Using Fluorescence Nanosensors to Detect Vitamin B_{12} Deficiency

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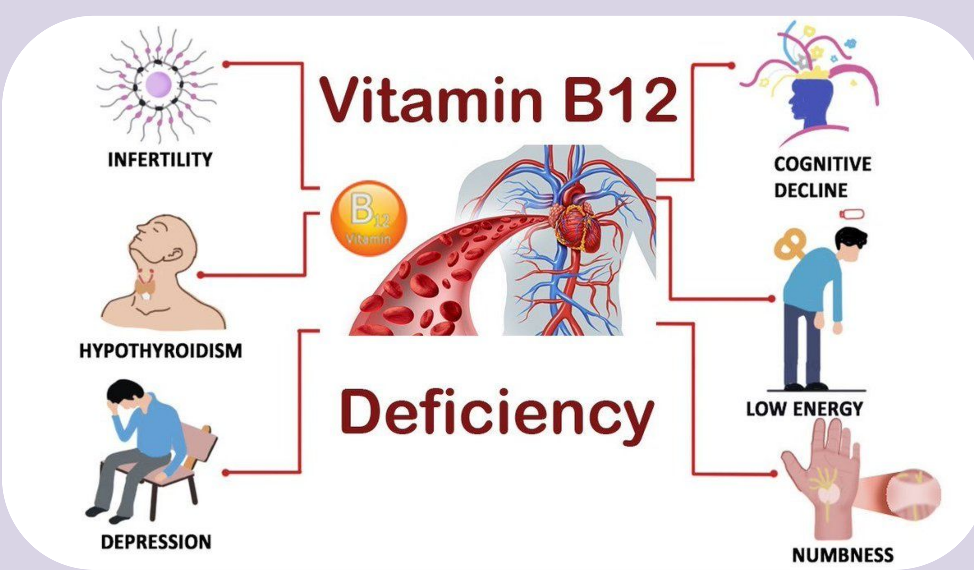
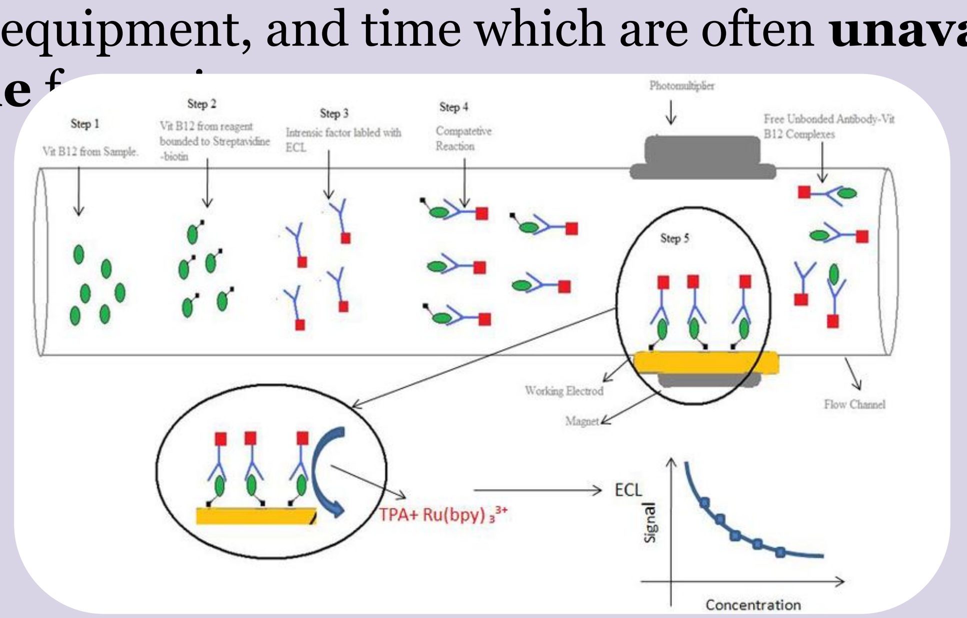
Problem and Solution

