

INTRODUCTION

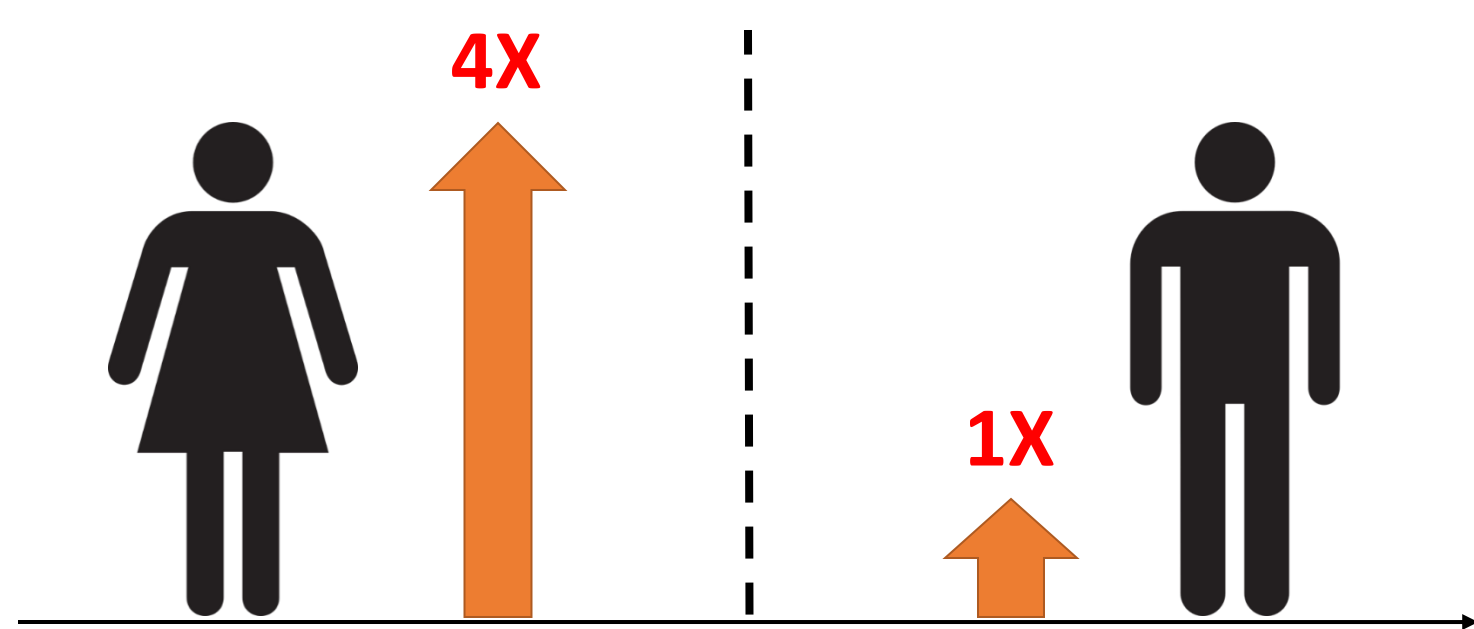
Chronic Fatigue Syndrome (CFS), a **debilitating** medical condition, continues to silently affect and even totally renders **incapable** an **increasing** number of people in the present days.

CFS Symptoms

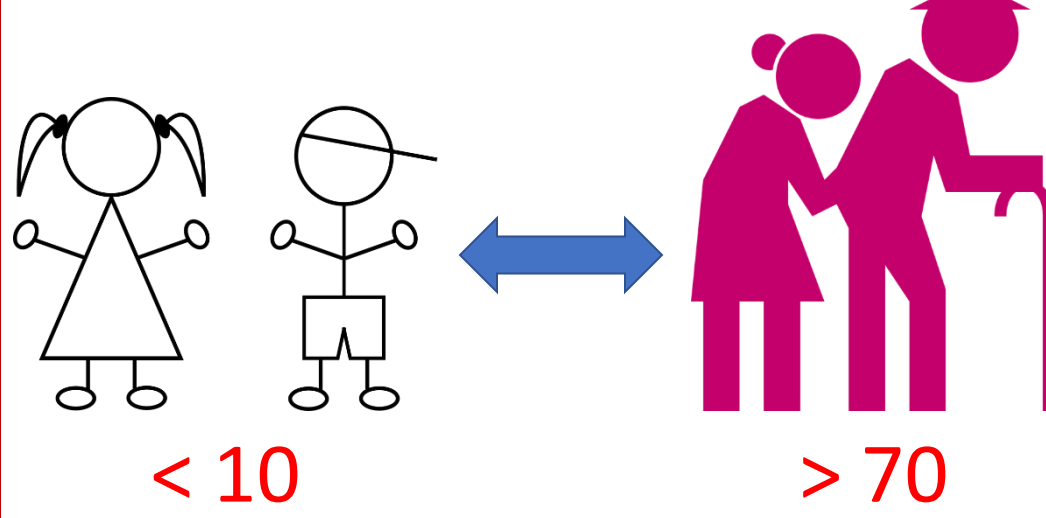
1. Profound **fatigue**2. Postexertional **malaise**3. **Unrest** sleep cycle4. **Cognitive difficulties** and orthostatic intolerance

• CFS affects a wide range of populations in terms of age, sex, racial and ethnic background.

