Model Equations

1 Virus (V)

$$\frac{dV}{dT} = \alpha_v \cdot I - f_{Vint} k_{int}(AT2) \cdot V \cdot \left(1 - k_{int\_IFN_\beta} \frac{(IFN_\beta)}{km_{int\_IFN_\beta} + (IFN_\beta)}\right) - k_{V\_phago} \cdot V \cdot (DC + M1) - \beta_V \cdot V$$

The virus is infects healthy type II alveolar cells $(AT2)$ and is productively shed by these infected cells I. Type I Interferon $(IFN\beta)$ inihibits the formation of infected cells through an indirect response model. The virus is can also be phagocytosed by dendritic cells (DC) and macrophages $(M1)$ and is undergoes non-specific clearance at a rate β_V.

2 Healthy Alveolar Type 2 Cell $(AT2)$

$$\frac{dAT2}{dT} = \mu_{AT2}(AT2) - k_{int}(AT2) \cdot V \cdot \left(1 - k_{int[IFN_\beta)} \frac{(IFN_\beta)}{km_{int\_IFN_\beta} + (IFN_\beta)}\right) - \beta_{AT2}(AT2) - k_{ROS\_damage}(AT2) - k_{cyt\_damage}(AT2)$$

$$\mu_{AT2} = \mu_{basal_{[AT2)}} \left(1 + k_\mu \frac{\delta AT}{km_\mu + \delta AT}\right)$$

$$\delta AT2 = AT1_{basal} + AT2_{basal} - (AT1 + AT2)$$

$$k_{cyt\_damage} = k_{damage} \left[\left(\frac{k_{damage\_TNF}(TNF)}{km_{damage\_TNF} + (TNF)} \right) + \frac{k_{damage\_IL6}(IL6)}{km_{damage\_IL6} + (IL6)} + \frac{k_{damage\_IL1\beta}(IL1\beta)}{km_{damage\_IL1\beta} + (IL1\beta)} + \frac{k_{damage\_IFN\gamma}(IFN\gamma)}{km_{damage\_IFN\gamma} + (IFN\gamma)} \right]$$

$$k_{ROS\_damage} = k_{ROS\_N} \left(\frac{N}{km_{ROS\_N} + N} \right)$$

$(AT2)$ cells are depleted due to infection by virus, apoptotic damage by (ROS) secreted by neutrophils (N) and damage due to proinflammatory cytokines at a rate k_{cyt_damage}. $(AT2)$ cells are additionally formed at a rate μ_{AT2} that is dependent on the extent of $(AT2)$ depletion and cleared with a death rate of β_{AT2}.

3 Infected Alveolar Type 2 Cells (I)

$$\frac{dI}{dT} = k_{int}(AT2) \cdot V \left(1 - k_{int(IFN_\beta)} \frac{(IFN_\beta)}{km_{int\_IFN_\beta} + (IFN_\beta)}\right) - \beta_I \cdot I - k_{kill} \left(1 + \frac{(IFN_\beta)}{km_{kill} + (IFN_\beta)}\right) \cdot I \cdot (CTL) - k_{I\_phago} \cdot I \cdot (DC + M1) - k_{ROS\_damage} \cdot I$$

Infected cells, (I) are formed by infection of $(AT2)$ cells and non-specifically cleared at a rate β_I. Additionally, they are apoptotically cleared by cytotoxic T cells (CTL) and (ROS), and phagocytosed by (DC) and $(M1)$.

4 Healthy Alveolar Type 1 Cells $(AT1)$

$$\frac{dAT1}{dt} = k_{diff\_AT2\_AT1}(AT2) - \beta_{AT1}(AT1) - k_{ROS\_damage}(AT1) - k_{cyt\_damage}(AT1)$$

$$k_{diff\_AT2\_AT1} = k\_basal_{diff\_AT2\_AT1}(1 + k_{\mu}\frac{\delta AT}{km_{\mu} + \delta AT})$$

$$\delta AT = AT1_{basal} + AT2_{basal} - (AT1 + AT2)$$

$(AT1)$ are resistant to infection but can undergo inflammatory cell death mediated by (ROS) and proinflammatory cytokines (k_{cyt_damage}). Additionally, they are formed from differentiation $(AT2)$ cells and undergo non-specific clearance at at a rate β_{AT1}.

