MOROMOS 2025: MOLECULAR ROTORS, MOTORS & SWITCHES

25.-26. SEPTEMBER 2025, PRAGUE, CZECH REPUBLIC

BOOK OF ABSTRACTS

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ÚOCHB AV ČR
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Thursday 25th of September 2025

8:30-8:45	CONFERENCE OPENING	
8:45-9:35	**Ben FERINGA**	Light-powered Rotary Molecular Motors
9:35-10:25	**Angiolina COMOTTI**	Engineering Rotors and Switches in Porous Materials: Dynamics Control by Guests and Irradiation
10:25-11:00	COFFEE BREAK + POSTER SESSION	
11:00-11:50	**Steve GOLDUP**	Making the Mechanical Bond Useful: the Synthesis, Symmetry and Applications of Interlocked Molecules
11:50-13:30	LUNCH BREAK	
13:30-14:20	**Alberto CREDI**	Using Light to Operate Artificial Molecular Motors and Pumps
14:20-15:10	**Miguel GARCIA-GARIBAY**	Crystalline Molecular Rotors Under Viscous and Inertial Regimes
15:10-16:00	COFFEE BREAK + POSTER SESSION	
16:00-16:50	**Arri PRIIMÄGI**	On Photoswitchable Surfaces and Moving Polymer Films
16:50-17:40	**Gwénaël RAPENNE**	Prototypes of Molecular Motors, Winches and Gears
17:40-18:30	**Amar Hugh FLOOD**	Switching and Dynamics in Anion-driven Assemblies
18:30	CONFERENCE DINNER	(invited speakers)

Friday 26th of September 2025

9:00-9:50	**Nathalie KATSONIS**	Mechanochemistry of Artificial Molecular Motors
9:50-10:40	**Rainer HERGES**	Chiral Diazocines and Supramolecular Catalysis
10:40-11:10	COFFEE BREAK + POSTER SESSION	
11:10-12:00	**Zbigniew L. PIANOWSKI**	Illuminating Biology with Molecular Photoswitches
12:00-13:40	LUNCH	
13:40-14:30	**Henry DUBE**	Indigoid Molecular Machines
14:30-15:20	**Eric MASSON**	Phantom Hosts: Predicting Binding Affinities to Macrocycles Without Ever Invoking Them
15:20-16:00	COFFEE BREAK + POSTER SESSION	
16:00-16:50	**Bo DURBEEJ**	Improved Molecular Photoswitching and Photogearing: Some Insights from Computational Modeling
16:50-17:40	**Jiří KALETA**	Surface Mounted Molecular Devices
17:40-18:00	CLOSING REMARKS	
18:00	CONFERENCE DINNER	(invited speakers)

SURFACE-DECOUPLED ALTITUDINAL AND AZIMUTHAL TRIPTYCENE-FUSED TETRAPODAL MOLECULAR MOTORS

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The development of molecular machines capable of converting light energy into controlled mechanical motion on surfaces is a major frontier in nanoscale engineering. Achieving efficient operation of unidirectional light-driven motors on surfaces requires simultaneous control over multiple design parameters, including orientation, anchoring, electronic decoupling, structural rigidity, and spatial isolation.[1]

Here, we report the design, synthesis, and surface-immobilized operation of two geometrically distinct, photoresponsive molecular motors (Figure 1), each based on a rigid tetrapodal triptycene scaffold. These systems differ in the orientation of their rotation axes—nearly parallel (altitudinal) or perpendicular (azimuthal) to the gold substrate. Both motors exhibit unidirectional rotation upon light stimulation, as demonstrated through photochemical studies in solution and functional self-assembled monolayers on Au(111). Strong surface adhesion is achieved via multidentate anchoring, while the stiff triptycene core ensures structural integrity and isolation from neighboring units. These molecular architectures represent versatile, surface-compatible components for next-generation light-driven nanomachinery.[2]

