Table 1: **High dimensional** (**dim = 43**) experimental results on the organoid drug-screen dataset across ***replicate*** populations.

	Train				Test			
	$\mathcal{W}_1(\downarrow)$	$\mathcal{W}_2(\downarrow)$	MMD ($\times 10^{-3}$) ($\downarrow$)	$r^2(\uparrow)$	$\mathcal{W}_1(\downarrow)$	$\mathcal{W}_2(\downarrow)$	MMD ($\times 10^{-3}$) ($\downarrow$)	$r^2(\uparrow)$
FM	3.925 ± 0.019	4.041 ± 0.023	3.76 ± 0.26	0.952 ± 0.007	3.961 ± 0.036	4.089 ± 0.042	5.90 ± 0.25	0.941 ± 0.010
FM$^{w}/\mathcal{N}$	6.908 ± 0.037	7.181 ± 0.033	57.70 ± 0.75	0.639 ± 0.005	6.972 ± 0.022	7.244 ± 0.022	60.39 ± 0.98	0.642 ± 0.007
CGFM	$\mathbf{3.864 \pm 0.064}$	3.975 ± 0.069	$\mathbf{3.16 \pm 0.89}$	0.964 ± 0.006	4.087 ± 0.063	4.211 ± 0.066	8.84 ± 0.75	0.938 ± 0.006
CGFM$^{w}/\mathcal{N}$	4.187 ± 0.008	4.340 ± 0.009	8.69 ± 0.50	0.936 ± 0.002	6.852 ± 0.045	7.114 ± 0.044	71.24 ± 3.71	0.666 ± 0.016
ICNN	4.286 ± 0.018	4.313 ± 0.112	38.6 ± 0.212	0.897 ± 0.031	4.194 ± 0.110	4.313 ± 0.112	37.9 ± 2.84	0.897 ± 0.008
MFM$^{w}/\mathcal{N}$ ($k = 0$)	3.940 ± 0.022	4.047 ± 0.023	3.91 ± 0.18	0.959 ± 0.006	3.896 ± 0.026	4.002 ± 0.030	$\mathbf{4.35 \pm 0.18}$	0.950 ± 0.005
MFM$^{w}/\mathcal{N}$ ($k = 10$)	3.976 ± 0.044	4.086 ± 0.049	4.52 ± 0.42	0.961 ± 0.002	3.943 ± 0.032	4.051 ± 0.034	5.28 ± 0.25	0.952 ± 0.001
MFM$^{w}/\mathcal{N}$ ($k = 50$)	3.968 ± 0.013	4.075 ± 0.014	4.36 ± 0.44	0.961 ± 0.002	3.934 ± 0.007	4.041 ± 0.008	4.99 ± 0.35	0.954 ± 0.000
MFM$^{w}/\mathcal{N}$ ($k = 100$)	3.937 ± 0.014	4.040 ± 0.015	3.94 ± 0.00	0.963 ± 0.001	3.908 ± 0.030	4.011 ± 0.033	4.68 ± 0.52	0.953 ± 0.002
MFM ($k = 0$)	3.874 ± 0.015	$\mathbf{3.973 \pm 0.020}$	3.37 ± 0.14	$\mathbf{0.967 \pm 0.003}$	$\mathbf{3.880 \pm 0.009}$	$\mathbf{3.990 \pm 0.011}$	4.68 ± 0.16	0.955 ± 0.002
MFM ($k = 10$)	3.896 ± 0.021	4.000 ± 0.021	3.82 ± 0.12	0.964 ± 0.001	3.899 ± 0.013	4.012 ± 0.011	5.13 ± 0.48	0.955 ± 0.001
MFM ($k = 50$)	3.888 ± 0.038	3.991 ± 0.030	3.59 ± 0.41	0.963 ± 0.001	3.900 ± 0.038	4.013 ± 0.034	5.06 ± 0.22	0.954 ± 0.003
MFM ($k = 100$)	3.906 ± 0.010	4.008 ± 0.005	4.05 ± 0.38	0.964 ± 0.002	3.898 ± 0.008	4.009 ± 0.009	5.19 ± 0.05	$\mathbf{0.957 \pm 0.000}$

Table 2: **High dimensional** (**dim = 43**) experimental results on the organoid drug-screen dataset across ***patient*** populations.

