List of misprints and minor corrections for
"Gauge Theories in Particle Physics", Third Edition, volume 2:
"QCD and the Electroweak Theory"

pxvii in lines 4-6 of the second paragraph, note that the book's website given there is no longer operational; all communication of queries, errors, etc should be to i.aitchison1@physics.ox.ac.uk

p12 line following equation (12.45) after 'Hermitian.' insert 'Here $\boldsymbol{\tau}_I$ ($I = 1, 2, \ldots A$) is the $\boldsymbol{\tau}$-matrix for the I-th nucleon.'

p14 4 lines after equation (12.48) replace '$(2T+1)\times(2T+1)$ matrices $\mathbf{T}^{(T)}$' by 'matrices $\mathbf{T}^{(T)}$ of dimension $(2T+1)\times(2T+1)$'

p18 replace third line of equation (12.65) by '$= (\delta_{ik} + \mathrm{i}\epsilon_j (T_j^{(1)})_{ik})\psi_k^{(1)}$'

p20 in line 7 of the second paragraph, replace 'M.4(v)' by 'M.4.5'; in line 12 of the same paragraph, replace 'hyperchange' by 'hypercharge'; in the summation in equation (12.75), replace '$i = 1$' by '$a = 1$'; in the second line after equation (12.75), replace 'M.4(v)' by 'M.4.5'

p21 in the third line after equation (12.76) replace 'M.4(v)' by 'M.4.5'

p23 in the fifth line after equation (12.84) replace 'π^+' by '$\pi^\pm$'

p29 in the first line after equation (12.125) replace '(8.76)' by '(12.124)'

p52 in the second term on the RHS of equation (13.57) replace 'V^α' by 'V^γ'

p53 in the second line of the second paragraph replace '(3.8.2)' by '(3.82)'

p57 in the second line of equation (13.78) replace 'ie' by '$-$ie'; in the first line after equation (13.78) replace '$F^{\mu\nu} = \partial^\nu A^\mu - \partial^\mu A^\nu$' by '$F^{\mu\nu} = \partial^\mu A^\nu - \partial^\nu A^\mu$'

p58 on the RHS of equation (13.81) replace 'A^μ' by '$\boldsymbol{W}^\mu$'

p61 in line 6 of section 13.5.1 replace '(13.28)' by '(13.2)' p65 in expression (13.118), and in the second line after equation (13.119), replace $\bar{X}^*_\mu(2)$' by '$X^*_\mu(2)$'; in equation (13.119) replace '$X_3^\mu(1)$' by '$X_3^\mu(3)$'

p68 in figure 13.13, replace the label 'k_2, ϵ_3, j' by 'k_2, ϵ_2, j'; on the RHS of equation (13.132) replace '$-\hat{\boldsymbol{X}}^\mu \times \hat{\boldsymbol{X}}^\nu$' by '$-e\hat{\boldsymbol{X}}^\mu \times \hat{\boldsymbol{X}}^\nu$'

p71 on the LHS of equation (13.151) replace '$>$' by '$\rangle$'

p73 on the LHS of equation (13.155) replace 'Im' by '2 Im'; on the RHS of equation (13.155) replace '$-g^{\mu_1\nu_1}$' by '$-g^{\mu_1\mu_2}$' and replace '$-g^{\mu_2\nu_2}$' by '$-g^{\nu_1\nu_2}$'

p75 replace equation (13.163) by

$$`\quad 2\,\mathrm{Im}\,\mathcal{M}^{(4)}_{\mathrm{q\bar{q}\to q\bar{q}}} = \int \mathcal{M}^{(2)}_{\mu_1\nu_1}[U^{\mu_1\mu_2}(k_1,t_1)]\mathcal{M}^{(2)}_{\mu_2\nu_2}[U^{\nu_1\nu_2}(k_2,t_2)]\,\mathrm{d}\rho_2 \quad ' \quad ;$$

in line 12 of the third paragraph replace '(13.3.2)' by '(13.5.2)'; on the LHS of equation (13.165) replace '$\epsilon_1^\mu(k_1,\lambda_1)$' by '$\epsilon_1^{\mu_1}(k_1,\lambda_1)$'