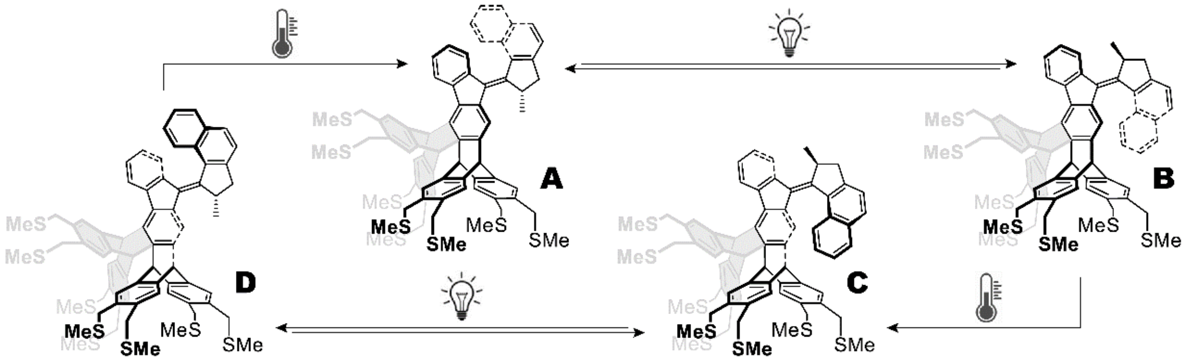

Figure 1. Four-stages unidirectional rotation cycle of molecular motors.

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Mechanochemical control over molecular motors in elastomer networks

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The integration of artificial molecular machines into soft matter has opened avenues to regulate macroscopic material properties, yet such approaches have largely remained one-directional: from the molecular to the macroscopic[1]. Harnessing the full potential of artificial molecular machines requires going beyond this paradigm and enabling feedback, where machine function adapts to environmental conditions[2], as in biology. For example, the rotary motor of Escherichia coli modulates its rotation speed according to the viscosity of the surrounding medium[3]. Inspired by this principle, we show that overcrowded-alkene molecular motor embedded in polymer networks accelerates its rotary frequency under mechanical stretching. By combining full-spectrum UV–Vis fitting with kinetic analysis, we directly quantify the force-accelerated thermal helix inversion steps within the rotary cycle. This work introduces a strategy to actively couple mechanical stress with molecular motor dynamics, providing a foundation for the design of adaptable materials that integrate artificial molecular machines as responsive elements.

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Precise chemical tools for photopharmacology based on Hemipiperazines

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Photopharmacology is an emerging drug development approach that harnesses light to achieve precise spatiotemporal control over therapeutic activity. Inspired by Paul Ehrlich's "magic bullet" concept of selectively targeting diseased tissues while sparing healthy ones, photopharmacology aims to overcome common limitations of traditional therapies such as systemic toxicity, off-target effects, and drug resistance. This strategy relies on light-induced isomerization of molecules, where each isomer exhibits distinct biological activities. Common photoswitches such as azobenzenes and spiropyrans have been widely studied but suffer from key drawbacks, including activation by UV light, toxic metabolites and hydrophobicity, limiting their application in aqueous biological environments.[1]

To address these limitations, hemipiperazines (HPIs), a novel class of peptide-derived photoswitches, have emerged as promising alternatives. HPIs are activated by visible light and +function effectively in aqueous environments, making them well-suited for therapeutic applications. We have synthesized a key intermediate as part of our ongoing efforts to develop a trimethoprim (TMP)-HPI conjugate.[2]

Natural products such as neihumicin and nocazines, which inherently possess hemipiperazine-like motifs, exhibit notable cytotoxic and antibacterial properties, positioning them as valuable scaffolds for photopharmacological development. As we plan to synthesize them, we explore the influence of methylation pattern and other structural modifications within the diketopiperazine (DKP) core, and their influences on the photoswitching behavior. By elucidating these structure–function relationships, we aim to guide the rational design of next-generation HPI-based therapeutics with enhanced selectivity, efficacy, and photochemical performance.

