Summary of cell grammar for PhysiCell (signals and behaviors)

Key words:

- cell type: refers to a specific cell type (cell definition) previously defined in PhysiCell
- substrate: refers to a specific substrate previously defined in Physicell

Signals:

0 : substrate
1 : intracellular substrate
2 : substrate gradient
3 : pressure
4 : volume
5 : contact with cell type
6 : contact with live cell
7 : contact with dead cell
8 : contact with apoptotic cell
9 : contact with necrotic cell
10 : contact with other dead cell
11 : contact with basement membrane
12 : damage
13 : damage delivered
14 : attacking
15 : dead
16 : total attack time
17 : time
18 : custom:sample
19 : apoptotic
20 : necrotic

Behaviors:

0 : substrate secretion
1 : substrate secretion target
2 : substrate uptake
3 : substrate export
4 : cycle entry
5 : exit from cycle phase 1
6 : exit from cycle phase 2
7 : exit from cycle phase 3
8 : exit from cycle phase 4
9 : exit from cycle phase 5
10 : apoptosis
11 : necrosis

12 : migration speed
13 : migration bias
14 : migration persistence time
15 : chemotactic response to substrate
16 : cell-cell adhesion
17 : cell-cell adhesion elastic constant
18 : adhesive affinity to cell type
19 : relative maximum adhesion distance
20 : cell-cell repulsion
21 : cell-BM adhesion
22 : cell-BM repulsion
23 : phagocytose apoptotic cell
24 : phagocytose necrotic cell
25 : phagocytose other dead cell
26 : phagocytose cell type
27 : attack cell type
28 : fuse to cell type
29 : transition to cell type
30 : asymmetric division to cell type
31 : custom:sample
32 : is_movable
33 : immunogenicity to cell type
34 : cell attachment rate
35 : cell detachment rate
36 : maximum number of cell attachments
37 : attack damage rate
38 : attack duration
39 : damage rate
40 : damage repair rate

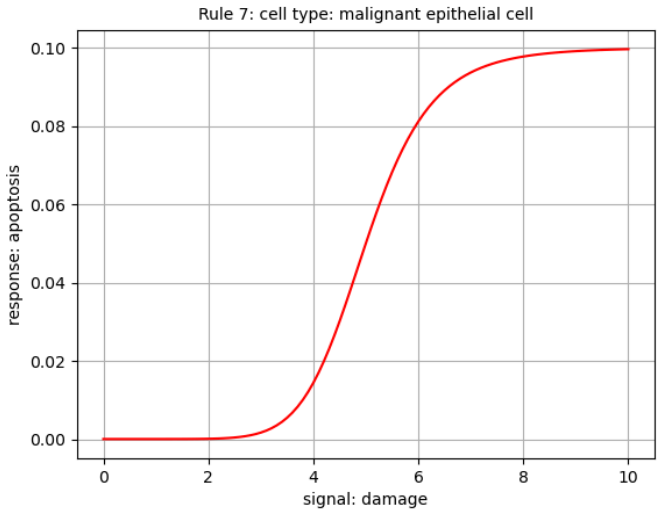
Fundamental structure of the cell grammar:

Cell type | Signal | increases/decreases (also called Direction) | Behavior | Saturation Value | Half-max | Hill power | Apply to dead (Boolean Flag)

Examples:

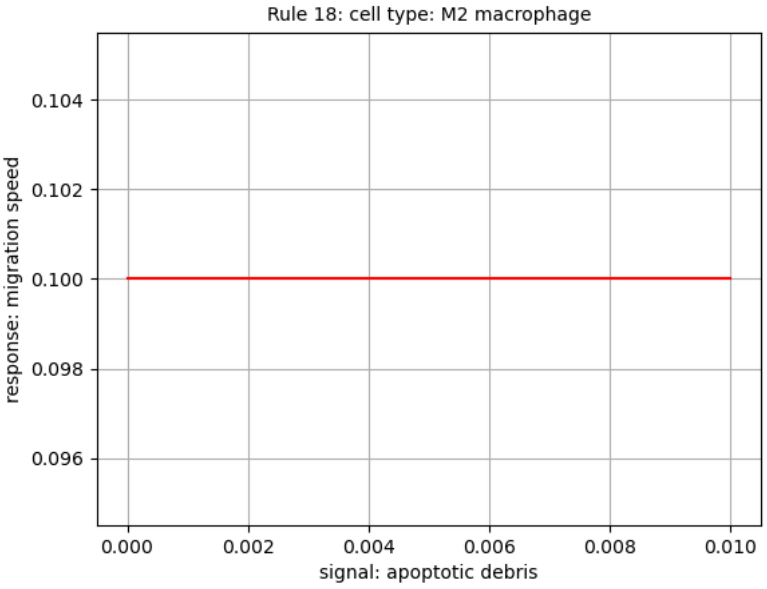
1) standard rule implementation

malignant epithelial cell | damage | increases | apoptosis | 0.1 | 5 | 8 | 0



2) English style rule implementation

In M2 macrophage *cells:*
apoptotic debris decreases migration speed *from 1 towards* 0.1 *with a Hill response, with half-max* 0.005 *and Hill power* 4*.*
… (more rules below)...



Tumor immune example rule set:

1. tumor,pressure,decreases,cycle entry,0,0.25,3,0
2. tumor,oxygen,increases,cycle entry,0.0072,21.5,4,0
3. tumor,oxygen,decreases,necrosis,0,3.75,8,0
4. tumor,damage,increases,apoptosis,0.023,45,16,0
5. tumor,dead,increases,debris secretion,0.017,0.1,10,1
6. M0 macrophage,contact with dead cell,decreases,migration speed,0.1,0.1,4,0
7. M0 macrophage,contact with dead cell,increases,transform to M1 macrophage,0.05,0.1,10,0
8. M0 macrophage,dead,increases,debris secretion,0.017,0.1,10,1
9. M1 macrophage,contact with dead cell,decreases,migration speed,0.1,0.1,4,0
10. M1 macrophage,oxygen,decreases,transform to M2 macrophage,0,5,4,0
11. M1 macrophage,dead,increases,debris secretion,0.017,0.1,10,1
12. M2 macrophage,contact with dead cell,decreases,migration speed,0.1,0.1,4,0
13. M2 macrophage,dead,increases,debris secretion,0.017,0.1,10,1
14. naive T cell,IL-10,decreases,transform to CD8 T cell,0,0.25,2,0
15. naive T cell,IFN-gamma,increases,transform to CD8 T cell,0.01,0.25,2,0
16. naive T cell,dead,increases,debris secretion,0.017,0.1,10,1
17. CD8 T cell,IL-10,decreases,attack tumor,0,0.25,2,0
18. CD8 T cell,IL-10,decreases,migration speed,0.1,0.25,2,0
19. CD8 T cell,contact with tumor,decreases,migration speed,0.1,0.1,2,0
20. CD8 T cell,IFN-gamma,increases,cycle entry,0.00041,0.25,2,0
21. CD8 T cell,IL-10,increases,transform to exhausted T cell,0.005,0.25,4,0
22. CD8 T cell,dead,increases,debris secretion,0.017,0.1,10,1
23. exhausted T cell,dead,increases,debris secretion,0.017,0.1,10,1

Cell types:

1. tumor
2. M0 macrophage
3. M1 macrophage
4. M2 macrophage
5. naive T cell
6. CD8 T cell
7. exhausted T cell

Substrates:

1. oxygen
2. debris
3. IFN-gamma
4. IL-10