	Train				Test			
	$\mathcal{W}_1(\downarrow)$	$\mathcal{W}_2(\downarrow)$	MMD ($\times 10^{-3}$) ($\downarrow$)	$r^2(\uparrow)$	$\mathcal{W}_1(\downarrow)$	$\mathcal{W}_2(\downarrow)$	MMD ($\times 10^{-3}$) ($\downarrow$)	$r^2(\uparrow)$
FM	3.985 ± 0.054	4.115 ± 0.067	4.64 ± 0.43	0.938 ± 0.014	4.340 ± 0.078	4.564 ± 0.111	13.00 ± 0.67	0.865 ± 0.034
FM$^{w}/\mathcal{N}$	6.892 ± 0.027	7.164 ± 0.033	57.03 ± 1.00	0.655 ± 0.003	7.114 ± 0.1001	7.404 ± 0.086	64.97 ± 3.79	0.613 ± 0.008
CGFM	$\mathbf{3.882 \pm 0.019}$	3.999 ± 0.020	$\mathbf{3.16 \pm 0.59}$	0.952 ± 0.004	4.443 ± 0.033	4.621 ± 0.041	17.00 ± 1.03	0.899 ± 0.008
CGFM$^{w}/\mathcal{N}$	4.313 ± 0.077	4.480 ± 0.081	11.51 ± 1.96	0.918 ± 0.004	7.135 ± 0.045	7.390 ± 0.037	79.78 ± 4.67	0.637 ± 0.010
ICNN	4.289 ± 0.020	4.382 ± 0.021	37.0 ± 2.84	0.913 ± 0.003	4.525 ± 0.051	4.681 ± 0.054	74.0 ± 0.570	0.862 ± 0.127
MFM$^{w}/\mathcal{N}$ ($k = 0$)	3.982 ± 0.014	4.095 ± 0.015	5.04 ± 0.36	0.951 ± 0.002	4.177 ± 0.042	4.355 ± 0.048	10.53 ± 0.59	0.911 ± 0.001
MFM$^{w}/\mathcal{N}$ ($k = 10$)	4.006 ± 0.008	4.119 ± 0.012	5.13 ± 0.30	0.948 ± 0.001	4.156 ± 0.065	4.324 ± 0.067	9.58 ± 1.63	0.912 ± 0.003
MFM$^{w}/\mathcal{N}$ ($k = 50$)	3.982 ± 0.018	4.095 ± 0.016	4.74 ± 0.21	0.951 ± 0.002	4.153 ± 0.069	4.324 ± 0.070	9.63 ± 1.45	0.912 ± 0.002
MFM$^{w}/\mathcal{N}$ ($k = 100$)	4.004 ± 0.012	4.119 ± 0.014	5.19 ± 0.43	0.949 ± 0.002	4.166 ± 0.001	4.341 ± 0.003	9.52 ± 0.33	0.915 ± 0.005
MFM ($k = 0$)	3.905 ± 0.005	4.012 ± 0.006	4.18 ± 0.25	$\mathbf{0.958 \pm 0.001}$	4.209 ± 0.007	4.380 ± 0.012	12.34 ± 0.50	$\mathbf{0.918 \pm 0.002}$
MFM ($k = 10$)	3.896 ± 0.033	4.005 ± 0.036	3.89 ± 0.44	0.957 ± 0.005	4.216 ± 0.090	4.395 ± 0.098	11.99 ± 2.36	0.917 ± 0.005
MFM ($k = 50$)	3.902 ± 0.018	4.008 ± 0.022	4.20 ± 0.17	$\mathbf{0.958 \pm 0.000}$	4.214 ± 0.017	4.396 ± 0.020	12.09 ± 0.75	0.916 ± 0.002
MFM ($k = 100$)	3.884 ± 0.039	$\mathbf{3.986 \pm 0.044}$	3.77 ± 0.49	0.955 ± 0.001	$\mathbf{4.100 \pm 0.093}$	$\mathbf{4.269 \pm 0.104}$	$\mathbf{8.96 \pm 1.88}$	0.917 ± 0.004

Algorithm 1: Meta Flow Matching (training)

Input : Dataset of populations $\{(\pi(x_0, x_1 \mid i), c^i)\}_{i=1}^N$ and treatments c^i, and parametric models $v_t(\cdot;\omega), \varphi(\cdot;\theta)$.