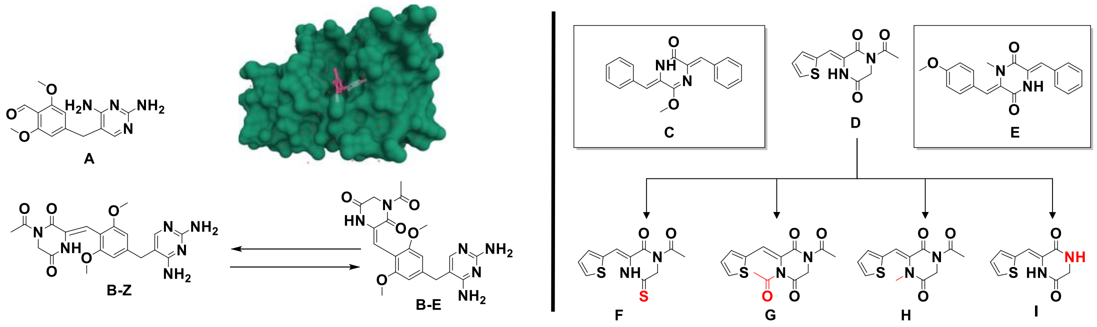

Figure 1: ***left:*** **A**: key intermediate for the TMP-HPI conjugate; structure of dihydrofolatreductase with TMP; TMP-HPI conjugate ***right:*** thiophen-HPI and its core modifications; **C**: neihumicin; **E**: nocazine A

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PHOTOSWITCHABLE CUCURBIT[7]URILS

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Milan Mašat,[a] and Jiří Kaleta[a]

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Self-assembled monolayers (SAMs) with photoresponsive functionality were constructed on gold surfaces through the use of host–guest complexes incorporating cucurbit[7]uril (CB[7]). In this system, CB[7] functions as a universal anchoring motif, binding to the gold substrate via one of its portals, while the opposite portal captures a photoswitchable molecular rod bearing a pyridinium–adamantyl recognition element. To showcase the flexibility of this modular design, four different molecular rods were synthesized. In solution, the supramolecular CB[7] complexes[1] maintained the intrinsic light-responsive behavior of the original rods, undergoing reversible isomerization with minimal influence from complexation and demonstrating excellent fatigue resistance. Once immobilized on surfaces, the resulting monolayers preserved their photoactivity, as confirmed by the light-triggered isomerization of a representative diarylethene derivative. These findings highlight the promise of CB[7]-mediated architectures in developing stable, switchable molecular interfaces and devices.

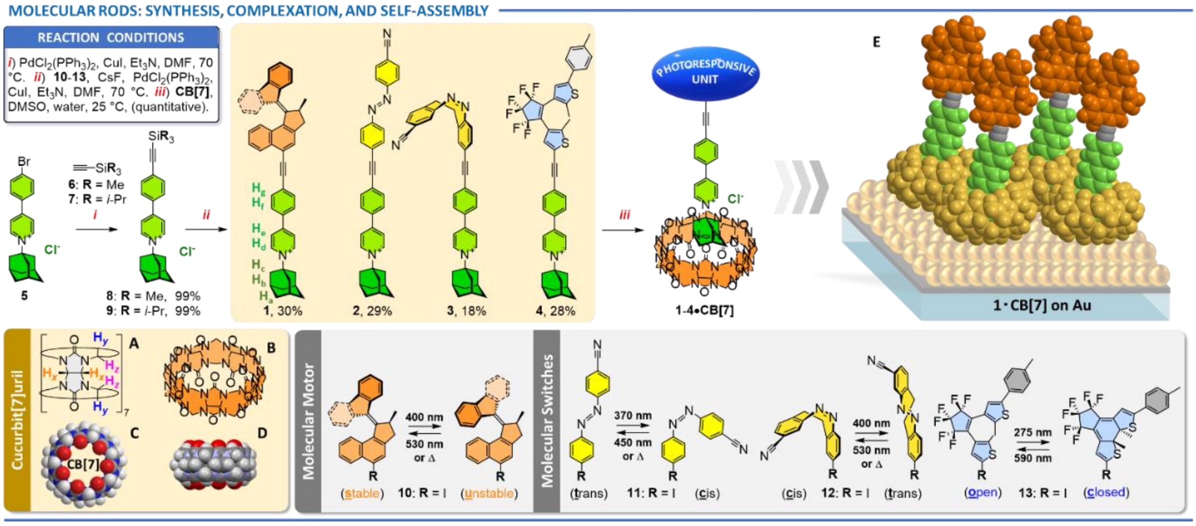

Figure 1. Synthesis of molecular rods **1**-**4** and their reaction with **CB[7]** leading to supramolecular complexes **1-4·CB[7]**. **CB[7]**: a schematic representation (A), chemical structure (B), and top (C) and side (D) view on a space-filling model. Idealized visualization of **1·CB[7]** on a gold surface (E).