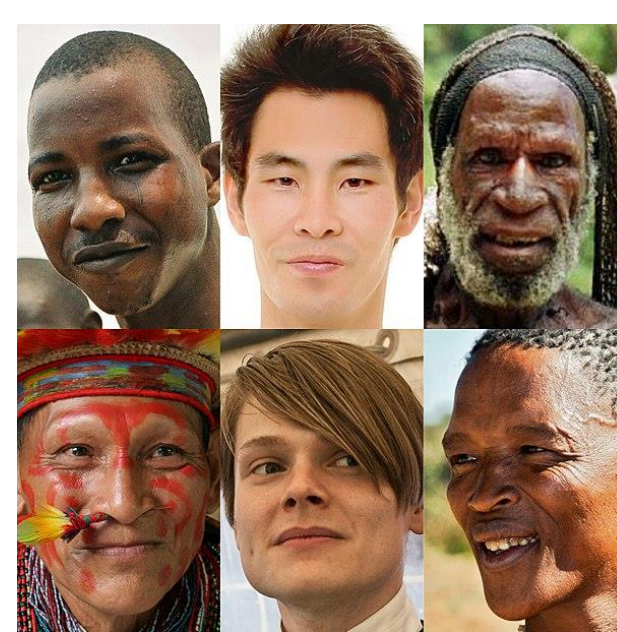
Affected Gender Distribution



Affected Age Distribution



Affected Races

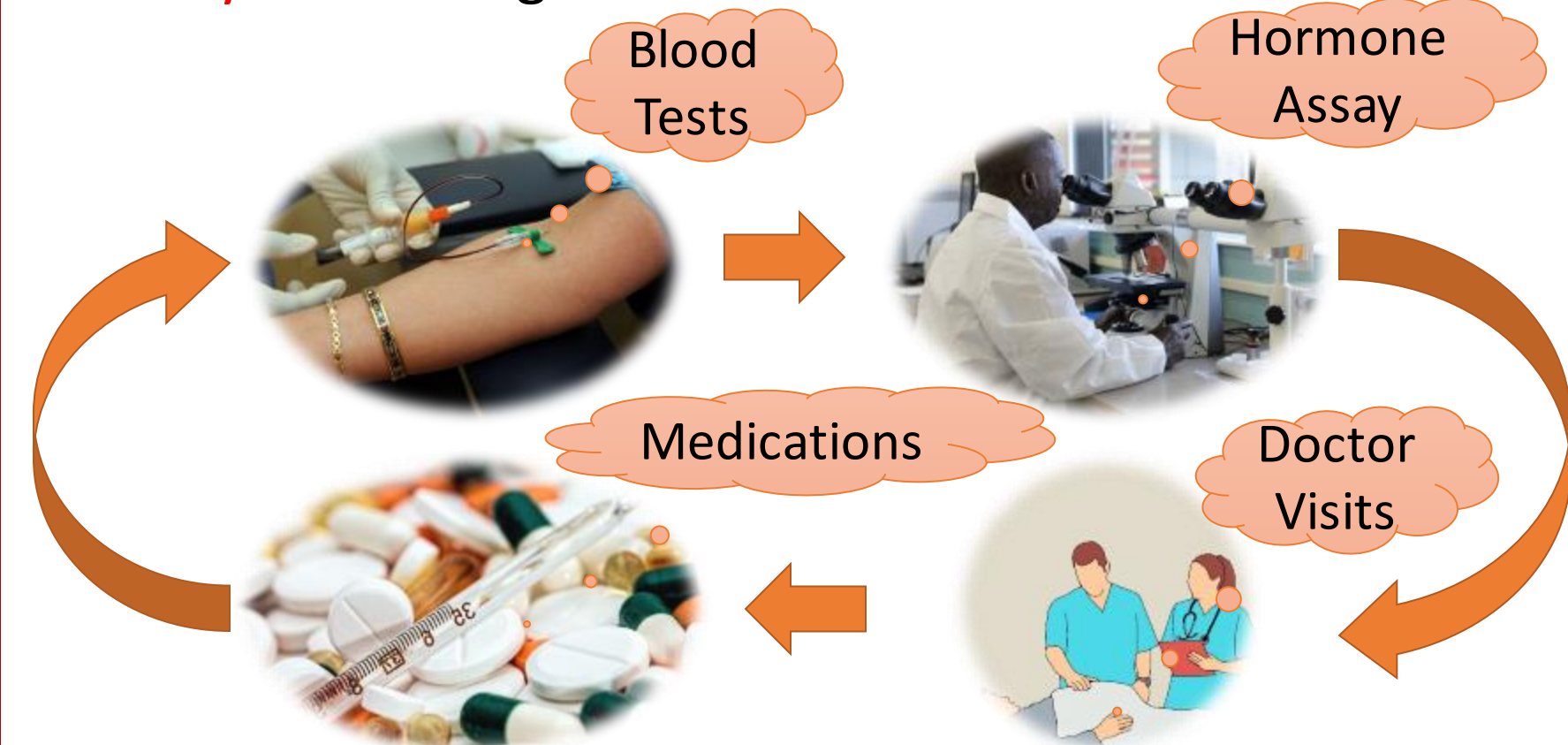


• CFS patients, their families, and society **all** bear **costly** burdens associated with CFS.

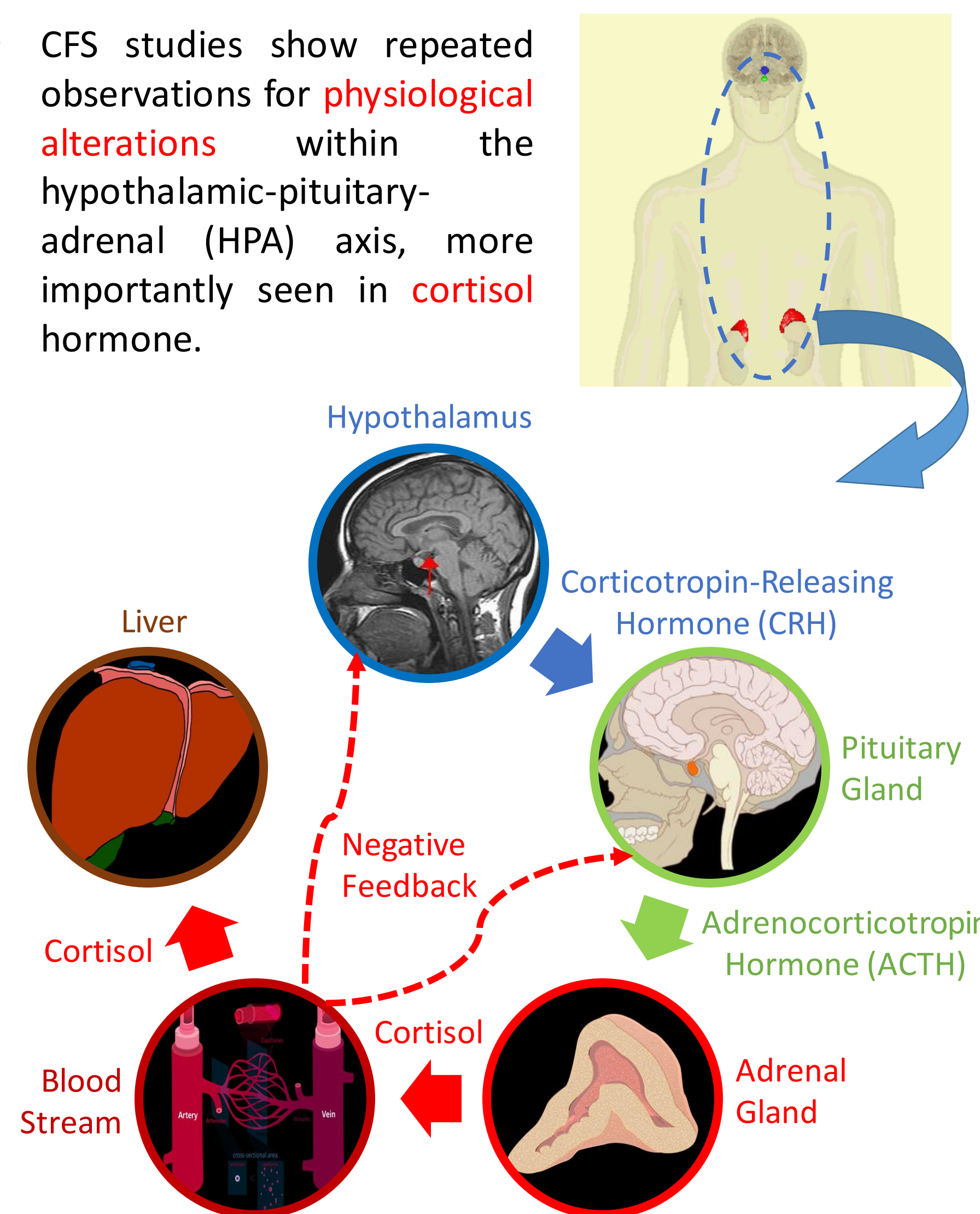
Economic Impacts of CFS

Approximated number of affected individuals	1,000,000 – 4,000,000
Estimated annual cost of lost productivity for the U.S.	\$9 – 37 Billion
Estimated direct medical cost	\$9 – 14 Billion
Direct out-of-pocket medical expenses paid by individuals with CFS	\$2 – 3.2 Billion

