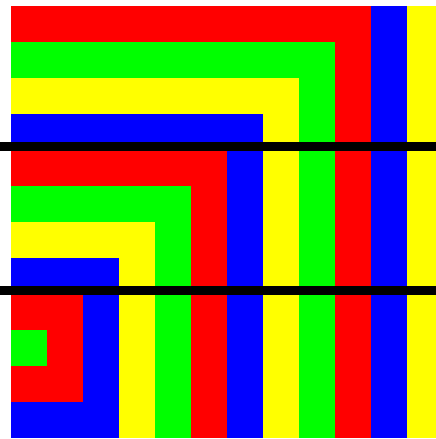
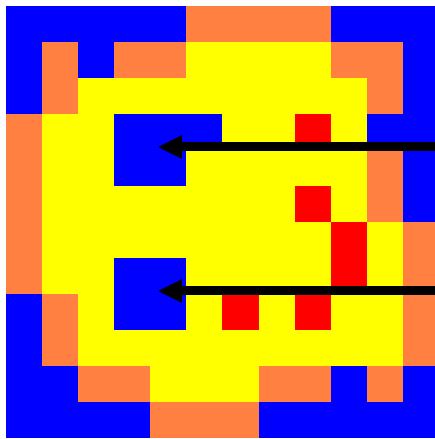
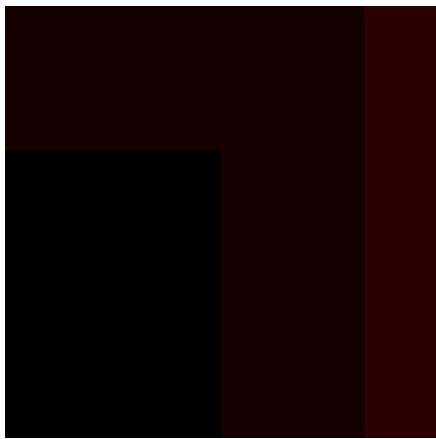




Regardez les yeux...

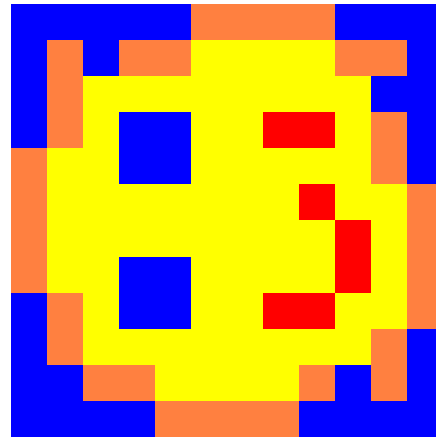
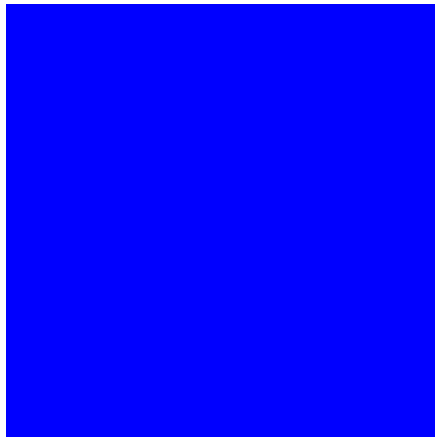
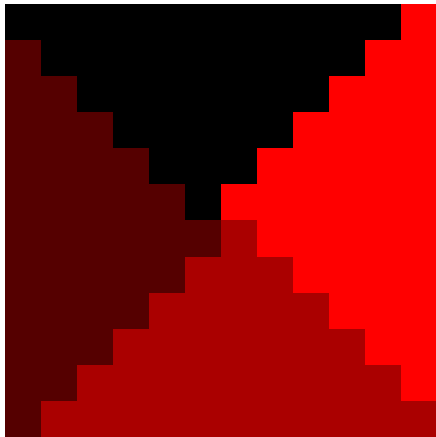
Le compte est nulle.