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Sensitized Azoarene Disequilibration with water soluble polymers

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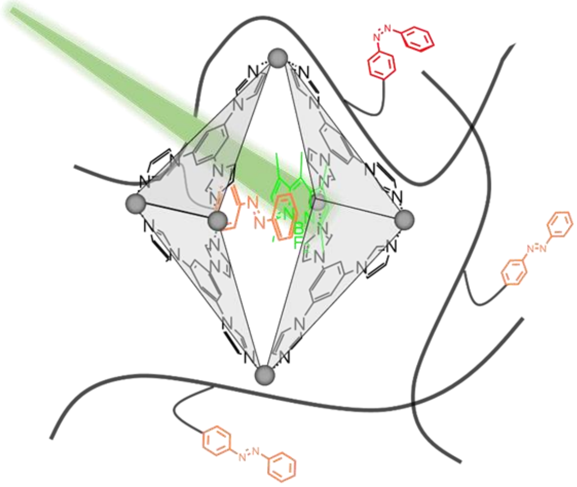

Molecular photoswitches are a popular motif to integrate light-responsivity to a supramolecular system. As the *E*-Z isomerization of unsubstituted azobenzenes can only be achieved by irradiation with UV-light, great synthetic effort has been put into red-shifting this excitation wavelength to the visible and NIR region, introducing different substitution patterns, opening up possibilities to be used in the medical sector. Recently, Gemen et al. presented a novel approach to red-shift azobenzene-isomerisation, called “**DESC**”, confining different azobenzenes alongside a sensitizer molecule within a supramolecular cage, allowing triplet-energy-transfer from the sensitizer onto the azobenzene, yielding the isomerisation of the molecular switch, circumventing the need for tedious synthetic modifications.[1] We are advancing this technique into water-soluble polymeric systems, probing its general potential for macromolecular systems. Our study focuses on dimethylacrylamide based azopolymers and BODIPY-polymers, optimizing both the polymer architectures but also photoswitch structure to maximize switching using DESC, reaching up to 70 % efficiency for azopolymers and nearly quantitative switching of monomeric azopyrazoles using BODIPY-polymers. The combination of both polymeric systems or the use of bivalent linkers is probed as platforms for the creation for supramolecularly linked polymeric assemblies. These will serve as basis for the creation of hydrogels or other soft materials.

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Engineering molecular rotors and switches in low-density architectures: from single-molecule motion to framework dynamics

Jacopo Perego,[a] Charl X. Bezuidenhout,[a] Silvia Bracco,[a] Sergio Piva,[a] Jinyu Sheng,[b,c] Wojciech Danowski,[b,d] Ben L. Feringa,[b] Jiří Kaleta,[e] Angiolina Comotti[a]

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The arrangement of dynamic building blocks, such as molecular rotors and switches, in close proximity to one another with precise geometry and topology, is realised in low-density framework materials, including Metal-Organic Frameworks (MOFs) and Porous Aromatic Frameworks (PAFs). We reported on the benchmark dynamics of the isolated di-carboxylate bicyclo[1.1.1]pentane (BCP) molecular rotor within a cubic zinc MOF.[1] Indeed, ^{1}H T_1 relaxation NMR and muon-spin spectroscopy revealed hyperfast rotary motion in the gigahertz regime even at temperatures as low as 2 K, with a negligible energy barrier (E_a) of 6.2 cal·mol^{-1}. Pillared-layer MOFs comprising bipyridine-based co-ligands generate 3D structures where the BCP rotors can interact with their neighbours.[2] Indeed, these rotors navigate the rotational potential energy landscape to produce co-rotating pairs of rotors. These geared molecular rotors have very low energy barriers for rotation (24 cal·mol^{-1}) owing to the synchronicity of their rotation. Fluorinated MOFs, comprising a wheel-shaped ligand with geminal rotating fluorine atoms, produced a benchmark mobility of correlated dipolar rotors at 2 K, with practically null activation energy (E_a = 17 cal·mol^{-1}), promising innovative applications as electric-field-responsive porous materials.[3] Light-responsive Porous Switchable Frameworks (PSFs) based on bistable chiroptical overcrowded alkenes exhibit high surface area (up to 3950 m^2·g^{-1}) and reversible bulk photoisomerization in the solid state. Notably, their porosity and gas sorption properties can be reversibly modulated in response to light and heat, mimicking a sponge-like behaviour.[4] Spiropyran-based materials, created via *in-situ* solid-state grafting, maintain high porosity and reversibly switch to zwitterionic merocyanine under chemical or physical stimuli.[5] These materials show promise for on-command pH control, gas uptake/release, ion capture, and water harvesting. Orthogonal PSFs combining different molecular switches enable the selective activation of four states using distinct light wavelengths, paving the way for complex, responsive frameworks with emergent properties.[6]