p84 replace equation (14.1) by

$$`\quad \psi_{\mathrm{3q}} = \psi_{\mathrm{3q,\,space}}\,\psi_{\mathrm{3q,\,spin}}\,\psi_{\mathrm{3q,\,flavour}} \quad '$$

p93 first line after equation (14.36) replace 'ϵFF' by '$\epsilon\hat{F}\hat{F}$'; second line after equation (14.36) replace '$\boldsymbol{E}\cdot\boldsymbol{B}$' by '$\hat{\boldsymbol{E}}\cdot\hat{\boldsymbol{B}}$'; fourth line after equation (14.36) replace '$\boldsymbol{E}\to-\boldsymbol{E}$ and $\boldsymbol{B}\to\boldsymbol{B}$, while under T, $\boldsymbol{E}\to\boldsymbol{E}$ and $\boldsymbol{B}\to-\boldsymbol{B}$' by '$\hat{\boldsymbol{E}}\to-\hat{\boldsymbol{E}}$ and $\hat{\boldsymbol{B}}\to\hat{\boldsymbol{B}}$, while under T, $\hat{\boldsymbol{E}}\to\hat{\boldsymbol{E}}$ and $\hat{\boldsymbol{B}}\to-\hat{\boldsymbol{B}}$'

p100 first line after equation (14.43) replace 'Here $\hat{s}$' by 'Here $\alpha_{\mathrm{s}} = g_{\mathrm{s}}^2/4\pi$, and $\hat{s}$'

p101 first line below Table 14.1 replace '$\mathrm{e^+e^-}\to\mu^+\mu^-$' by '$\mathrm{e}^-\mu^-\to\mathrm{e}^-\mu^-$'; on RHS of equation (14.46) replace '$-\frac{1}{2}$' by '$\frac{1}{2}$'

p103 third line after equation (14.52) replace '$F(x)$' by '$F(x)/x$'

p107 in Figure 14.17 replace 'g, p_3' by 'g, p_3, c' in both diagrams p108 on the LHS of equation (14.55) replace 'spin$s$' by 'spins'; on the RHS of equation (14.55) replace '$8Q^4$' by 'Q^4'; on the RHS of equation (14.57), first line, replace '$p_1 \cdot p_2$' by '$p_1 \cdot p_3$'

p109 line 6 after equation (14.63) replace 'F' by '$\mathcal{M}_{\mathrm{q\bar{q}g}}$'

p110 on the RHS of equation (14.65) replace 'x_i' by 'x_1'

p111 third line after equation (14.68) replace '(14.63)' by '(14.62)'

p113 in the first line of problem 14.1(a) replace '(14.2) is invariant' by '(14.2) is (i) a determinant, (ii) invariant'; in the second line of problem 14.2 replace '$\boldsymbol{E} \cdot \boldsymbol{B}$' by '$\hat{\boldsymbol{E}} \cdot \hat{\boldsymbol{B}}$'; in the second line of problem 14.3 replace 'gluon contains' by 'gluon between two quarks (or between a quark and an antiquark) contains'

p114 in both parts (ii) and (iii) of problem 14.4 replace '$\mathrm{Tr}(\lambda_c)^2$' by '$\mathrm{Tr}(\lambda_c \lambda_c)$'; in the first line of problem 14.7 replace '(14.63)' by '(14.62)'

p121 on the LHS of equation (15.17) replace '$\Pi_\gamma^{[2]}(q^2, \mu)$' by '$\bar{\Pi}_\gamma^{[2]}(q^2, \mu)$'

p122 on the RHS of equation (15.23) replace 'm/μ' by 'm_{e}/μ'

p126 replace equation (15.46) by

$$
\text{`}\quad \begin{aligned} S(1, \alpha(|q^2|) &\approx 1 + S_1 \alpha(|q^2|) = 1 + S_1 \alpha_\mu \left[1 - \frac{\alpha_\mu}{3\pi} t\right]^{-1} \\ &= 1 + S_1 \alpha_\mu \left[1 + \frac{\alpha_\mu t}{3\pi} + \left(\frac{\alpha_\mu t}{3\pi}\right)^2 + \ldots\right] \end{aligned} \quad \text{'}
$$

p130 second line of section 15.4 replace '11.5' by '11.3'

p132 first line of the page replace '$\beta(e_\mu)$' by '$\beta(\alpha_\mu)$'; second line after equation (15.64) replace '$(|q^2|/\mu^2)^{\frac{1}{2}\gamma_2}$' by '$(|q^2|/\mu^2)^{\gamma_2}$'