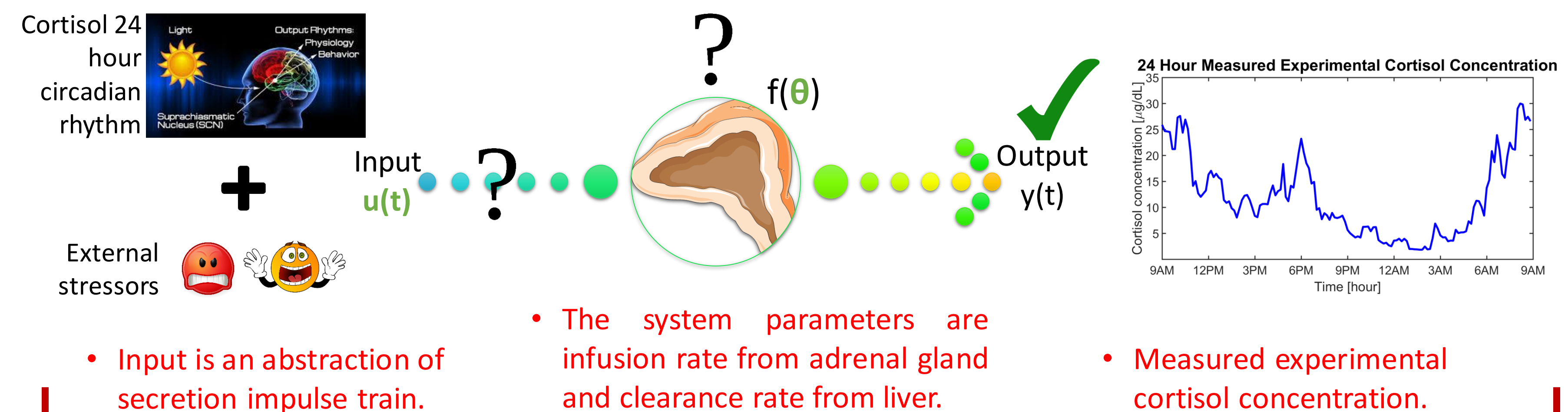
• As of right now, there is neither **therapeutic** treatment nor **systemic** diagnosis.



- CFS studies show repeated observations for **physiological alterations** within the hypothalamic-pituitary-adrenal (HPA) axis, more importantly seen in **cortisol** hormone.



METHODS



- Input is an abstraction of secretion impulse train.

- The system parameters are infusion rate from adrenal gland and clearance rate from liver.

- Measured experimental cortisol concentration.

State-Space Model and Optimization Problem Formulation [1]

HPA Axis States Equation:

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} -\theta_1 & 0 \\ \theta_1 & -\theta_2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u$$
$$y = \begin{bmatrix} 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

Solution to State-Space model:

$$y = A_\theta y_0 + B_\theta u + v$$

Optimization Problem Formulation:

$$J(\theta, u) = \frac{1}{2} \|y - A_\theta y_0 - B_\theta u\|_2^2 + \lambda \|u\|_p^p$$