5 Damaged Alveolar Type 1 Cells $(DAT1)$

$$\frac{dDAT1}{dt} = k_{ROS\_damage}(AT1) + k_{cyt\_damage}(AT1) - \beta_{dAT1}(DAT1)$$

$DAT1$ are formed by ROS-mediated and cytokine-mediated damage (k_{cyt_damage}) of $AT1$ cells.

6 Damaged Alveolar Type 2 Cells $(DAT2)$

$$\frac{d(DAT2)}{dt} = k_{ROS\_damage}(I + AT2) + k_{cyt\_damage}(AT2) - \beta_{dAT2}(DAT2)$$

$(DAT2)$ are formed by cytokine-mediated damage (k_{cyt_damage}) of $(AT2)$ cells and ROS-mediated damage of $(AT2)$ and (I).

7 Dendritic Cell Matuaration (DC)

$$\frac{dDC}{dt} = \alpha_{DC}\left[\frac{k_V \cdot V}{K_V + V} + \frac{k_I \cdot I}{K_I + I} + \frac{k_D(DAT1 + DAT2)}{K_D + (DAT1 + DAT2)}\right]\left[k_{DC(TNF)} \cdot \left(\frac{(TNF\alpha)}{K_{DC(TNF)} + (TNF\alpha)}\right) + k_{DC(IFN\gamma)} \cdot \left(\frac{(IFN\gamma)}{K_{DC(IFN\gamma)} + (IFN\gamma)}\right) + k_{DC(GM-CSF)} \cdot) \left(\frac{(GM-CSF)}{K_{DC(GM-CSF)} + (GM-CSF)}\right)\right]\left[\frac{K_{DC(IL10)}}{K_{DC(IL10)} + (IL10)}\right] - \beta_{DC}.(DC)$$

Mature (DC) are formed upon recognition of viral particles (V), infected cells (I), and damaged $(AT1)$ and $(AT2)$ cells. (DC) maturation is further induced by $(TNF\alpha)$, $(IFN\gamma)$, $(GM-CSF)$, and inhibited by $(IL10)$. Mature (DC) undergo nonspecific clearance at at a rate β_{DC}.

8 Macrophage Activation $(M1)$

$$\frac{dM1}{dt} = \alpha_{M1}\Bigg[\Big(\frac{k_V \cdot V}{K_V + V} + \frac{k_I \cdot I}{K_I + I} + \frac{k_D(DAT1 + DAT2)}{K_D + (DAT1 + DAT2)}\Bigg]\Bigg[k_{M1(TNF)} \cdot \left(\frac{(TNF\alpha)}{K_{M1(TNF)} + (TNF\alpha)}\right) +$$

$$k_{M1(IFN\gamma)} \cdot \left(\frac{(IFN\gamma)}{K_{DC(IFN\gamma)} + (IFN\gamma)}\right) + k_{M1(GM-CSF)} \cdot \Big) \left(\frac{(GM - CSF)}{K_{M1(GM-CSF)} + (GM - CSF)}\right)\Bigg]$$

$$\left[\frac{K_{M1(IL10)}}{K_{M1(IL10)} + (IL10)}\right] - \beta_{M1}.(M1)$$

Activated $(M1)$ are formed upon recognition of viral particles (V), infected cells (I), and damaged $(AT1)$ and $(AT2)$ cells. $(M1)$ activation is induced by $(TNF\alpha)$, $(IFN\gamma)$, $(GM - CSF)$, and inhibited by $(IL10)$. Activated $(M1)$ undergo nonspecific clearance at at a rate β_{M1}.

9 Neutrophil Activation (N)

$$\frac{dN}{dt} = \alpha_{N}\Bigg[\Big(\frac{k_V \cdot V}{K_V + V} + \frac{k_I \cdot I}{K_I + I} + \frac{k_D(DAT1 + DAT2)}{K_D + (DAT1 + DAT2)}\Bigg]\Bigg[k_{M1(TNF)} \cdot \left(\frac{(TNF\alpha)}{K_{M1(TNF)} + (TNF\alpha)}\right) +$$

$$k_{M1(IFN\gamma)} \cdot \left(\frac{(IFN\gamma)}{K_{DC(IFN\gamma)} + (IFN\gamma)}\right) + k_{M1(GM-CSF)} \cdot \Big) \left(\frac{(GM - CSF)}{K_{M1(GM-CSF)} + (GM - CSF)}\right)\Bigg]$$

$$ktr_N \cdot N_c \cdot \Big(\frac{(IL17)}{km_{N\_IL17} + (IL17)}\Big) - \beta_N \cdot N - k_{tr(N)} \cdot N$$