p134 on the RHS of equation (15.72) replace 'μ^2' by '$\ln \mu^2$' and replace '$|q^2|$' by '$\ln |q^2|$'

p138 on the RHS of equation (15.83) replace '$4/\pi$' by '4π'; first line after equation (15.84) replace 'Hinchcliffe' by 'Hinchliffe'; replace equation (15.85) by

$$\sigma \approx \sigma_{\rm pt}\left(1 + \frac{\alpha_{\rm s}(\mu^2)}{\pi} + C_2(s/\mu^2)(\alpha_{\rm s}(\mu^2)/\pi)^2\right)$$

p152 first line of problem 15.9 replace '14.6' by '14.4'

p157 first line of expression (16.17) replace '$\frac{1}{2}$' by '$\frac{a}{2}$'; first line of expression (16.18) replace '$\frac{1}{2a^2}$' by '$\frac{1}{2a}$'; in expression (16.19) replace '$\tilde{\psi}(-k_{\nu_1})$' by $\tilde{\psi}(k_{\nu_1})$'

p175 line before equation (16.106) replace '(16.104)' by '(16.103)'

p186 in Figure 16.11 replace '$V(r)$' on the vertical axis by '$r_0 V(r)$'

p191 last line of the page replace 'K_{p+j}' by 'K_{p+j-1}'

p198 line before equation (17.16) replace '(1986)' by '(1966)'

p203 on the RHS of equation (17.29) replace '$\bar{v}(\boldsymbol{k}_1 - \boldsymbol{k}_1')$' by '$\bar{v}(|\boldsymbol{k}_1 - \boldsymbol{k}_1'|)$'; replace equation (17.32) by

$$`\quad \bar{v}(|\boldsymbol{k}|) = \int v(\boldsymbol{r})\mathrm{e}^{-\mathrm{i}\boldsymbol{k}\cdot\boldsymbol{r}}\,\mathrm{d}^3\boldsymbol{r}. \quad '$$

p206 replace '$\bar{v}(\boldsymbol{l})$' throughout by '$\bar{v}(|\boldsymbol{l}|)$' i.e. in equations (17.43), (17.44), (17.45), (17.46), and in lines three, eight and ten of the second paragraph

p218 on the RHS of equation (17.107) replace '$\exp(-\mathrm{i}(\hat{\boldsymbol{\theta}}(x) \cdot \boldsymbol{\tau}/2)v)$' by '$\exp(-\mathrm{i}\hat{\boldsymbol{\theta}}(x) \cdot \boldsymbol{\tau}/2v)$'

p220 first equality in equation (17.111) replace '$c_{\boldsymbol{k}}$' by '$\hat{c}_{\boldsymbol{k}}$'

p224 first equation of problem 17.4 replace '$\hat{a}^{\dagger 2}]$' by '$\hat{a}^{\dagger 2})]$'

p232 first line after equation (18.32) replace '$\hat{q}_{\rm R} = ((1-\gamma_5)/2)q$, $\hat{q}_{\rm L} = ((1+\gamma_5)/2)\hat{q}$' by '$\hat{q}_{\rm R} = ((1+\gamma_5)/2)\hat{q}, \hat{q}_{\rm L} = ((1-\gamma_5)/2)\hat{q}$'

p239 on RHS of equation (18.72) replace '$\mathrm{i}g_{\pi\mathrm{NN}}\bar{\hat{\psi}}\boldsymbol{\tau}\gamma_5\hat{\psi}\cdot\boldsymbol{\pi}$' by '$\mathrm{i}g_{\pi\mathrm{NN}}\bar{\hat{\psi}}\boldsymbol{\tau}\gamma_5\hat{\psi}\cdot\hat{\boldsymbol{\pi}}$', and replace '$\partial^\mu\bar{\hat{\boldsymbol{\pi}}}$' by '$\partial^\mu\hat{\boldsymbol{\pi}}$'

p240 on RHS of equation (18.79) replace '$\boldsymbol{\pi}+\boldsymbol{\eta}\sigma$' by '$\hat{\boldsymbol{\pi}}+\boldsymbol{\eta}\hat{\sigma}$'