Coordinate Descent Algorithm [1] Overview

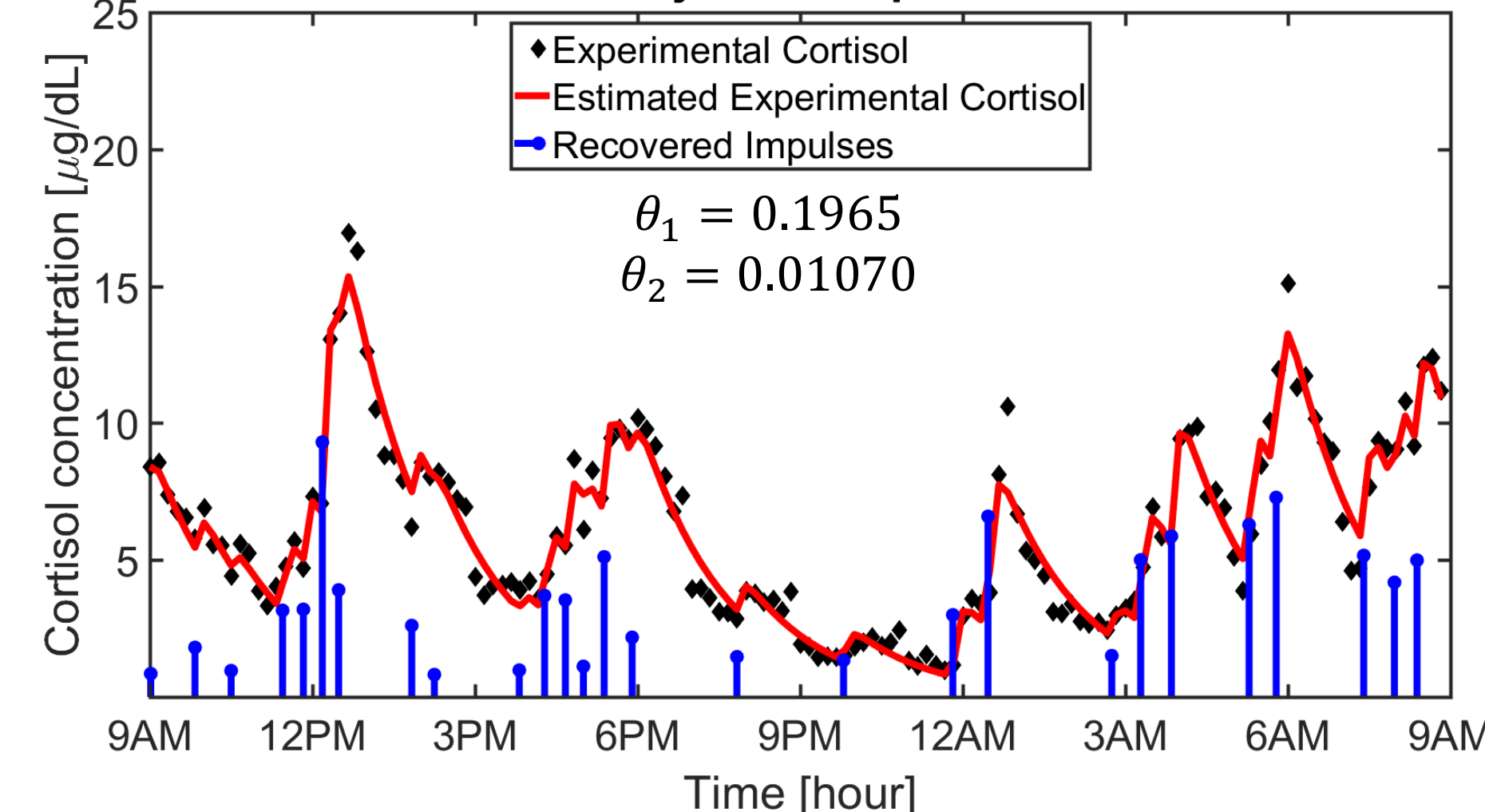
Multiple Random Initializations of System Parameters