Activated (N) are formed upon recognition of viral particles (V), infected cells (I), and damaged $(AT1)$ and $(AT2)$ cells. (N) activation is induced by $(TNF\alpha)$, $(IFN\gamma)$, $(GM - CSF)$, and inhibited by $(IL10)$. Activated (N) undergo nonspecific clearance at at a rate β_N. Activated (N) migration is also induced by $(IL17)$.

10 T-helper 1 (Th1) Cell Activation $(Th1)$

$$\frac{dTh1}{dt} = \alpha_{Th1}\,[DC]\Bigg[k_{Th1(IL12)}\left(\frac{(IL12)}{K_{Th1(IL12)} + (IL12)}\right)$$

$$\left(1 + k_{Th1(IL12/IL2)}\left(\frac{(IL2)}{K_{Th1(IL12/IL2)} + (IL2)}\right)\right)\left(\frac{K_{Th1(IL10)}}{K_{Th1(IL10)} + (IL10)}\right)\left(\frac{K_{Th1(TGF\beta)}}{K_{Th1(TGF\beta)} + (TGF\beta)}\right) +$$

$$k_{Th1(IFN\gamma)}\left(\frac{(IFN\gamma)}{K_{Th1(IFN\gamma)} + (IFN\gamma)}\right)\left(\frac{K_{Th1(IL10)}}{K_{Th1(IL10)} + (IL10)}\right)\left(\frac{K_{Th1(TGF\beta)}}{K_{Th1(TGF\beta)} + (TGF\beta)}\right)\left(\frac{K_{Th1(IL6)}}{K_{Th1(IL6)} + (IL6)}\right)\Bigg] +$$

$$k_{Th1(Th17)}.(Th17).\left(\frac{(IL12)}{K_{Th1(Th17)} + (IL12)}\right)\left(\frac{K_{Th1(TGF\beta)}}{K_{Th1(TGF\beta)} + (TGF\beta)}\right) +$$

$$k_{Th1(Treg)}.(Treg).\left(\frac{(IL12)}{K_{Th1(Treg)} + (IL12)}\right) - \beta_{Th1}.(Th1) + k_{tr(Th1)}.(Th1)$$

The production of $(Th1)$ is activated by viral epitope-responsive mature (DC), and further induced by $(IL12)$, $(IL2)$, $(IFN\gamma)$, $(IFN\beta)$ and inhibited by $(IL10)$ and $(TGF\beta)$. Additionally, the ability of $(IFN\gamma)$ and $(IL6)$ to negatively regulate each other's activity is also incorporated. The clearance rate of $(Th1)$ is determined by a nonspecific death/deactivation rate β_{Th1}, and inter-compartmental transport rate $k_{tr(Th1)}$.

11 T-helper 17 (Th17) Cell Activation $(Th17)$

$$
\begin{aligned}
\frac{dTh17}{dt} &= \alpha_{Th17}(DC)\Bigg[\\
& k_{Th17(TGF\beta)}.\left(\frac{(TGF\beta)}{K_{Th17(TGF\beta)}+(TGF\beta)}\right)\left(\frac{K_{Th17(IL10)}}{K_{Th17(IL10)}+(IL10)}\right)\left(\frac{K_{Th17(IFN\gamma)}}{K_{Th17(IFN\gamma)}+(IFN\gamma)}\right)\left(\frac{K_{Th17(IL2)}}{K_{Th17(IL2)}+(IL2)}\right)+ \\
& k_{Th17(IL6)}\left(\frac{(IL6)}{K_{Th17(IL6)}+(IL6)}\right)\left(\frac{K_{Th17(IL10)}}{K_{Th17(IL10)}+(IL10)}\right)\left(\frac{K_{Th17(IFN\gamma)}}{K_{Th17(IFN\gamma)}+(IFN\gamma)}\right)\left(\frac{K_{Th17(IL2)}}{K_{Th17(IL2)}+(IL2)}\right)+ \\
& k_{Th17(IL1\beta)}\left(\frac{(IL1\beta)}{K_{Th17(IL1\beta)}+(IL1\beta)}\right)\left(\frac{K_{Th17(IL10)}}{K_{Th17(IL10)}+(IL10)}\right)\left(\frac{K_{Th17(IFN\gamma)}}{K_{Th17(IFN\gamma)}+(IFN\gamma)}\right)\left(\frac{K_{Th17(IL2)}}{K_{Th17(IL2)}+(IL2)}\right)\Bigg]- \\
& k_{Th1(Th17)}.(Th17).\left(\frac{(IL12)}{K_{Th1(Th17)}+(IL12)}\right)\left(\frac{K_{Th1(TGF\beta)}}{K_{Th1(TGF\beta)}+(TGF\beta)}\right)-\beta_{Th17}.(Th17)-k_{tr(Th17)}.(Th17)
\end{aligned}
$$