Bloque la permutation
des couleurs

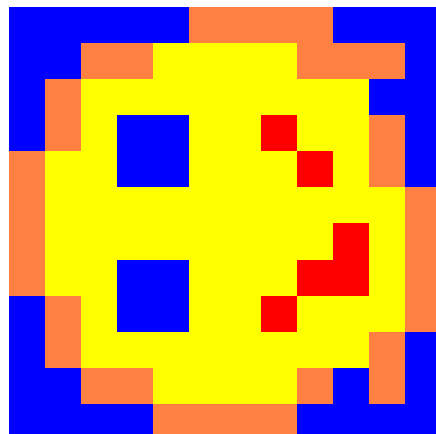
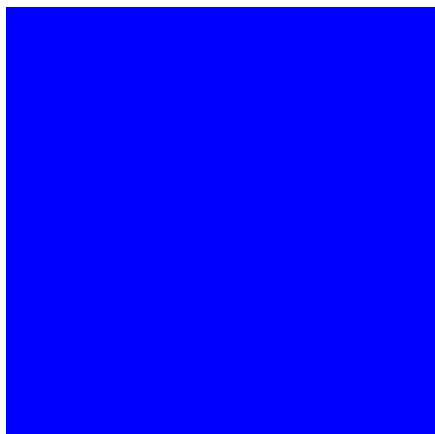
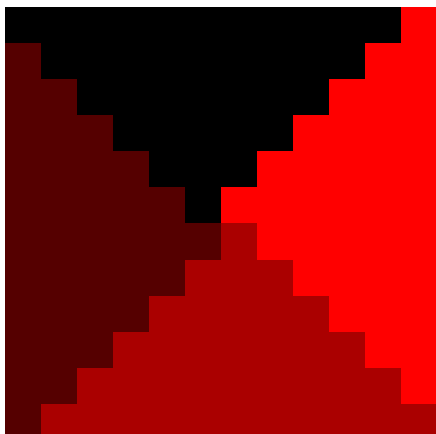
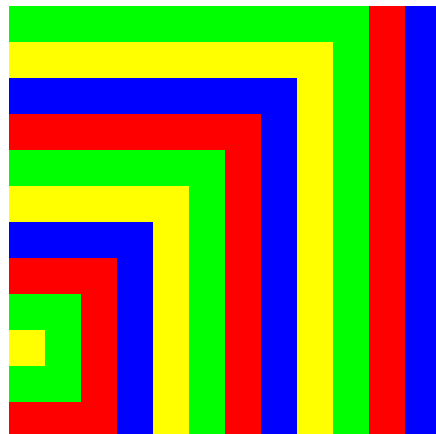
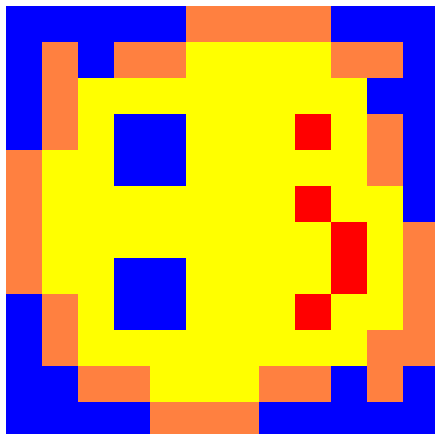


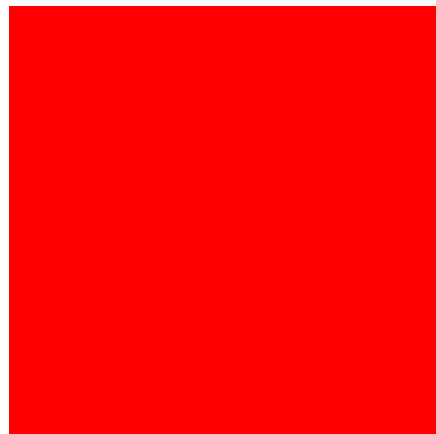