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Photoswitchable Molecular Systems: Design, Evaluation, and Applications in Data Transmission and Photopharmacology

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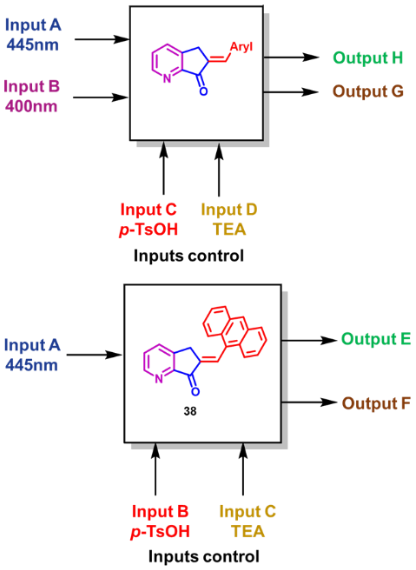
To harness the properties of photoswitches for data transmission, we proposed the design of compounds that function as a multiplexer/demultiplexer as a complex logic gate.[1] In this system, two distinct types of inputs are required: a) a chemical input that encodes information and regulates the output, represented here by protons (acid equivalents), and b) a photonic input provided by light, which operates the photoswitch. To achieve this, a collection of pseudo-hemiindigoids was synthesized and successfully validated as such logic gates (Figure 1).[2]

To apply the properties of photoswitches within pharmacology**, ANA-12** is a well-studied TrkB inhibitor, with reported antidepressant, anxiolytic, and antineoplastic properties.[3] However, administration of **ANA-12** at high doses has been associated with neuronal loss and neurotoxic effects, highlighting the need for precise spatial and temporal control over its bioactivity. Thus, we explore the synthesis of photoswitchable **ANA-12** analogues, either by their decoration with azobenzenes (**A**), or by replacing structural fragments with photochromic motifs (**B**). The synthetic targets were evaluated *in silico*, employing molecular docking and theoretical calculations (Figure 2).



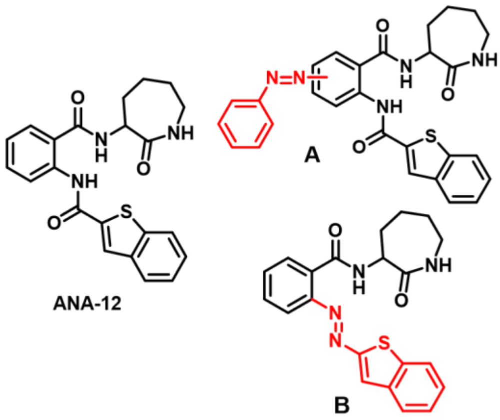


Figure 1. Molecular logic gates.

Figure 2. Photoswitchable **ANA-12** derivatives.

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Controlling molecular motion in azobenzene based molecular brakes and hemithioindigo-based macrocyclic molecular motors with light

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Attaining precise control over molecular motion is a central topic in molecular machine research. Especially light-driven variants are highly desirable as they use easy to provide, easy to dose, and waste-free fuel with high energy content and high spatio-temporal control. Here we present two approaches to achieve precise control of molecular motion in (visible) light-driven molecular machines and elucidate their design and working principles with a combination theoretical and variable temperature NMR methods.

First, we show that azotriptycenes can serve as a structural framework for photoswitchable molecular brakes, which change their intrinsic kinetics in response to light irradiation. Upon *cis/trans* isomerization of the azobenzene-triptycene hybrids, the C-N bond rotation rates can be reversibly decelerated or accelerated by up to five orders of magnitude. The respective rate change effects are highly localized and are strongest for the 120° rotation around the C-N bond connecting the triptycene rotor fragment to the diazo group.