The production of $(Th17)$ is activated by viral epitope-responsive mature (DC), and further induced by $(TGF\beta)$, $(IL6)$, $(IL1\beta)$ and inhibited by $(IL10)$ and $(IFN\gamma)$. Additionally, the ability of $(IFN\gamma)$ and $(IL6)$ to negatively regulate each other's activity is also incorporated. $(Th17)$ cells can also undergo $(IL12)$-mediated differentiation to $(Th1)$ cells. The clearance rate of $(Th17)$ is determined by a nonspecific death/deactivation rate β_{Th17}, and inter-compartmental transport rate $k_{tr(Th17)}$.

12 Cytotoxic T Cell Activation (CTL)

$$
\begin{aligned}
\frac{dCTL}{dt} &= \alpha_{CTL}\,[DC]\left[1+\frac{k_{MHCI(IFN\beta)}(IFN\beta)}{km_{MHCI(IFN\beta)}+(IFN\beta)}\right]\Bigg[1+k_{CTL(IL12)}\left(\frac{(IL12)}{K_{CTL(IL12)}+(IL12)}\right) \\
& \left(1+k_{CTL(IL12/IL2)}\left(\frac{(IL2)}{K_{CTL(IL12/IL2)}+(IL2)}\right)\right)+ \\
& k_{CTL(IFN\gamma)}\left(\frac{(IFN\gamma)}{K_{CTL(IFN\gamma)}+(IFN\gamma)}\right)\left(\frac{K_{CTL(IL6)}}{K_{CTL(IL6)}+(IL6)}\right)\Bigg]\left(\frac{K_{CTL(IL10)}}{K_{CTL(IL10)}+(IL10)}\right)\left(\frac{K_{CTL(TGF\beta)}}{K_{CTL(TGF\beta)}+(TGF\beta)}\right) \\
& -\beta_{CTL}(CTL)-k_{tr(CTL)}(CTL)
\end{aligned}
$$

The production of (CTL) is activated by viral epitope-responsive mature (DC), and further induced by $(IL12)$, $(IL2)$, $(IFN\gamma)$, $(IFN\beta)$ and inhibited by $(IL10)$ and $(TGF\beta)$. Additionally, the ability of $(IFN\gamma)$ and $(IL6)$ to negatively regulate each other's activity is also incorporated. The clearance rate of (CTL) is determined by a nonspecific death/deactivation rate β_{CTL}, and inter-compartmental transport rate $k_{tr(CTL)}$.

13 T regulatory (Treg) Cell Activation $(Treg)$

$$
\begin{aligned}
\frac{dTreg}{dt} &= \alpha_{Treg}(DC)\Bigg[k_{Treg(IL2)}\left(\frac{(IL2)}{K_{Treg(IL2)}+(IL2)}\right)\left(\frac{K_{Treg(IL17)}}{K_{Treg(IL17)}+(IL17)}\right)\left(\frac{K_{Treg(IL6)}}{K_{Treg(IL6)}+(IL6)}\right)+ \\
& k_{Treg(TGF\beta)}\left(\frac{(TGF\beta)}{K_{Treg(TGF\beta)}+(TGF\beta)}\right)\left(\frac{K_{Treg(IL17)}}{K_{Treg(IL17)}+(IL17)}\right)\left(\frac{K_{Treg(IL6)}}{K_{Treg(IL6)}+(IL6)}\right)\Bigg] \\
& -k_{Th1(Treg)}.(Treg).\left(\frac{(IL12)}{K_{Th1(Treg)}+(IL12)}\right)-\beta_{Treg}(Treg)-k_{tr(Treg)}(Treg)
\end{aligned}
$$

The production of $(Treg)$ is activated by viral epitope-responsive mature (DC), and further induced by $(TGF\beta)$ and $(IL2)$ and inhibited by $(IL17)$ and $(IL6)$. $(Treg)$ cells can also undergo $(IL12)$-mediated differentiation to $(Th1)$ cells. The clearance rate of $(Treg)$ is determined by a nonspecific death/deactivation rate β_{Treg}, and inter-compartmental transport rate $k_{tr(Treg)}$.