p241 on the RHS of equation (18.88), second line, replace '$+\mu^2\hat{\sigma}'^2$' by '$-\mu^2\hat{\sigma}'^2$'

p248 on RHS of equation (18.103) replace '$k_{2\mu}$' by '$k_{2\beta}$'

p249 first line of problem 18.7 replace 'Lagrangian (18.72) becomes' by 'Lagrangian (18.72) (with the sign of μ^2 as in (18.83)) becomes'

p250 line 12 of first paragraph replace '11.4' by '11.3' and '13.51' by '13.5.1'

p259 on RHS of equation (19.40) replace '$(\partial^\mu+\mathrm{i}q\hat{A}_\mu)$' by '$(\partial^\mu+\mathrm{i}q\hat{A}^\mu)$'

p260 first line after equation (19.45) replace '(19.40)' by '(19.44)'; second line after equation (19.45) replace '(17.81)' by '(17.80)'

p279 equation (20.3) replace '$\gamma^\mu\hat{\psi}_\mathrm{e}$' by '$\gamma_\mu\hat{\psi}_\mathrm{e}$'

p282 in last term on RHS of equation (20.21) replace 'ψ' by '$\psi_{\mathbf{P}}$'

p283 in the last equality in equation (20.27) replace '$\hat{\psi}_2$' by '$\gamma^0\hat{\psi}_2$'; first line after equation (20.27) replace '$\mathbf{P}$' by '$\hat{\mathbf{P}}$'; last line of page replace '$\hat{\psi}$' by '$\hat{\psi}_2$'

p284 first line after equation (20.31) replace 'γ_0' by 'γ^0'

p286 second identity in equation (20.42) replace 'P_R' by '$P_\mathrm{R}u$'

p287 in equation (20.53) replace '$\frac{m}{2E}$' by '$\frac{m}{(2E)^{1/2}}$'

p291 line 9 after equation (20.73) replace 'positive' by 'negative'

p294 line 2 from the bottom of the page replace '$\nu_\mathrm{e}\leftrightarrow\nu_\mu$' by '$\nu_\mu\leftrightarrow\nu_\tau$'; last line of page replace 'ν_e' by 'ν_τ'

p295 replace the two lines following equation (20.80) by 'where E is the neutrino energy and Δm^2 is the squared mass difference $|m^2_{\nu_\mu}-m^2_{\nu_\tau}|$. If $\Delta m^2\sim 3\times10^{-3}$ eV^2 and $E\sim 1$ GeV, as for neutrinos produced by interactions of cosmic rays in the earth's atmosphere, we see that $L_0\sim 24000$ km, so'; line 4 after equation (20.80) replace 'or' by 'and' p297 2 lines before equation (20.94) replace ‘scattering’ by ‘scattering in the CM frame’

p299 in equation (20.109) replace ‘$p^{\mu\prime}$’ and ‘$p^{\nu\prime}$’ by ‘p'^{μ}’ and ‘p'^{ν}’

p303 3 lines after equation (20.133) replace ‘$\hat{j}_{\mathrm{CC}\mu}$’ by ‘$\hat{j}^{\dagger}_{\mathrm{CC}\mu}$’

p306 line before equation (20.147) replace ‘nothing’ by ‘noting’

p310 on RHS of equation (20.176) replace ‘$(1-y^2)$’ by ‘$(1-y)^2$’

p315 in first line of caption for figure 20.9 replace ‘results’ by ‘results (CCFRR, CDHSW, CHARM)’; in second line of caption replace ‘production’ by ‘production (BCDMS, BFP, EMC)’

p316 line 10 replace ‘linit’ by ‘limit’; in problem 20.2 replace ‘$\bar{\hat{\psi}}_1(\boldsymbol{x},t)\gamma^0\hat{\psi}_2(\boldsymbol{x},t)$’ by ‘$\bar{\hat{\psi}}_1(\boldsymbol{x},t)\gamma^0\gamma_5\hat{\psi}_2(\boldsymbol{x},t)$’; replace ‘$\hat{\boldsymbol{P}}$’ by ‘$\hat{\mathbf{P}}$’; and replace ‘$\bar{\hat{\psi}}(\boldsymbol{x},t)\boldsymbol{\gamma}\hat{\psi}_2(\boldsymbol{x},t)$’ by ‘$\bar{\hat{\psi}}_1(\boldsymbol{x},t)\boldsymbol{\gamma}\gamma_5\hat{\psi}_2(\boldsymbol{x},t)$’