Problem: Vitamin B_{12} is crucial for neurological function, the production of red blood cells, and DNA synthesis. Vitamin B12 deficiency anemia is extremely common in the US with *over 3 million* diagnosed cases every year. Its symptoms include muscle weakness, shortness of breath, memory loss, and nausea.
Solution: Our solution seeks to develop new methods for vitamin B_{12} detection using nanosensors to improve accessibility and detection speed. Similarly to a glucose meter, our device will take a small blood sample then analyze it using nanosensors that detect the cobalt structure of vitamin B_{12} as well as the symptoms of vitamin B_{12} deficiency such as high methylmalonic acid levels.



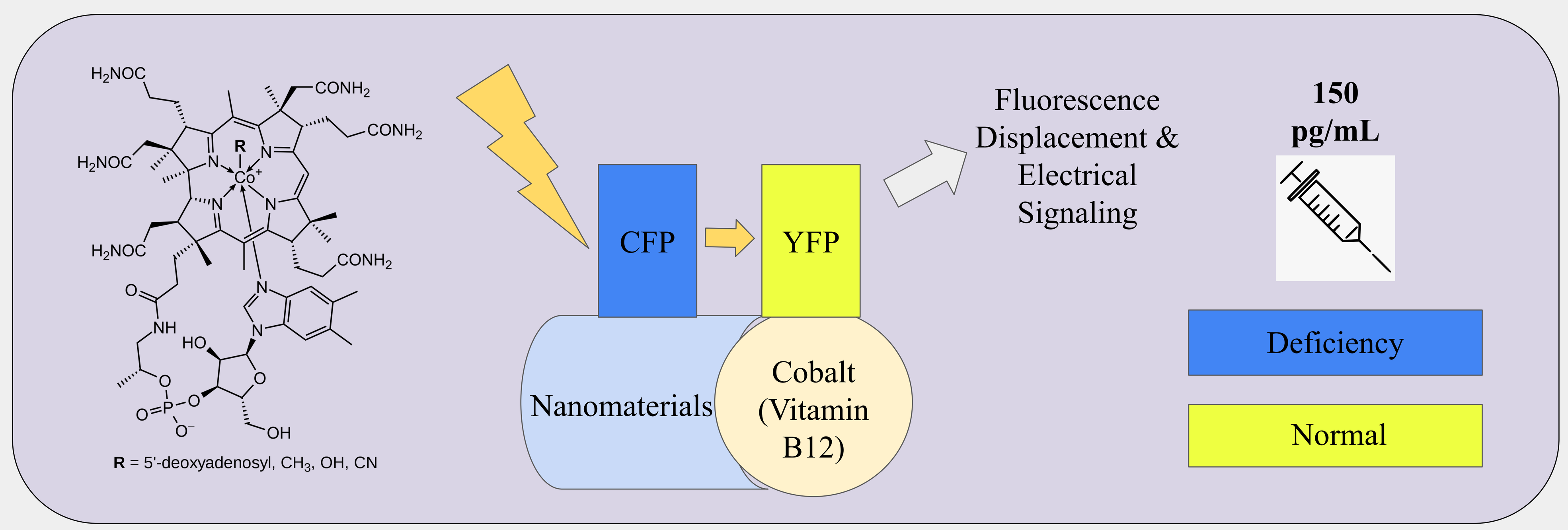
History and Alternatives

Historically, vitamin B_{12} levels were detected with **microbiological methods**. Microbes that could only grow in the presence of B_{12} would be grown in a culture containing a patient's blood serum to test for B_{12} levels. However, this was time consuming, tedious, and could fail if the patient was taking antibiotics. Using similar mechanism, blood serum tests are currently utilized to check levels of vitamin B_{12} and complete blood cells (CBC) counts to identify this deficiency.
One of the most common current detection methods uses **electroluminescence**: a process where biotinted B_{12} is added to a mixture of reactive molecules that produce light proportional to the level of vitamin B_{12}.
Additionally, mass spectrometry, atomic absorption spectroscopy, high-performance liquid chromatography, capillary electrophoresis, and radioimmunoassay are some common methods for vitamin B_{12} detection. All these tests require professional expertise, expensive laboratory equipment, and time which are often **unavailable** or **unsuitable**