In a second study, we demonstrate how the unidirectional rotation around a dedicated chemical bond can be reprogrammed into unidirectional rotation around a virtual axis. To this end, a classical hemithioindigo molecular motor is restricted by macrocyclization, and its intrinsic directional rotation around the C=C bond is transformed into a directional rotation of the macrocyclic chain in the opposite direction. A further level of control is achieved by simply changing the solvent polarity, which allows to toggle the function of this molecular machine between a directional motor and a nondirectional switch.

Both studies open up new concepts for designing light-driven molecular machines and provide a basis for analyzing and precisely controlling their motions at the nanoscale.

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Photomodulation of Plinabulin – a Tubulin Polymerization Inhibitor with low-nanomolar Toxicity

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Photopharmacology has attracted growing interest in recent years. In this research area, molecular photoswitches are attached to bioactive agents to precisely control their activity both temporally and spatially. For example, the severe side effects of chemotherapy may be significantly reduced by local activation of a photomodulable drug in tumor tissue. However, modulation of the structure of a bioactive agent with a photoswitch often suffers from drastic reduction in its activity or biostability.

Plinabulin is a tubulin polymerization inhibitor with low-nanomolar activity which is currently in phase III clinical trials against non-small cell lung cancer (NSCLC) and chemotherapy-induced neutropenia (CIN). We found that plinabulin itself is capable of photomodulation without further modification as it contains a previously unexplored photoswitch motif in its structure, which we refer to as hemipiperazine (HPI). In contrast to other photopharmacological agents, plinabulin does not suffer from loss of activity due to structural changes and furthermore exhibits pronounced thermal stability and compatibility with aqueous media. In addition, the difference in toxicity between the two isomers is significant, being 85-fold (unidirectional) and 11-fold (bidirectional), respectively.[1] Recently, we were able to use the in vivo photomodulation of plinabulin to reversibly influence the early development of zebrafish embryos.[2]

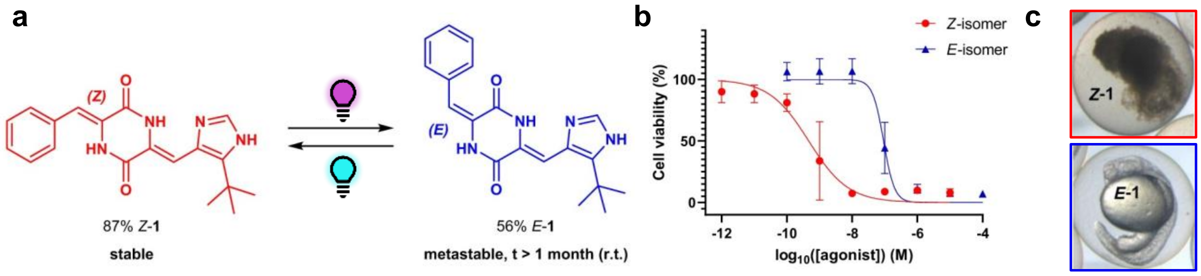

Figure 1: **a** The two photoisomers of plinabulin; **b** differences in the cytotoxicity of the isomers can be quantified *via* MTT assay and **c** demonstrated for the development of zebrafish embryos.

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COUPLED ROTATION: WHEN A LIGHT-DRIVEN MOTOR MEETS A MOLECULAR ROTOR

Lukáš Severa,[a] Katarina Majerová Varga,[a] Kateřina Bezděková,[a] Martin Dračínský,[a]
Ivana Císařová,[b] Jiří Kaleta[a]

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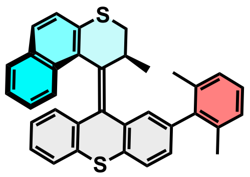
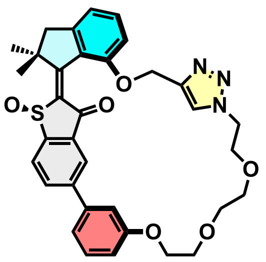
The pioneering discovery of light-driven molecular motors by Feringa in 1999 introduced unidirectional rotary motion at the nanoscale.[1] Later, in 2011, Feringa's group presented the concept of a "molecular gearbox," in which a single aryl substituent attached at the stereogenic center acted as a secondary rotor, its motion modulated by the motor cycle.[2] In 2018, Dube and co-workers transmitted motor rotation to a remote biaryl axis *via* an ethylene glycol linker, demonstrating long-range coupling of motion.[3] These representative systems are illustrated in the attached structures, alongside our newly designed construct.