Sparse Identification
Until Convergence
System Parameters Estimation

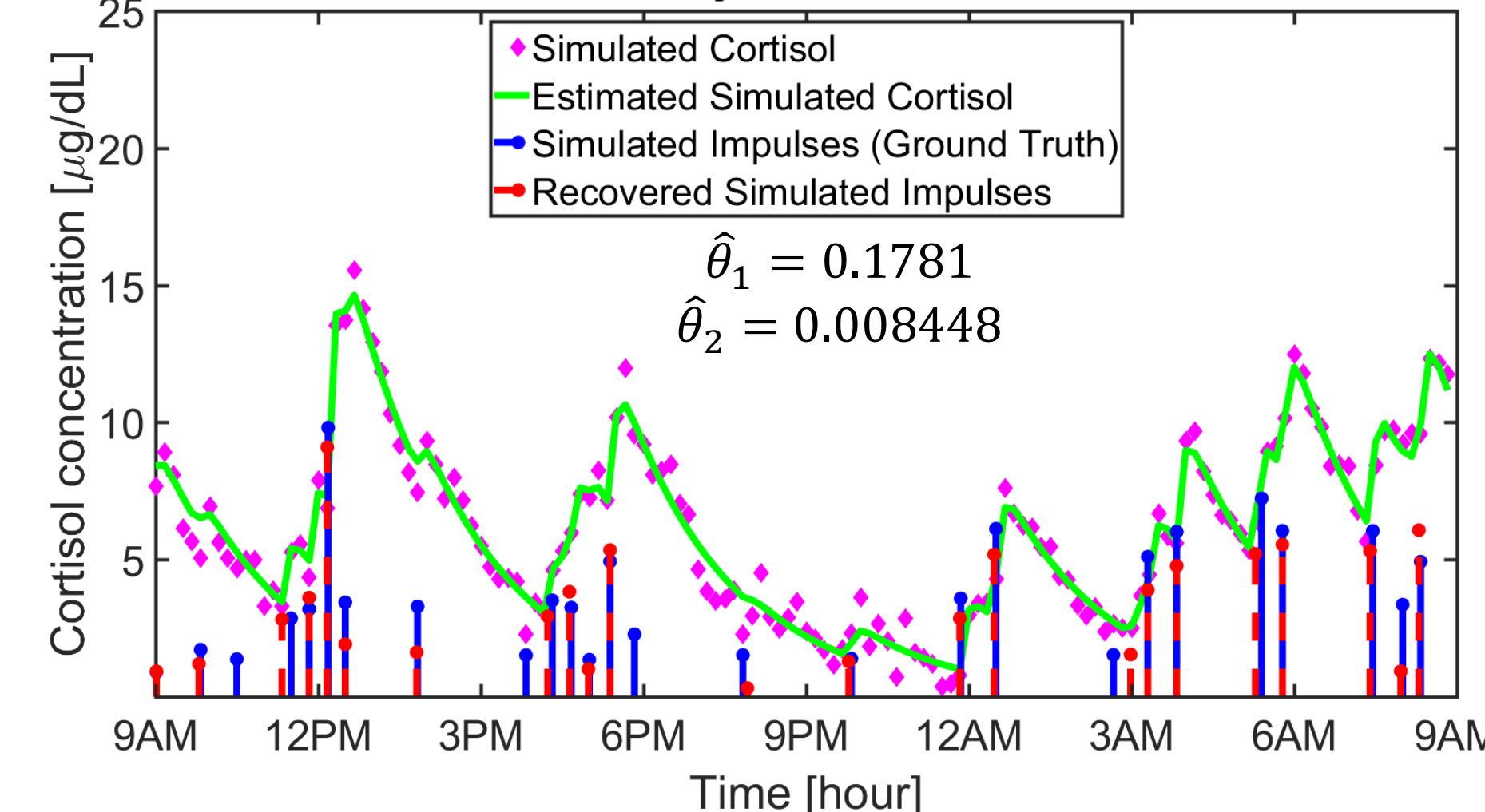
RESULTS

We applied the deconvolution on cortisol data collected by Crofford *et al.* [2] of CFS patients and their matched healthy controls.

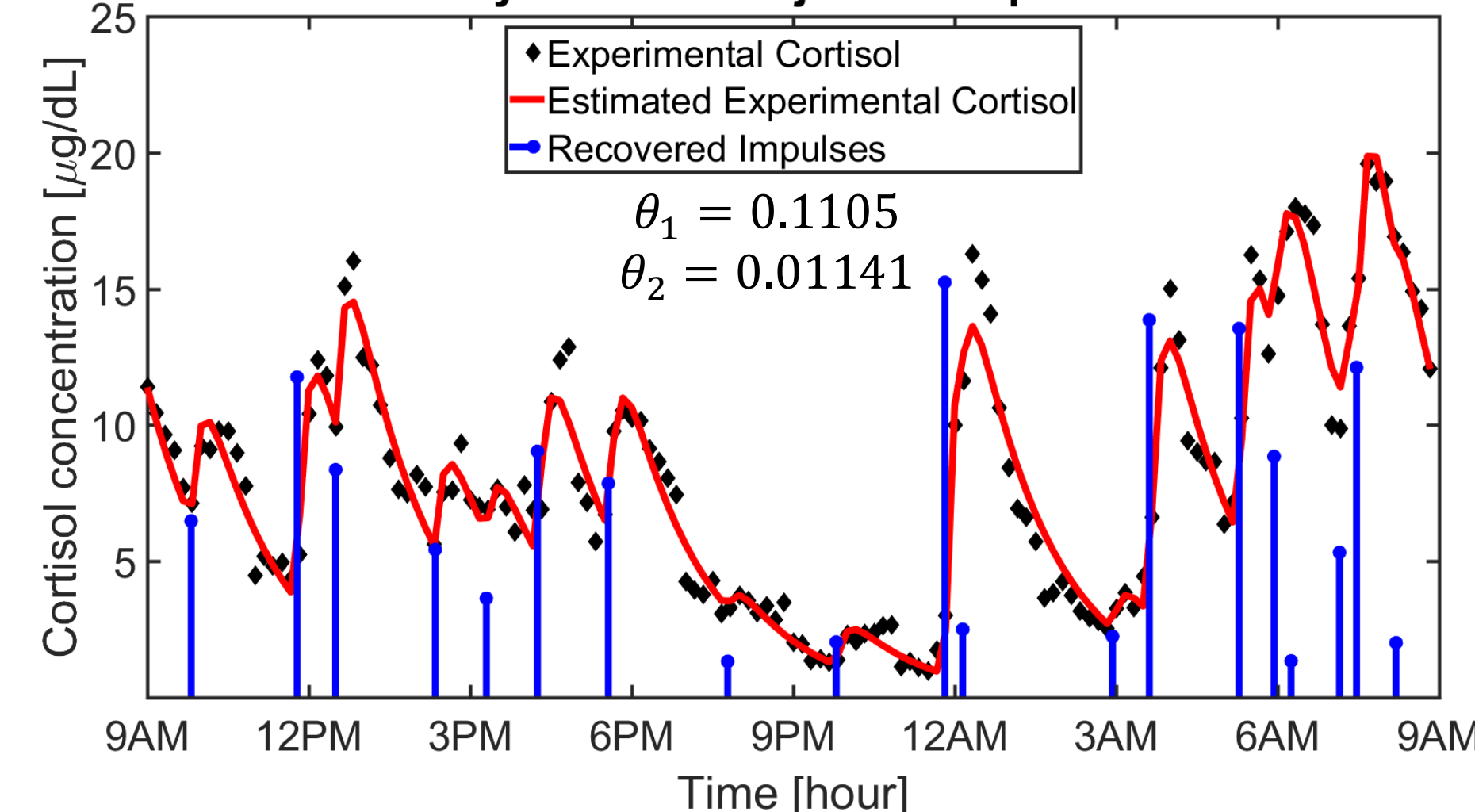
Results From CFS Subject 11 Experimental Cortisol Data