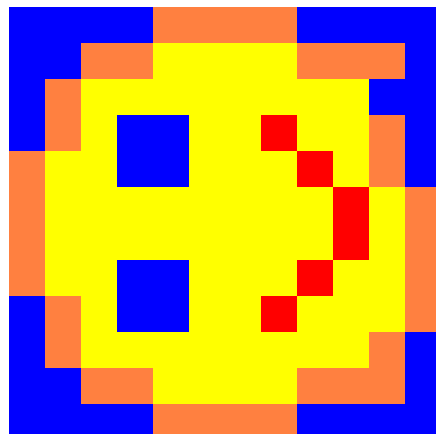
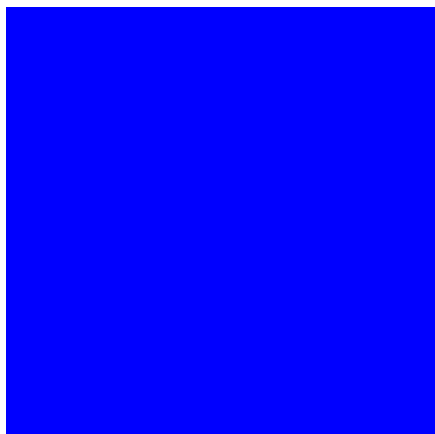
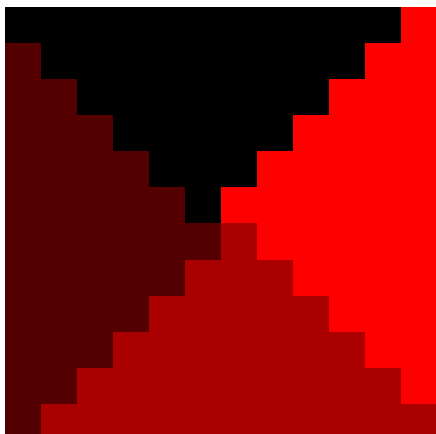
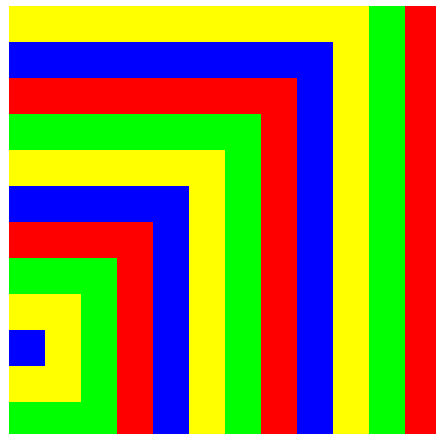
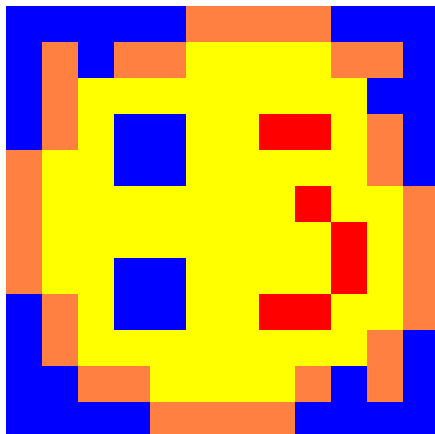
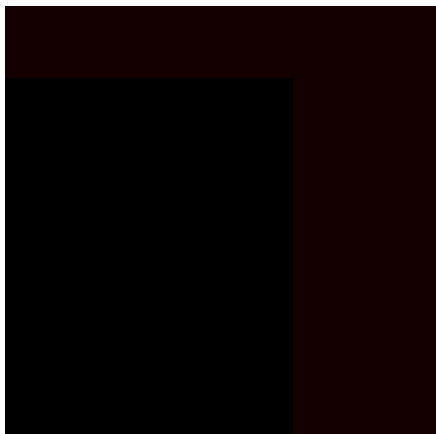


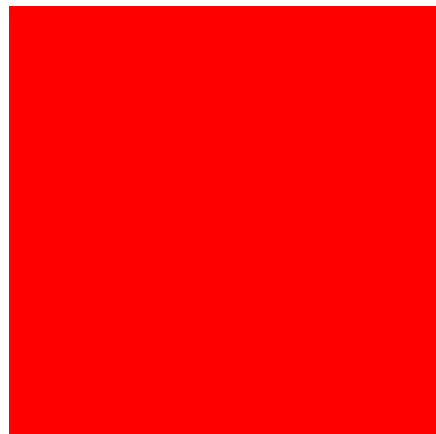
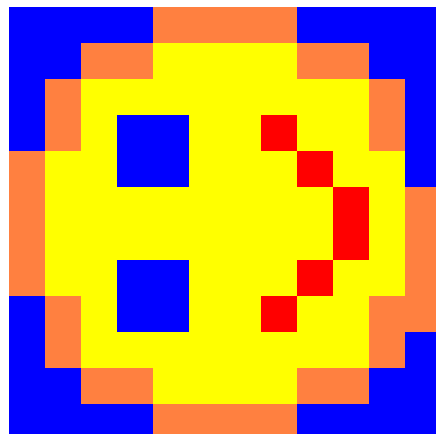