for *training iterations* **do**

$i \sim \mathcal{U}_{\{1,N\}}(i)$ `// sample a batch of` n `populations ids`

$(x_0^j, x_1^j, t^j) \sim \pi(x_0, x_1 \mid i)\mathcal{U}_{[0,1]}(t)$ `// sample batch of` n_i `particles for every population` i

$f_t(x_0^j, x_1^j) \leftarrow (1 - t^j)x_0^j + t^j x_1^j$,

$h^i(\theta) \leftarrow \varphi\left(\{x_0^j\}_{j=1}^{N_i}; \theta\right)$ `// embed the entire population` $\{x_0^j\}_{j=1}^{N_i}$ `into` $h^i(\theta)$. `In CGFM` $h \leftarrow i$. `In FM` $h \leftarrow \emptyset$.

$\mathcal{L}_{\text{MFM}}(\omega, \theta) \leftarrow \frac{1}{n}\sum_i \frac{1}{n_i}\sum_j \left\| \frac{\partial}{\partial t} f_t(x_0^j, x_1^j) - v_{t^j}\left(f_t(x_0^j, x_1^j) \mid h^i(\theta), c^i; \omega\right)\right\|^2$

$\omega' \leftarrow \text{Update}(\omega, \nabla_\omega \mathcal{L}_{\text{MFM}}(\omega, \theta))$ `// evaluate new parameters of the flow model`

$\theta' \leftarrow \text{Update}(\theta, \nabla_\theta \mathcal{L}_{\text{MFM}}(\omega, \theta))$ `// evaluate new parameters of the embedding model`

$\omega \leftarrow \omega', \quad \theta \leftarrow \theta'$ `// update both models`

return $v_t(\cdot;\omega^*), \varphi(\cdot;\theta^*)$

Table 3: Synthetic letters experiment for population prediction on fully unseen test populations (Y's).

	Test		
	$\mathcal{W}_1$	$\mathcal{W}_2$	MMD ($\times 10^{-3}$)
FM	0.238 ± 0.000	0.316 ± 0.000	3.32 ± 0.01
FM$^{w}/\mathcal{N}$	1.030 ± 0.000	1.228 ± 0.000	45.36 ± 0.00
CGFM	0.327 ± 0.000	0.405 ± 0.000	6.85 ± 0.00
CGFM$^{w}/\mathcal{N}$	1.062 ± 0.011	1.229 ± 0.010	55.66 ± 0.76
MFM$^{w}/\mathcal{N}$ ($k = 0$)	0.402 ± 0.011	0.485 ± 0.010	10.92 ± 0.18
MFM$^{w}/\mathcal{N}$ ($k = 1$)	0.391 ± 0.035	0.477 ± 0.041	10.71 ± 1.86
MFM$^{w}/\mathcal{N}$ ($k = 10$)	0.413 ± 0.018	0.502 ± 0.024	11.93 ± 1.14
MFM$^{w}/\mathcal{N}$ ($k = 50$)	0.446 ± 0.021	0.536 ± 0.028	13.40 ± 0.23
MFM ($k = 0$)	0.218 ± 0.001	0.262 ± 0.002	3.79 ± 0.11
MFM ($k = 1$)	0.215 ± 0.006	0.258 ± 0.007	3.78 ± 0.25
MFM ($k = 10$)	0.208 ± 0.003	0.252 ± 0.002	3.55 ± 0.06
MFM ($k = 50$)	$\mathbf{0.204 \pm 0.005}$	$\mathbf{0.249 \pm 0.006}$	$\mathbf{3.14 \pm 0.18}$

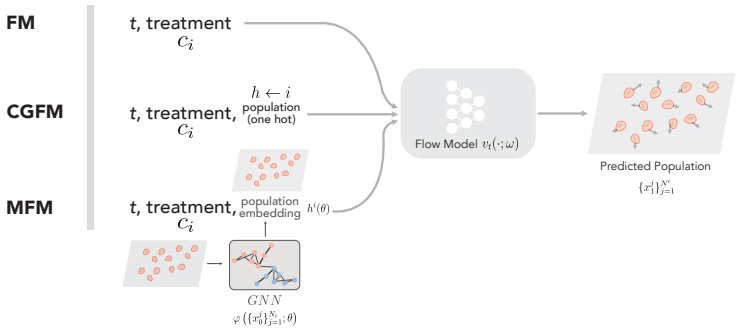

Figure 1: Illustrative comparison between Flow Matching (FM), conditional flow matching (CGFM), and Meta Flow Matching (MFM).