p318 in problem 20.9, first line, replace ‘written as’ by ‘written as (see (18.52))’; on RHS of first equation replace ‘$(G_{\mathrm{F}}/\sqrt{2})$’ by ‘$-G_{\mathrm{F}}\cos\theta_{\mathrm{C}}$’; on RHS of last equation replace ‘$(G_{\mathrm{F}}/\sqrt{2})$’ by ‘$-G_{\mathrm{F}}\cos\theta_{\mathrm{C}}$’

p319 in problem 20.11, part (c), last equation on the page, replace ‘$\frac{\mathrm{d}^2}{\mathrm{d}x\,\mathrm{d}y}$’ by ‘$\frac{\mathrm{d}^2\sigma^{(\nu)}}{\mathrm{d}x\,\mathrm{d}y}$’

p328 on RHS of equation (21.29) replace ‘M_{W}’ by ‘M_{W}^2’

p333 second line after figure 21.10 replace ‘21.5’ by ‘21.3’

p337 line 10 from the bottom of the page replace ‘$\hat{c}$’ by ‘$\hat{b}$’

p340 on RHS of second equality in equation (22.18) replace ‘$\sqrt{2\lambda}v$’ by ‘$\sqrt{\lambda}\,v/\sqrt{2}$’

p341 on RHS of equation (22.22) replace ‘B^{μ}’ by ‘$\hat{B}^{\mu}$’; on RHS of equation (22.23) replace ‘$\bar{\hat{l}}_{f\mathrm{L}}\mathrm{i}\not{D}\hat{l}_{f\mathrm{L}}$’ by ‘$\bar{\hat{l}}_{f\mathrm{L}}\mathrm{i}\hat{\not{D}}\hat{l}_{f\mathrm{L}}$’ and replace ‘$\bar{\hat{l}}_{f\mathrm{R}}\mathrm{i}\not{D}\hat{l}_{f\mathrm{R}}$’ by ‘$\bar{\hat{l}}_{f\mathrm{R}}\mathrm{i}\hat{\not{D}}\hat{l}_{f\mathrm{R}}$’

p343 first line after equation (22.34) replace ‘thatused’ by ‘that used’; in equation (22.35) replace ‘$\hat{Z}^{\mu}$’ by ‘$\hat{Z}_{\mu}$’

p346 line 2 of section 22.4 replace 'known data' by 'known neutrino data'

p347 line 2 from the bottom of the page replace 'lepton-lepton' by 'neutrino-lepton'

p348 line before equation (22.66) replace 'lepton-lepton' by 'neutrino-lepton'; line 2 before equation (22.67) replace '22.4.' by '22.4, and in addition a t-channel Z^0 exchange graph similar to that in figure 22.3.'

p350 line 3 above equation (22.74) replace 'Many such measurements' by 'At the CERN e^+ e^- collider LEP, many such measurements'; on RHS of equation (22.78) replace 'g_A^2' by 'g_A^f'

p352 line 1 after figure 22.7 replace 'MeV' by 'GeV'; line 1 after equation (22.85) replace 'MeV' by 'GeV'

p358 in figure 22.13 replace '$|1+$' by '$(1+$'

p362 in equation (22.111) replace '$\phi_3+\mathrm{i}\phi_4$' by '$\hat{\phi}_3+\mathrm{i}\hat{\phi}_4$' and replace '$\phi_1+\mathrm{i}\phi_2$' by '$\hat{\phi}_1+\mathrm{i}\hat{\phi}_2$'

p367 line 2 before equation (22.141) replace 'the elements' by 'the magnitude of the elements'; last line of the page replace 'V_{cd}' by 's_{12}'

p368 on LHS of equation (22.147) replace '$\hat{\mathbf{P}}$' by '$\hat{\mathbf{C}}$'; replace equation (22.149) by

$$\text{`}\quad \hat{\mathbf{C}}\hat{\mathbf{P}}(\hat{\boldsymbol{W}}_0(\boldsymbol{x},t),\hat{\boldsymbol{W}}_i(\boldsymbol{x},t))(\hat{\mathbf{C}}\hat{\mathbf{P}})^{-1} = (\hat{\boldsymbol{W}}_0^{\dagger}(-\boldsymbol{x},t),-\hat{\boldsymbol{W}}_i^{\dagger}(-\boldsymbol{x},t)) \quad \text{'}\ ;$$