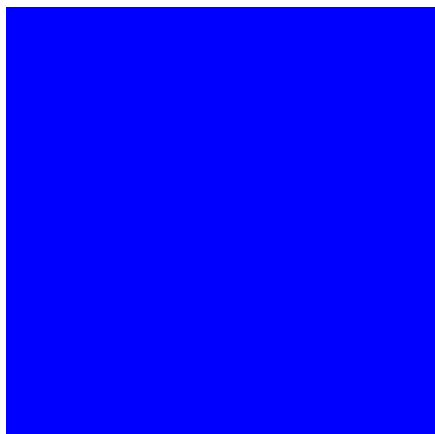
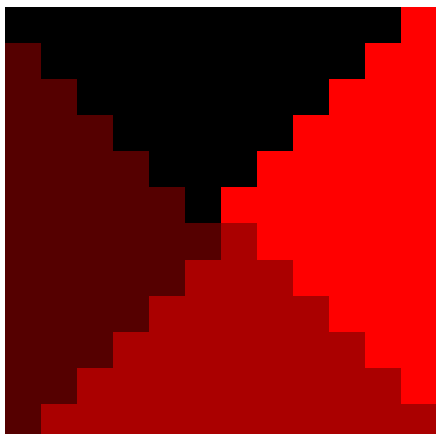
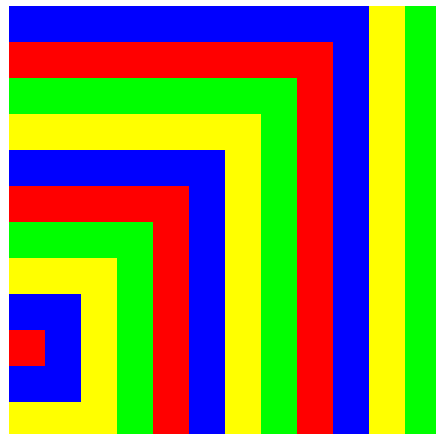
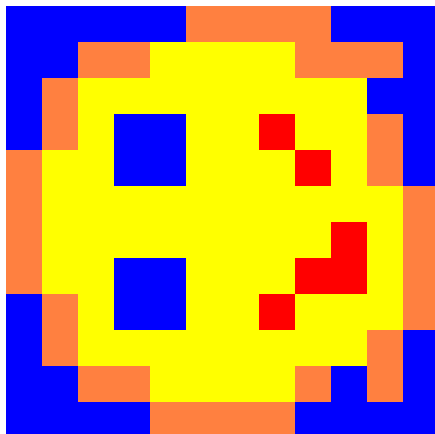
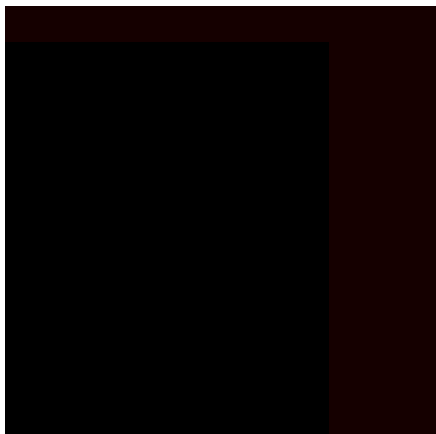
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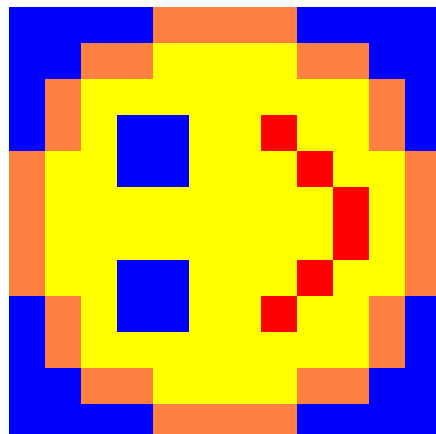