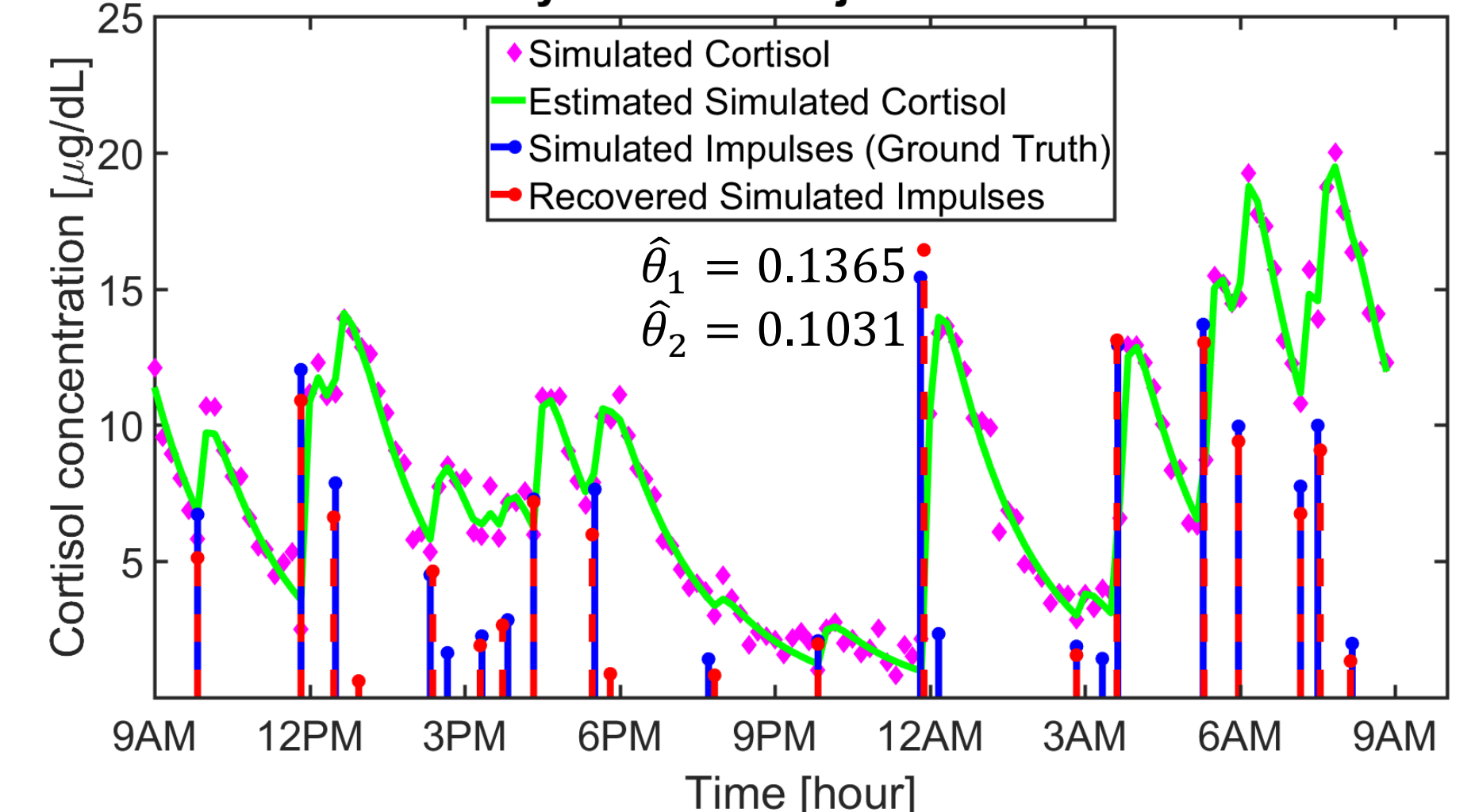
Results From CFS Subject 11 Simulated Cortisol Data