on RHS of equation (22.150) replace '$\bar{\hat{d}}_{\mathrm{L}}V_{\mathrm{ud}}\gamma^\mu\hat{u}_{\mathrm{L}}\hat{\boldsymbol{W}}_\mu^{\dagger}$' by '$-\bar{\hat{d}}_{\mathrm{L}}V_{\mathrm{ud}}\gamma^\mu\hat{u}_{\mathrm{L}}\hat{\boldsymbol{W}}_\mu^{\dagger}$'; line after equation (22.150) replace '$\boldsymbol{x}$' by '$-\boldsymbol{x}$'; on RHS of equation (22.151) replace '$\bar{\hat{d}}_{\mathrm{L}}V_{\mathrm{ud}}^*\gamma^\mu\hat{u}_{\mathrm{L}}\hat{\boldsymbol{W}}_\mu^{\dagger}$' by '$-\bar{\hat{d}}_{\mathrm{L}}V_{\mathrm{ud}}^*\gamma^\mu\hat{u}_{\mathrm{L}}\hat{\boldsymbol{W}}_\mu^{\dagger}$'

p371 line 15 replace '(in loops)' by '(i.e. in loops, as shown for example in figure 22.17 below)'; last line of page replace 'ν' by 'v'

p375 on LHS of equation (22.181) replace 'D_μ' by '$\hat{D}_\mu$'; in second line after equation (22.181) replace '$(D_\mu\hat{\phi})^\dagger(D^\mu\hat{\phi})$' by '$(\hat{D}_\mu\hat{\phi})^\dagger(\hat{D}^\mu\hat{\phi})$'

p376 third line of the page replace '$(D_\mu\hat{\phi})^\dagger(D^\mu\hat{\phi})$' by '$(\hat{D}_\mu\hat{\phi})^\dagger(\hat{D}^\mu\hat{\phi})$'; third line of RHS of equation (22.183) replace '$\frac{g^2}{4}\hat{\boldsymbol{W}}_\mu^2(\hat{\sigma}^2+\hat{\boldsymbol{\pi}}^2)+\frac{g^2}{4}\hat{\boldsymbol{\pi}}^2\hat{\boldsymbol{W}}_\mu^2$' by '$\frac{g^2}{8}\hat{\boldsymbol{W}}_\mu^2(\hat{\sigma}^2+\hat{\boldsymbol{\pi}}^2)$'

p385 line 1 after equation (22.201) replace 'decay. At' by 'decay. The forthcoming Higgs searches will be carried out at hadron colliders. At'

p387 on RHS of equation (22.203) replace '$\left(1-\frac{4M_{\rm W}^2}{m_{\rm H}^2}\right)$' by '$\left(1-\frac{4M_{\rm W}^2}{m_{\rm H}^2}\right)^{1/2}$'

p388 in problem 22.2 replace '(22.56)' by '(22.58)'

p389 on RHS of first equation of problem 22.6 replace '$\begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & -1 \end{pmatrix}$' by '$\begin{pmatrix} 0 \\ 0 \\ f \end{pmatrix}$'

p404 on RHS of equation (M.98) replace '$\boldsymbol{\eta}\cdot\sigma$' by '$\boldsymbol{\eta}\cdot\boldsymbol{\sigma}$'

p419 in first line of RHS of equation (P.7) replace '$-{\rm i}\boldsymbol{\epsilon}\cdot\boldsymbol{\sigma}$' by '${\rm i}\boldsymbol{\epsilon}\cdot\boldsymbol{\sigma}$'; in second line of RHS of equation (P.7) replace '$+{\rm i}\boldsymbol{\epsilon}\cdot\boldsymbol{\sigma}^*$' by '$-{\rm i}\boldsymbol{\epsilon}\cdot\boldsymbol{\sigma}^*$'; in third line of RHS of equation (P.7) replace '$-{\rm i}\boldsymbol{\epsilon}\cdot\boldsymbol{\sigma}$' by '$+{\rm i}\boldsymbol{\epsilon}\cdot\boldsymbol{\sigma}$'