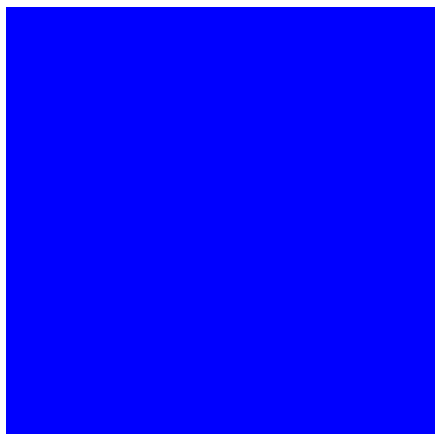
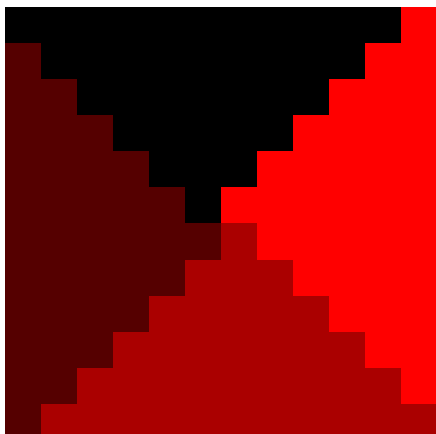
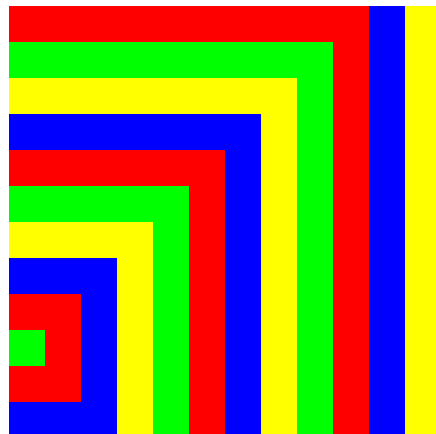
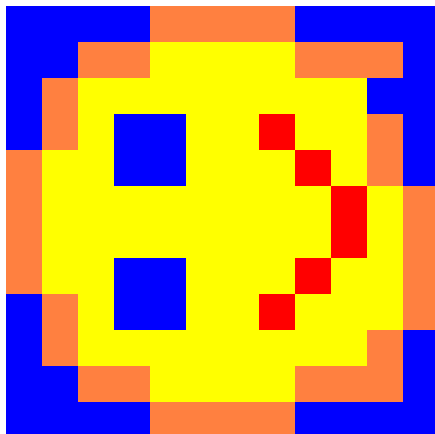
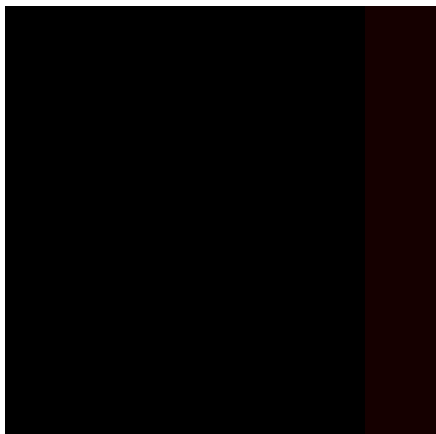
Exécution bloquée

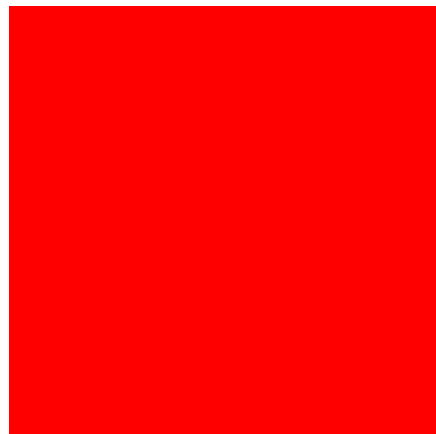
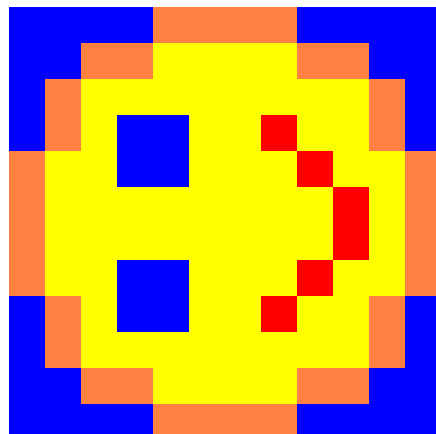
