$$\frac{\mathrm{d}S_a}{\mathrm{d}t} = -p_a S_a \sum_{j=1}^{A} \left(M_{a,j} I_j + \tilde{M}_{a,j} Q_j \right) - \nu_a \left(1 - \frac{D_V}{N_V} \right) S_a \tag{1}$$

$$\frac{\mathrm{d}E_a}{\mathrm{d}t} = p_a S_a \sum_{j=1}^{A} \left(M_{a,j} I_j + \tilde{M}_{a,j} Q_j \right) - \sigma E_a - \tau E_a \sum_{j=1}^{A} M_{a,j} \left(Q_j + H_j + C_j \right) - \nu_a \left(1 - \frac{D_V}{N_V} \right) E_a \tag{2}$$

$$\frac{\mathrm{d}V_a}{\mathrm{d}t} = -p_a (1 - \varepsilon_a) V_a \sum_{j=1}^{A} \left(M_{a,j} I_j + \tilde{M}_{a,j} Q_j \right) + \nu_a \left(1 - \frac{D_V}{N_V} \right) S_a \tag{3}$$

$$\frac{\mathrm{d}F_a}{\mathrm{d}t} = p_a (1 - \varepsilon_a) V_a \sum_{j=1}^{A} \left(M_{a,j} I_j + \tilde{M}_{a,j} Q_j \right) - \sigma F_a - \tau F_a \sum_{j=1}^{A} M_{a,j} \left(Q_j + H_j + C_j \right) + \nu_a \left(1 - \frac{D_V}{N_V} \right) E_a \tag{4}$$

$$\begin{aligned} \frac{\mathrm{d}I_a}{\mathrm{d}t} &= (1 - q)\sigma (E_a + F_a) - \left(1 - h \left(1 - \frac{\sum_{i=1}^{A} H_a}{B_H} \right) - c \left(1 - \frac{\sum_{i=1}^{A} C_a}{B_C} \right) \right) \gamma I_a - h \left(1 - \frac{\sum_{i=1}^{A} H_a}{B_H} \right) \delta I_a \\ &- c \left(1 - \frac{\sum_{i=1}^{A} C_a}{B_C} \right) \theta I_a - \tau I_a \sum_{j=1}^{A} M_{a,j} \left(Q_j + H_j + C_j \right) - \mu \frac{\sum_{j=1}^{A} (H_j + C_j)}{B_H + B_C} I_a \end{aligned} \tag{5}$$

$$\frac{\mathrm{d}O_a}{\mathrm{d}t} = \tau (F_a + E_a) \sum_{j=1}^{A} M_{a,j} \left(Q_j + H_j + C_j \right) - \sigma O_a \tag{6}$$

$$\begin{aligned} \frac{\mathrm{d}Q_a}{\mathrm{d}t} &= q\sigma (E_a + F_a) + \sigma O_a + \tau I_a \sum_{j=1}^{A} M_{a,j} \left(Q_j + H_j + C_j \right) - h \left(1 - \frac{\sum_{i=1}^{A} H_a}{B_H} \right) \delta Q_a - c \left(1 - \frac{\sum_{i=1}^{A} C_a}{B_C} \right) \theta Q_a \\ &- \left(1 - h \left(1 - \frac{\sum_{i=1}^{A} H_a}{B_H} \right) - c \left(1 - \frac{\sum_{i=1}^{A} C_a}{B_C} \right) \right) \gamma Q_a - \mu \frac{\sum_{j=1}^{A} (H_j + C_j)}{B_H + B_C} Q_a \end{aligned} \tag{7}$$

$$\frac{\mathrm{d}H_a}{\mathrm{d}t} = h\delta \left(1 - \frac{\sum_{i=1}^{A} H_a}{B_H} \right) (I_a + Q_a) - \left(m_H \mu_H + (1 - m_H) \psi_H \right) H_a \tag{8}$$

$$\frac{\mathrm{d}C_a}{\mathrm{d}t} = c \left(1 - \frac{\sum_{i=1}^{A} C_a}{B_C} \right) \theta (I_a + Q_a) - \left(m_C \mu_C + (1 - m_C) \psi_C \right) C_a \tag{9}$$

$$\frac{\mathrm{d}D_V}{\mathrm{d}t} = \sum_{j=1}^{A} \left(\nu_a \left(1 - \frac{D_V}{N_V} \right) (S_a + E_a) \right) \tag{10}$$