14 Tumor necrosis factor α $(TNF\alpha)$

$$\frac{dTNF\alpha}{dt} = \alpha_{TNF}\cdot\Big[\alpha_{TNF(basal)} + \alpha_{TNF(dAT1)}(DAT1) + \alpha_{TNF(I)}\cdot I + \alpha_{TNF(dAT2)}(DAT2)$$
$$\alpha_{TNF(M1)}(M1) + \alpha_{TNF(Th1)}(Th1) + \alpha_{TNF(Th17)}(Th17)\Big] - \beta_{TNF}(TNF\alpha) - k_{tr(TNF\alpha)}(TNF\alpha)$$

$(TNF\alpha)$ is secreted by $(DAT1)$, $(DAT2)$, (I), $(M1)$, $(Th1)$ and $(Th17)$. $(TNF\alpha)$ additionally has a basal non-specific production rate $\alpha_{TNF}.\alpha_{TNF(basal)}$, a clearance rate β_{TNF} and inter-compartmental transport rate $k_{tr(TNF\alpha)}$.

15 Interluekin-6 (IL-6) $(IL6)$

$$\frac{dIL6}{dt} = \alpha_{IL6}\Big[\alpha_{IL6(basal)} + \alpha_{IL6(dAT1)}.(DAT1) + \alpha_{IL6(I)}\cdot I + \alpha_{IL6(dAT2)}(DAT2) + \alpha_{IL6(M1)}(M1) +$$
$$\alpha_{IL6(Th17)}(Th17) + \alpha_{IL6(Neu)}(N) + \alpha_{IL6(I)}\cdot I\Big] - \beta_{IL6}(IL6) - k_{tr(IL6)}(IL6)$$

$(IL6)$ is secreted by $(DAT1)$, $(DAT2)$, (I), $(M1)$, (N) and $(Th17)$. $(IL6)$ additionally has a basal non-specific production rate $\alpha_{IL6}.\alpha_{IL6(basal)}$, a clearance rate β_{IL6} and inter-compartmental transport rate $k_{tr(IL6)}$.

16 Interleukin-1β (IL-1β) $(IL1\beta)$

$$\frac{dIL1\beta}{dt} = \alpha_{IL1\beta}\Big[\alpha_{IL1\beta(basal)} + \alpha_{IL1\beta(dAT1)}.(DAT1) + \alpha_{IL1\beta(I)}\cdot I + \alpha_{IL1\beta(dAT2)}(DAT2)$$
$$+ \alpha_{IL1\beta(M1)}(M1) + \alpha_{IL1B(DC)}(DC) + \alpha_{IL1\beta((I)}\cdot I\Big] - \beta_{IL1\beta}(IL1\beta) - k_{tr(IL1\beta)}(IL1\beta)$$

$(IL1\beta)$ is secreted by $(DAT1)$, $(DAT2)$, (I), $(M1)$ and (DC). $(IL1\beta)$ additionally has a basal non-specific production rate $\alpha_{IL1\beta}.\alpha_{IL1\beta(basal)}$, a clearance rate $\beta_{IL1\beta}$ and inter-compartmental transport rate $k_{tr(IL1\beta)}$.

17 Interferon γ (IFNγ) $(IFN\gamma)$

$$\frac{dIFN\gamma}{dt} = \alpha_{IFN\gamma}\Big[\alpha_{IFN\gamma(basal)} + \alpha_{IFN\gamma(DC)}.(DC) + \alpha_{IFN\gamma(Th1)}(Th1) + \alpha_{IFN\gamma(CTL)}(CTL)\Big] - \beta_{IFN\gamma}(IFN\gamma) - k_{tr(IFN\gamma)}(IFN\gamma)$$

$(IFN\gamma)$ is secreted by $(Th1)$, (CTL) and (DC). $(IFN\gamma)$ additionally has a basal non-specific production rate $\alpha_{IFN\gamma}.\alpha_{IFN\gamma(basal}$ a clearance rate $\beta_{IFN\gamma}$ and inter-compartmental transport rate $k_{tr(IFN\gamma)}$.