Solution & Sketches

1. **Blood Drop:** The patient first drops blood into the medical device.
2. **Binding**: Nanomaterial is released from the device to the blood, allowing the nanomaterial ligand to create a noncovalent bond to the specific molecular structures in vitamin B_{12}– cobalt. Vitamin B_{12} has octahedral cobalt and corrin rings, unique from any other types of vitamin. The nanomaterial is specifically designed to match with cobalt for detection.
3. **FRET**: After the binding, a fixed range of wavelengths are emitted from the device, activating cyan fluorescence protein (CFP) on the nanomaterial. Following the CFP activation, yellow fluorescence protein (YFP) will be activated through the signaling process that only works within 10 nanometers. This process is also known as fluorescence resonance energy transferring process (FRET).
4. **Signaling**: FRET will send an optimal electrical signal to the device, converting it into a numerical value that allows the patient to know their vitamin B_{12} level. Additionally, the FRET provides a fluorescence (color) level of deficiency, providing easy recognition for older patients.
5. **Results**: Through the numerical levels provided, patients can go to their doctors for a Vitamin B_{12} injection or an intracellular cobalt injection to counteract the vitamin deficiency.



Testing, Benchmarking, and Comparison to Alternatives

Testing: Our device will be tested in a laboratory setting using various human blood samples containing low or high amounts of vitamin B_1. Data collected from these trials will then be used to discover the complications in recognizing deficiency of B_{12} in the patient's bloodstream.
Comparison to Alternatives: The current Vitamin B_{12} deficiency blood test requires the analysis of serum or plasma with a complete blood cell counts (CBC) initially. Afterwards, an MMA (methylmalonic acid test) levels are ordered to indicate lower B_{12} or folate levels in the body. However, this process requires going into the health office, which takes few business days to be processed. Through the **at-home concept**, the process is much faster and cost-efficient in terms of constant reuse, making detection easier for constant vitamin B_{12} deficiency patients.
Benchmarking: The results will indicate success if our nanosensor solution has similar level of vitamin B12 compared to traditional Vitamin B_{12} testing, while creating a cheaper and reusable device. Ultimately, our device will be easier, less time-consuming, and cost-efficient.

Technical Challenges

With current technological advances, our idea provides an innovative and plausible solution to test for Vitamin B_{12} deficiency anemia. However, there are possibilities where cobalt and methylmalonic acid levels are incorrectly detected within the blood sample, leading to a **falsifying** diagnosis for cobalamin deficiency. Furthermore, with little to no previous research on the usage of nanosensors in disease detection, there are chances for FRET electrical signals to be **incorrectly** displayed and different fluorescent proteins being activated through the nanosensors.

Ethical & Social Concerns

Our device will be tested first in **laboratory trials** with blood samples of patients with B_{12} deficiency anemia along with healthy citizens to ensure that **accurate results** are provided to the final user. By doing so, our goal is to discover and eliminate all risks that occur in the product and evaluate its effectiveness, especially if there is variation in results based on environmental and racial differences.

A proper diagnosis is crucial for the patient to know what further steps are necessary to resolve this issue, and being able to quickly identify B_{12} deficiency **at home** will play a key factor in the success of our device. However, since there has been minimal research regarding the use of nanosensors to detect various diseases, **accepting** and **trusting** in our technology to provide accurate data could be problematic for potential stakeholders.

When marketing our device to laboratories and pharmaceutical centers, **age** is a varying factor for **sales** and the **practicality** of our device. Humans of all ages are prone to B_{12} deficiency anemia, but the factor that differentiates these age groups is that life threatening effects are predominantly seen in mature adults, especially those with **pernicious anemia**. We will be able to target our device to citizens that fall within this category to maximize sales and development of our product throughout the world.

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