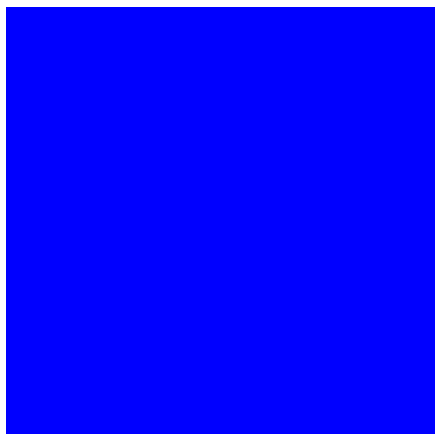
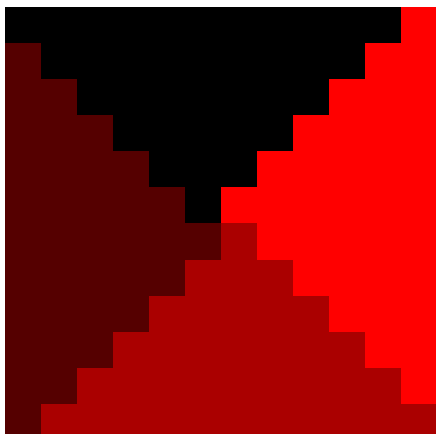
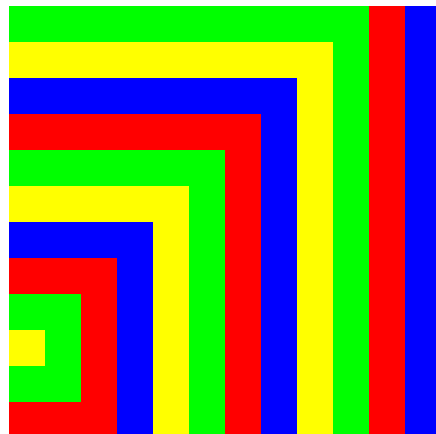
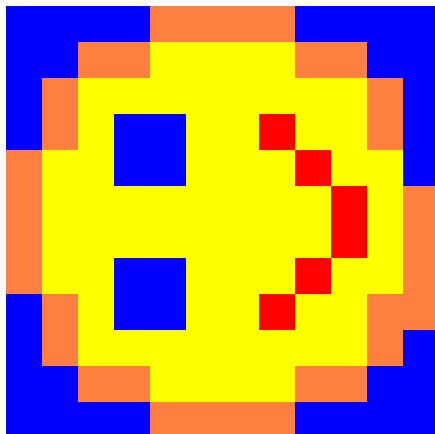
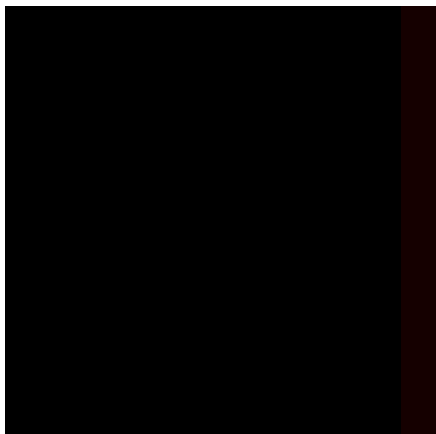


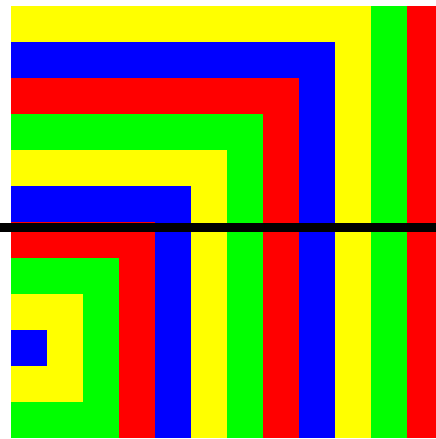
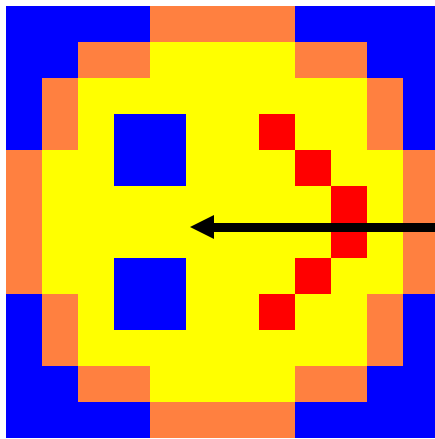