18 Type I Interferons $(IFN\beta)$

$$\frac{dIFN\beta}{dt} = \alpha_{IFN\beta}\left[\alpha_{IFN\beta(basal)} + \alpha_{IFN\beta(I)} \cdot I + \alpha_{IFN\beta(DC)}(DC)\right] - \beta_{IFN\beta}(IFN\beta) - k_{tr(IFN\beta)}(IFN\beta)$$

$(IFN\beta)$ is secreted by (I) and (DC). $(IFN\beta)$ additionally has a basal non-specific production rate $\alpha_{IFN\beta}.\alpha_{IFN\beta(basal)}$, a clearance rate $\beta_{IFN\beta}$ and inter-compartmental transport rate $k_{tr(IFN\beta)}$.

19 Interleukin-2 (IL-2) $(IL2)$

$$\frac{dIL2}{dt} = \alpha_{IL2}\left[\alpha_{IL2(basal)} + \alpha_{IL2(DC)}(DC) + \alpha_{IL2(Th1)}(Th1)\right] - \beta_{IL2}(IL2) - k_{tr(IL2)}(IL2)$$

$(IL2)$ is secreted by (DC) and $(Th1)$. $(IL2)$ additionally has a basal non-specific production rate $\alpha_{IL2}.\alpha_{IL2(basal)}$, a clearance rate β_{IL2} and inter-compartmental transport rate $k_{tr(IL2)}$.

20 Interluekin-12 (IL-12) $(IL12)$

$$\frac{dIL12}{dt} = \alpha_{IL12}\left[\alpha_{IL12(basal)} + \alpha_{IL12(DC)}(DC) + \alpha_{IL12(M1)}(M1)\right] - \beta_{IL12}(IL12) - k_{tr(IL12)}(IL12)$$

$(IL12)$ is secreted by (DC) and $(M1)$. $(IL12)$ additionally has a basal non-specific production rate $\alpha_{IL12}.\alpha_{IL12(basal)}$, a clearance rate β_{IL12} and inter-compartmental transport rate $k_{tr(IL12)}$.

21 Interleukin-17 (IL-17) $(IL17)$

$$\frac{dIL17}{dt} = \alpha_{IL17}\left[\alpha_{IL17(basal)} + \alpha_{IL17(Th17)}(Th17) + \alpha_{IL17(CTL)}(CTL)\right] - \beta_{IL17}(IL17) - k_{tr(IL17)}(IL17)$$

$(IL17)$ is secreted by (CTL) and $(Th17)$. $(IL17)$ additionally has a basal non-specific production rate $\alpha_{IL17}.\alpha_{IL17(basal)}$, a clearance rate β_{IL17} and inter-compartmental transport rate $k_{tr(IL17)}$.

22 Interluekin-10 (IL-10) $(IL10)$

$$\frac{dIL10}{dt} = \alpha_{IL10}\left[\alpha_{IL10(basal)} + \alpha_{IL10(Treg)}(Treg)\right] - \beta_{IL10}(IL10) - k_{tr(IL10)}(IL10)$$

$(IL10)$ is secreted by $(Treg)$. $(IL10)$ additionally has a basal non-specific production rate $\alpha_{IL10}.\alpha_{IL10(basal)}$, a clearance rate β_{IL10} and inter-compartmental transport rate $k_{tr(IL10)}$.

23 Transforming growth factor β (TGF-β) $(TGF\beta)$

$$\frac{dTGF\beta}{dt} = \alpha_{TGF\beta}\left[\alpha_{TGF\beta(basal)} + \alpha_{TGF\beta(Treg)}(Treg) + \alpha_{TGF\beta(Th17)}(Th17)\right] - \beta_{TGF\beta}(TGF\beta) - k_{tr(TGF\beta)}(TGF\beta)$$

$(TGF\beta)$ is secreted by $(Treg)$ and $(Th17)$. $(TGF\beta)$ additionally has a basal non-specific production rate $\alpha_{TGF\beta}.\alpha_{TGF\beta(basal)}$, a clearance rate $\beta_{TGF\beta}$ and inter-compartmental transport rate $k_{tr(TGF\beta)}$.