In our work, we investigate a Feringa-type motor covalently linked to a thermally driven molecular rotor, specifically a dimethylanthracene unit. This arrangement can be regarded as a new type of molecular gearbox, in which the motor's unidirectional cycle biases and synchronizes the otherwise stochastic dynamics of the thermally driven Brownian rotor. The coupled rotation was confirmed by theoretical calculations. The system was further examined by NMR and UV–Vis spectroscopy.

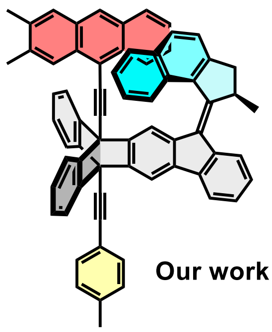
Our results show that deterministic molecular motor motion can be transmitted to a Brownian rotor, converting random fluctuations into synchronized rotation. This hybrid design bridges stochastic and deterministic dynamics at the molecular scale, opening new avenues for the design of integrated, multicomponent molecular machines.



Feringa et. al.



Dube et. al.



Our work

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Hemipiperazines: Biocompatible Photoswitches for Medical Applications, Fluorophores, and Fluorescent Sensing

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Plinabulin is a low-nM inhibitor of microtubule dynamics, recently in advanced FDA clinical trials against NSCLC and other human tumors. [1] Our group discovered a new photochromic motif, hemipiperazine (HPI), in plinabuline's structure. Its arylidene group undergoes reversible E/Z photoisomerization while also exhibiting a long thermal half-life. [2]

Building on these findings, monosubstituted DKP derivatives with electron-donating heteroarylidene groups were investigated to exploit the biocompatible nature of these cyclic dipeptide-derived switches while inducing a red-shifted absorption spectrum for therapeutic relevance. This strategy was based on reports of bathochromic shifts observed in other photochromic scaffolds (azobenzenes, indigoids) upon substitution with heteroarenes. In contrast to carbocyclic HPIs, the heterocyclic HPIs exhibited more efficient photoconversion with less spectral overlap. Moreover, the heteroarylidene HPIs displayed several additional favorable properties, such as good thermal stability, good isomerization efficiency in aqueous media, and resistance to reducing agents. [3]

Further considerations also led to the development of fluorescent, double-substituted HPIs, capable of forming metal complexes and sensitive to the protonation state of their heterocycles, which allows them to act as sensors for Zn^{2+} and Cd^{2+}. [4] Another approach involved the synthesis and characterization of "locked HPIs", which contain π-systems annulated to the HPI core. These compounds show promise as photoswitchable fluorophores, exhibiting significant, tunable fluorescence with quantitative isomerization inducible at visible and even red-light wavelengths. [5]

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Confinement Induced Chiroptical Photoswitching – An Encapsulation Approach for Advanced Photochemical Functions

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Controlling chiroptical properties is central to next-generation photonic technologies. Chiroptical photoswitching uniquely employs light both as a trigger for modulation of the chiroptical response and to read out chiroptical signals. Conventional chromophore-embedded chirality limits performance. Here, molecular confinement offers orthogonal control: photoswitches with remote chiral groups become chrial only upon encapsulation in a hexameric capsule, which induces folding and chirality transfer. This enables robust, reversible switching, while competitive guest exchange restores the achiral state. The strategy broadly activates dormant chiroptical responses, making them light-addressable and supramolecularly tunable.[1]

Boronic-Acid Photocaging for Visible Light-Controlled Applications in Synthesis

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Photolabile protecting groups (PPGs) enable simple masking of functions and controlled release by light. While widely applied, boronic acids have only recently become accessible to photocaging. We introduce a single-step PPG strategy for visible-light-triggered release of aromatic boronic acids, demonstrated in sequential cross-coupling and light-controlled macrocyclization, establishing boronic acid photocaging as a versatile synthetic tool.[2]

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