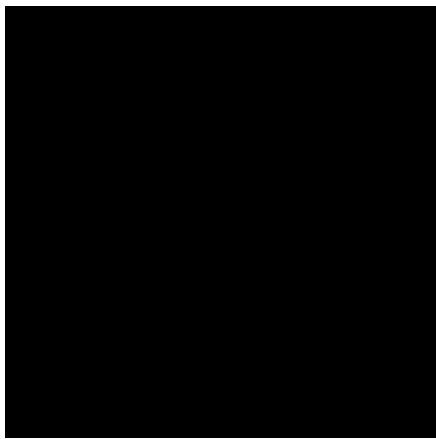




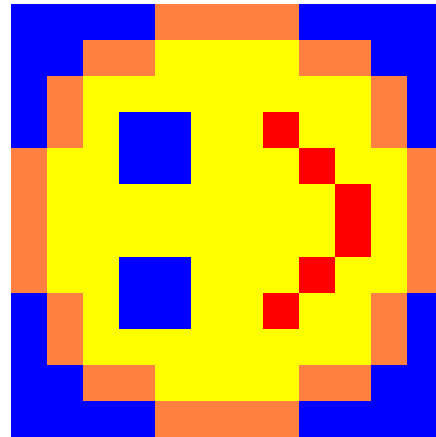
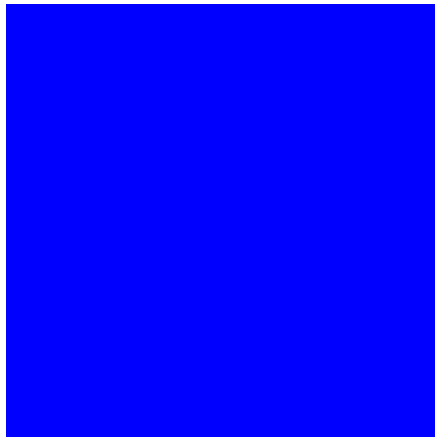


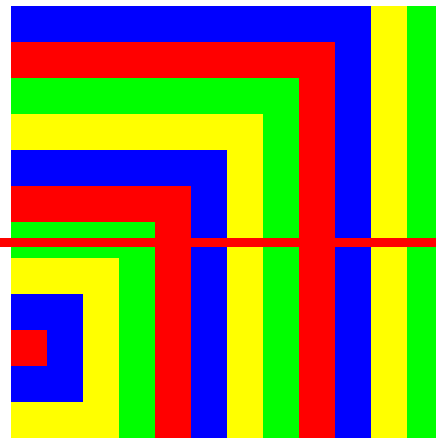
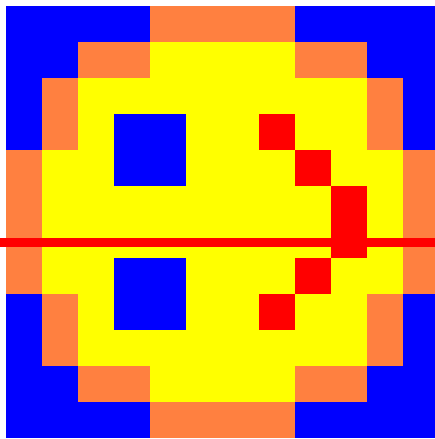
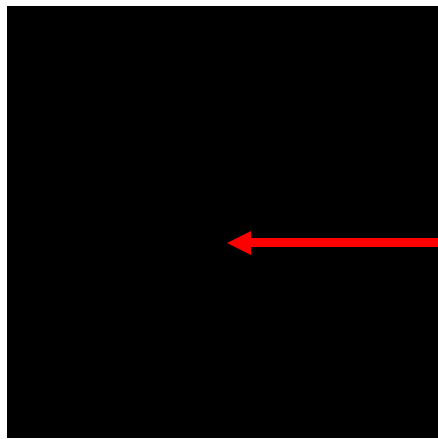






Résultat final





Tout est bloqué