24 Granulocyte macrophage-colony stimulating factor (GM-CSF) $(GM{-}CSF)$

$$\frac{d(GM-CSF)}{dt} = \alpha_{GM-CSF}\left[\alpha_{GM-CSF(basal)} + \alpha_{GM-CSF(Th1)}(Th1) + \alpha_{GM-CSF(M1)}(M1) + \alpha_{GM-CSF(Th17)}(Th17)\right] - \beta_{GM-CSF}(GM-CSF) - k_{tr(GM-CSF)}(GM-CSF)$$

$(GM-CSF)$ is secreted by $(M1)$, $(Th17)$ and $(Th1)$. $(GM-CSF)$ additionally has a basal non-specific production rate $\alpha_{GM-CSF}.\alpha_{GM-CSF(basal)}$, a clearance rate β_{GM-CSF} and inter-compartmental transport rate $k_{tr(GM-CSF)}$.

25 C-reactive Protein

$$\frac{dCRP_{extracellular}}{dt} = k_{CRP\_secretion}V_{m\_Prot\_synth} \cdot vol_{liver}(IL6_c) + k_{tr(CRP)}vol_{liver} - k_{deg\_CRP}(CRP_{extracellular})$$

$$\frac{dCRP_{blood}}{dt} = k_{basal\_CRP} - k_{tr(CRP)} - k_{deg\_CRP}(CRP_{blood})$$

CRP is produced in the liver ($(CRP_{exrtracellular})$) and is induced by liver concentrations of $(IL6)$. $(CRP_{exrtracellular})$ is tranported to blood at an inter-compartmental transit rate $k_{tr(CRP)}$. (CRP_{blood}) is also basally produced at a rate k_{basal_CRP}. Both $(CRP_{exrtracellular})$ and (CRP_{blood}) are cleared at a rate k_{deg_CRP} from their respective compartments.

26 Surfact Protein-D (SPD)

$$\frac{dSPD}{dt} = k_{basal\_SPD} + \alpha_{SPD(AT2)}(DAT2) + \alpha_{SPD(AT1)}(DAT1) + \alpha_{SPD(CTL\_I)}k_{kill}\left(1 + \frac{IFN_\beta}{km_{kill} + IFN_\beta}\right) \cdot I \cdot (CTL) - k_{tr(SPD)}(SPD)$$

(SPD) is released by $(DAT1)$, $(DAT2)$ and the cytotoxic clearance of (I) by (CTL) in the alveolar compartment. (SPD) has an inter-compartmental transit rate of $k_{tr(SPD)}$.

27 Ferritin (FER)

$$\frac{dFER}{dt} = k_{basal\_FER} + \alpha_{FER(AT1)}(DAT1) + \alpha_{FER(AT12)}(DAT2) + \alpha_{FER(CTL\_I)}k_{kill}\left(1 + \frac{IFN_\beta}{km_{kill} + IFN_\beta}\right) \cdot I \cdot (CTL) - k_{tr(FER)}(FER)$$

(FER) is released by $(DAT1)$, $(DAT2)$ and the cytotoxic clearance of (I) by (CTL) in the alveolar compartment. (FER) has an inter-compartmental transit rate of $k_{tr(FER)}$.

28 Immune Cell Transport

$$\frac{dIC_c}{dt} = tr_{IC}(IC)\left(\frac{vol_{alv}}{vol_{plasma}}\right) - \beta_{IC_c}(IC_c)$$

$$tr_{IC} = k_{tr\_IC}\left(\frac{IC}{vol_{alv}} - IC_c\right)$$

29 Cytokine Tranport

$$\frac{dCytokine_c}{dt} = \frac{tr_{cytokine}}{vol_{plasma}} - \beta_{cytokine_c}(Cytokine_c)$$

$$tr_{cytokine} = k_{tr\_cytokine}(Cytokine)$$

30 Biomarker Tranport

$$\frac{dSPD\_c}{dt} = k_{tr\_SPD}(SPD) - \beta_{SPDc}(SPD\_c)$$

$$\frac{dFER\_c}{dt} = k_{tr\_FER}(FER) - \beta_{FERc}(FER\_c)$$