Results From Healthy Control Subject 11 Experimental Cortisol Data



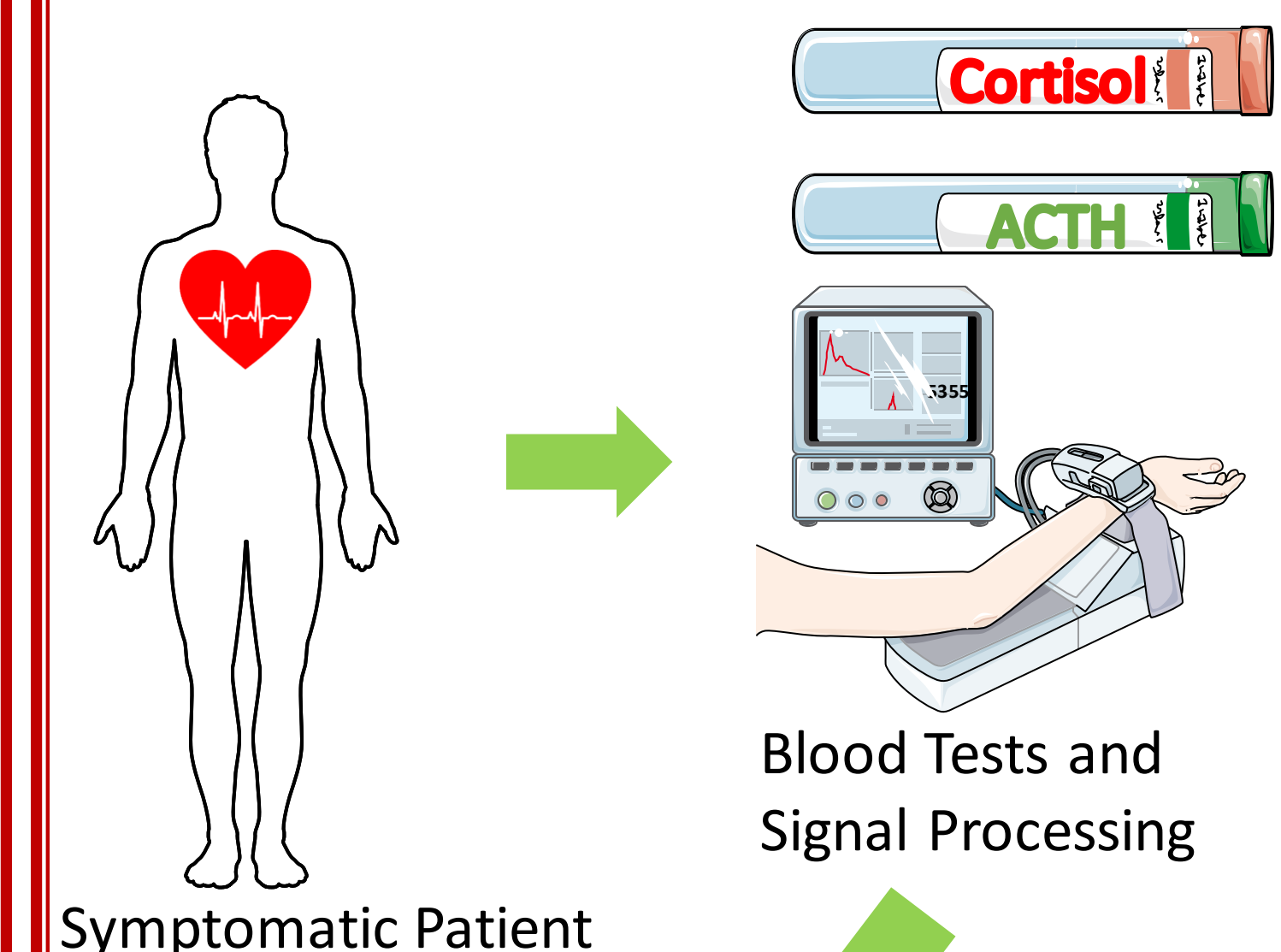
Results From Healthy Control Subject 11 Simulated Cortisol Data



DISCUSSION

- CFS is a debilitating illness and its **etiology** still remains **enigmatic** today.
- We obtain numbers, timings, and amplitudes of cortisol impulses along with cortisol infusion and clearance rates with R^2 above 0.88.
- Comparing the **mean amplitudes of the impulses** during the **nadir to peak (2AM to 9AM) time window**, the Wilcoxon signed rank test at an $\alpha=0.05$ level of significance revealed that the difference between the CFS patients and control subjects was significant.
- We hypothesize that analysis of **cortisol and ACTH** secretion pattern together can lead to diagnosis of CFS. **ACTH/cortisol concurrent deconvolution** could be the extension of this work.

Future Work



CFS Severity Scale

ACKNOWLEDGEMENT

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REFERENCES

1. Faghih, Rose T., et al. "Deconvolution of serum cortisol levels by using compressed sensing." *PLoS one* 9.1 (2014): e85204.
2. Crofford, Leslie J., et al. "Basal circadian and pulsatile ACTH and cortisol secretion in patients with fibromyalgia and/or chronic fatigue syndrome." *Brain, behavior, and immunity* 18.4 (2004): 314-325.